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2023

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Preface

Cafeo 41 Engineering Conference 2023

It is a great privilege for us to present the proceedings of the Cafeo 41st Conference to the authors and delegates of the event. This event showcases our dedication to engineering excellence, environmental sustainability, and economic progress. It serves as a valuable platform for knowledge sharing, collaboration, and strategic discussions among engineering professionals, policymakers, and industry leaders. This annual gathering serves as a unique platform that unites professionals and engineers, fostering an environment of collaboration and innovation. In this conference the theme is:

"IGNITING ASEAN'S BLUE ECONOMY AND GREEN ENERGY"

The conference explores various facets of project experience, cutting-edge research and development, and the commercialization of innovative engineering products. Total of 38 papers, each hailing from one of the 8 ASEAN countries are curated. The papers span diverse topics, including Cities and Building, Ecosystem Support, Emissions Reduction, New and Innovative Energy, Transport and Tourism. Notable papers include discussions on the readiness of digital transformation in Brunei Darussalam's green building construction industry, Kuala Lumpur's pioneering Smart City initiatives and carbon emission reduction, ASEAN's potential for sustainable ocean tourism, Assessment Of Horizontal Axis Wind Microturbine and In Myanmar, Towards Sustainable Nuclear Waste Management in Philippines and a comprehensive review of clean energy extraction from sea and saline brines in Indonesia. This book compiles all paper proceedings.

CAFEO 41ST ENGINEERING CONFERENCE 2023

RUNDOWN PAPER PRESENTATION CAFEO 41

NUSA 2, BALI 21-23 NOVEMBER 2023

Tuesday 21 Nov 2023 - 1st Session

No.	Time	Code	Session	Moderator	Paper Title	Presenter
1	08.00 - 08.15	B72	Cities & Building	Prof. Ir. Putu Alit Suthanaya, ST, M.EngSc, Ph.D	INCORPORATING URBAN SUSTAINABILITY PRINCIPLES IN THE DEVELOPMENT OF INDONESIAN NEW CAPITAL NUSANTARA	Naufal Azaki
2	08.15 - 08.30	A16	Cities & Building		EXPLORING THE READINESS OF DIGITAL TRANSFORMATION OR GREEN BUILDING CONSTRUCTION INDUSTRY IN BRUNEI DARUSSALAM	Ir.Chin Lee Tuck
3	08.30 - 08.45	A48	Cities & Building		NUMERICAL MODELING THE EFFECT OF EXTREME TEMPERATURES ON ROOMS WITH MORTAR FOAM WALLS USING LISA V.8 FEA	Ir. Aco Wahyudi Efendi
4	08.45 - 09.00	B75	Cities & Building		DVB-T2 AND DVB-S2 SIMULINK: GREEN MODELS FOR ASEAN ENGINEERS	Jeewa Vengadasalam
5	09.00 - 09.15	B77	Cities & Building		IMPLEMENTATION OF GREEN BUILDING FOR ENERGY SAVINGS POTENTIAL IN NIPAH MALL BUILDING	Muh. Agung Triady Putra
6	09.15 - 09.30	QA				
7	09.30 - 09.45	COFFEE BREAK				
8	09.45 - 10.00	A18	Ecosystem	Prof. Dr.-Ing Ir. Misri Gozan, M.Tech, IPU, ASEAN Eng	ESTIMATION OF BIOMASS CONTENT AND CO2 UPTAKE IN THE MANGROVE FOREST CONSERVATION AREA SERIBU CEMARA BEACH CSR PROGRAM PT PLN (PERSERO) UIP KALBAGBAR	Widyanto Hadi Prasetyo
9	10.00 - 10.15	B74	Ecosystem		TREATMENT OF SULLAGE WATER USING CDS TECHNOLOGY – A CASE STUDY OF TIONGNAM URBAN AREA SULLAGE WATER TREATMENT PLANT	Yale Wong
10	10.15 - 10.30	A58	Ecosystem		PROSPECTS OF LOW HEAD DAM SCHEMES IMPLEMENTATION ALONG AYEYARWADY RIVER	Kyi Thar
11	10.30 - 10.45	A26	Ecosystem		BUILDING BLUE ECONOMY CLUSTERS TOWARDS SUSTAINABLE DEVELOPMENT IN SOUTHEAST ASIA: ECOSYSTEM/S APPROACH WITH SECTORAL SYNERGIES, PATHWAYS, AND CHALLENGES	Nerissa Gatdula
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13	11.00 - 11.15	QA				
14	11.15 - 11.30	A08	Air & Emission	Prof. Ir. Meilana Dharma Putra, MSc, PhD., IPM.	EMISSION REDUCTION OF TRANSPORTATION SECTOR IN DKI JAKARTA	Dicky Arisikam
15	11.30 - 11.45	A60	Air & Emission		BUILDING A GREENER FUTURE: KUALA LUMPUR'S SMART CITY INITIATIVES AND CARBON EMISSION REDUCTION	Rusnida Talib
16	11.45 - 12.00	A54	Air & Emission		ASSESSMENT OF HORIZONTAL AXIS WIND MICROTURBINE WITH POWER OF 5 KW	Naing Htoo Hlaing
17	12.00 - 12.15	A61	Air & Emission		BALANCING ENERGY CONSUMPTION, ECONOMIC GROWTH, AND EMISSION REDUCTION IN ASEAN NATIONS: INSIGHTS INTO THE GREEN ENERGY TRANSITION	Prof. Romano Q. Neyra, ASEAN Eng.
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25	14.00 - 14.15	A53	New Energy		DESIGN AND CONSTRUCTION OF AUTOMATIC VOLTAGE REGULATOR FOR 1 KW WIND POWER GENERATION	Yin Yin Mya
26	14.15 - 14.30	A07	New Energy		UNLOCKING INDONESIA'S ENERGY POTENTIAL: COMPREHENSIVE REVIEW OF EXTRACTING CLEAN ENERGY FROM SEA AND SALINE BRINES	Rahadian Nopriantoko
27	14.30 - 14.45	A29	Innovative Environment		FIRST GBI GOLD-RATED CONFECTIONERY MANUFACTURING FACILITES IN MALAYSIA	Catherine Siew Ping Sim
28	14.45 - 15.00	QA				
29	15.00 - 15.15	A20	Innovative Environment	Dr. Ir. Soni Solistia Wirawan, M.Eng. IPU	IGNITING ASEAN BLUE ECONOMY THROUGH SUSTAINABLE OCEAN TOURISM	Ir. Vun Wey Tyng
30	15.15 - 15.30	B73	Innovative Environment		FLIPPING THROUGH HISTORY: MALAYSIA'S EXPERIENCE IN SMART PORTS DURING THE COVID-19 PANDEMIC	Syuhaida Ismail
31	15.30 - 15.45	A33	Innovative Environment		GREEN MINE ENERGY RESILIENCE PLAN; THE FUNDAMENTALLY OF NICKEL SMELTER INDUSTRY SUSTAINABLE SCENARIO INTO INTEGRATING BLUE ECONOMICAL INVESTMENT MODEL EFFICIENCY ON COASTAL MINING AREA IN SULAWESI ISLAND	Ir. Rahmat Mualllim
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35	16.30 - 16.45	A50	Material	Widyaka Kartanegara, ST, MT	NICKEL INDUSTRIAL DECARBONIZATION PROGRAM STUDY CASE IN SOROWAKO SMELTER	Zainuddin
36	16.45 - 17.00	A82	Energy		Grizzly Reduction Kiln Fatigue Analysis	Asep Suharto
37	17.00 - 17.15	QA				

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2	08.15 - 08.30	B76	Ecosystem		SURFACE HYDROPHOBIC MODIFICATION OF OPEFB CELLULOSE WITH TRIGLYCERIDES FROM VEGETABLE OILS FOR APPLICATION AS GREEN COATING ADDITIVES OF BUILDING	Ching Yern Chee
3	08.30 - 08.45	B81	Building		IDENTIFICATION OF BARRIERS AND CHALLENGES FACED BY CONTRACTORS IN ENERGY EFFICIENT BUILDING FOR AFFORDABLE HIGH-RISE HOUSING IN MALAYSIA TOWARDS GREEN SUSTAINABLE CONSTRUCTION IN MALAYSIA.	Ms. Ainarull Assikin Abdul Hadi
4	08.45 - 09.00	B79	Building		GREEN IOT: THE ENVIRONMENTAL GAME-CHANGER FOR ENERGY EFFICIENT BUILDING	Ir. Tony Cheng Yew Leong
5	09.00 - 09.15	A43	Building		WHY ARE GREEN BUILDING AS ENERGY EFFICIENT BUILDING IS A MUST? REVIEWING INDONESIA'S RESPONSE	Ngakan Ketut Acwin Dwijendra
6	09.15 - 09.30	**QA**				
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8	09.45 - 10.00	A21	Transport & Tourism	Prof. Ir. Putu Alit Suthanaya, ST, M.EngSc, Ph.D	ENGINEERING PROPERTIES OF SUSTAINABLE GREEN ASPHALT INCORPORATING CRUMB RUBBER USING DRY PROCESS: SABAH, MALAYSIA EXPERIENCE	Nurul Ariqah
9	10.00 - 10.15	A42	Transport & Tourism		MARITIME TRANSPORTATION IN THE CITY OF MANADO	Theo Kurniawan Sendow
10	10.15 - 10.30	B78	Transport & Tourism		FEASIBILITY STUDY OF SOLAR-POWERED ELECTRIC VEHICLE CHARGING INFRASTRUCTURE AT SELECTED PETROL STATIONS IN MALAYSIA	Ir. Dr. Siow Chun Lim
11	10.30 - 10.45	B80	Energy		OCEAN THERMAL ENERGY CONVERSION; POTENTIAL TECHNOLOGY FOR GREEN ENERGY IN ASEAN	Ir. Dr. Harris Abd Rahman Sabri
12	10.45 - 11.00	A28	Building		FIRST DGNB PLATINUM- CERTIFIED FACTORY IN ASIA: A SUSTAINABLE BUILDING DESIGN ACHIEVEMENT ON THE SEMICONDUCTOR FINAL TESTING FACILITY IN BATU KAWAN INDUSTRIAL PARK (BKIP) PENANG, MALAYSIA	Sophia Sheau Wei Than
	11.00 - 11.15	**QA**				
13	11.15 - 11.30	A15	Energy	Dr. Ir. Soni Solistia Wirawan, M.Eng. IPU	PENSTOCK REINFORCEMENT LARONA HYDRO POWER PLANT	Baso Murdin
14	11.30 - 11.45	A83	Energy		Plant Air Compressor Optimization Study Case In Sorowako Smelter	Muh. Amirul Wahyi. C
15	11.45 - 12.15	**QA**				
16	12.15 - 12.30	**END SESSION**				

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2	A16	Cities & Building	EXPLORING THE READINESS OF DIGITAL TRANSFORMATION OR GREEN BUILDING CONSTRUCTION INDUSTRY IN BRUNEI DARUSSALAM	Ir. Chin Lee Tuck, Dr. Chan Sai Keong, Prof. Ir. Dr Tan Chee Fai	Chin Lee Tuck
3	A48	Cities & Building	NUMERICAL MODELING THE EFFECT OF EXTREME TEMPERATURES ON ROOMS WITH MORTAR FOAM WALLS USING LISA V.8 FEA	Aco Wahyudi Efendi, Novia Safitri	Aco Wahyudi Efendi
4	B75	Cities & Building	DVB-T2 AND DVB-S2 SIMULINK: GREEN MODELS FOR ASEAN ENGINEERS	Jeewa Vengadasalam	Jeewa Vengadasalam
5	B77	Cities & Building	IMPLEMENTATION OF GREEN BUILDING FOR ENERGY SAVINGS POTENTIAL IN NIPAH MALL BUILDING	Muh. Agung Triady Putra, Nurul Asmarani	Muh. Agung Triady Putra
6	A18	Ecosystem	ESTIMATION OF BIOMASS CONTENT AND CO2 UPTAKE IN THE MANGROVE FOREST CONSERVATION AREA SERIBU CEMARA BEACH CSR PROGRAM PT PLN (PERSERO) UIP KALBAGBAR	Widyanto Hadi Prasetyo, Pradita Teguh Irawan, Dhio Dwinofiansyah Putra	Widyanto Hadi Prasetyo
7	B74	Ecosystem	TREATMENT OF SULLAGE WATER USING CDS TECHNOLOGY – A CASE STUDY OF TIONGNAM URBAN AREA SULLAGE WATER TREATMENT PLANT	Yale Wong, Chow Hock Lim	Yale Wong
8	A58	Ecosystem	PROSPECTS OF LOW HEAD DAM SCHEMES IMPLEMENTATION ALONG AYEYARWADY RIVER	Kyi Thar	Kyi Thar
10	A47	Ecosystem	ESTABLISHING REGIONAL REGULATION TO ENHANCE THE UTILIZATION OF PALM-OIL BASED SUSTAINABLE AVIATION FUEL (SAF) IN ASEAN AVIATION INDUSTRY	Prayitno, Dimas Ramadhan, Abdillah Fikri	Prayitno
11	A08	Air & Emission	EMISSION REDUCTION OF TRANSPORTATION SECTOR IN DKI JAKARTA	Dicky Arisikam, Shafira Nur Fadhillah	Dicky Arisikam
12	A60	Air & Emission	BUILDING A GREENER FUTURE: KUALA LUMPUR'S SMART CITY INITIATIVES AND CARBON EMISSION REDUCTION	Rusnida Talib, Rahayu Muhammad Taib	Rusnida Talib
13	A54	Air & Emission	ASSESSMENT OF HORIZONTAL AXIS WIND MICROTURBINE WITH POWER OF 5 KW	Naing Htoo Hlaing	Naing Htoo Hlaing
17	A53	New Energy	DESIGN AND CONSTRUCTION OF AUTOMATIC VOLTAGE REGULATOR FOR 1 KW WIND POWER GENERATION	Yin Yin Mya	Yin Yin Mya
18	A07	New Energy	UNLOCKING INDONESIA'S ENERGY POTENTIAL: COMPREHENSIVE REVIEW OF EXTRACTING CLEAN ENERGY FROM SEA AND SALINE BRINES	Rahadian NOPRIANTOKO, Aries Abbas	Rahadian Nopriantoko
19	A20	Innovative Environment	IGNITING ASEAN BLUE ECONOMY THROUGH SUSTAINABLE OCEAN TOURISM	Vun Wey Tyng	Vun Wey Tyng
20	B73	Innovative Environment	FLIPPING THROUGH HISTORY: MALAYSIA'S EXPERIENCE IN SMART PORTS DURING THE COVID-19 PANDEMIC	Mazlinawati Abdul Majid, Syuhaida Ismail	Syuhaida Ismail
21	A33	Innovative Environment	GREEN MINE ENERGY RESILIENCE PLAN; THE FUNDAMENTALLY OF NICKEL SMELTER INDUSTRY SUSTAINABLE SCENARIO INTO INTEGRATING BLUE ECONOMICAL INVESTMENT MODEL EFFICIENCY ON COASTAL MINING AREA IN SULAWESI ISLAND	Rahmat Muallim, Abdul Rahim Syaban, La Ode Bariun, Jamsir, Abu Sofyan Toppo	Rahmat Mualllim
22	A06	Innovative Environment	REVOLUTIONISING HOUSING CONSTRUCTION IN MALAYSIA: LEVERAGING BUILDING INFORMATION MODELLING FOR SAFE AND AFFORDABLE HOMES	Nur Syafika Artika Rahim, Mohammad Hussaini Wahab, Syuhaida Ismail	Nur Syafika Artika Rahim
23	A45	Innovative Environment	SUSTAINABLE INTEGRATION OF BLUE ECONOMY PRINCIPLES IN THE DEVELOPMENT OF INDONESIAN NEW CAPITAL NUSANTARA	Danis H Sumadilaga, Alfa Adib Ash Shiddiqi, Dapot Andri Agustinus	Alfa Adib Ash Shiddiqi
24	A63	Ecosystem	STRENGTH CHARACTERISTICS OF FLY ASH BOTTOM ASH WASTE AS A GEOPOLYMER FOR REINFORCEMENT OF EMBANKMENT MATERIALS ON ROAD PAVEMENTS WITH THE ADDITIONAL OF MICROORGANISM	Dewi Rantung, Oktovian B. A. Sompie, Steeva G. Rondonuwu, Audie Rumayar	Steeva Rondonuwu
25	B76	Ecosystem	SURFACE HYDROPHOBIC MODIFICATION OF OPEFB CELLULOSE WITH TRIGLYCERIDES FROM VEGETABLE OILS FOR APPLICATION AS GREEN COATING ADDITIVES OF BUILDING	Amirul Aiman Mohd A. Ching Yern Chee	Ching Yern Chee
26	B81	Building	IDENTIFICATION OF BARRIERS AND CHALLENGES FACED BY CONTRACTORS IN ENERGY EFFICIENT BUILDING FOR AFFORDABLE HIGH-RISE HOUSING IN MALAYSIA TOWARDS GREEN SUSTAINABLE CONSTRUCTION IN MALAYSIA.	Ainarull Assikin Abdul Hadi	Ainarull Assikin Abdul Hadi
27	B79	Building	GREEN IOT: THE ENVIRONMENTAL GAME-CHANGER FOR ENERGY EFFICIENT BUILDING	Ir. Cheng Yew Leong, Tony	Tony Cheng Yew Leong,
28	A43	Building	WHY ARE GREEN BUILDING AS ENERGY EFFICIENT BUILDING IS A MUST? REVIEWING INDONESIA'S RESPONSE	Ngakan Ketut Acwin Dwijendra, Kadek Diana Harmayani, I Dewa Gede Agung Diasana Putra, Ida Bagus Putu Adnyana, Desak Ayu Krystina Winastri K	Ngakan Ketut Acwin Dwijendra
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31	B78	Transport & Tourism	FEASIBILITY STUDY OF SOLAR-POWERED ELECTRIC VEHICLE CHARGING INFRASTRUCTURE AT SELECTED PETROL STATIONS IN MALAYSIA	Siow Chun Lim, Adeesarn Chindamanee	Siow Chun Lim
32	B80	Energy	OCEAN THERMAL ENERGY CONVERSION; POTENTIAL TECHNOLOGY FOR GREEN ENERGY IN ASEAN	Ir Dr Harris Abd Rahman Sabri, Dr Sathiabama T. Thirugnana	Harris Abd Rahman Sabri
33	A29	Innovative Environment	FIRST GBI GOLD-RATED CONFECTIONERY MANUFACTURING FACILITES IN MALAYSIA	Catherine Siew Ping Sim, Zi Xun Ooi, Tze Hoong Ooi, Ji Herng Tang, Yee En Seah	Catherine Siew Ping Sim
34	A28	Building	FIRST DGNB PLATINUM- CERTIFIED FACTORY IN ASIA: A SUSTAINABLE BUILDING DESIGN ACHIEVEMENT ON THE SEMICONDUCTOR FINAL TESTING FACILITY IN BATU KAWAN INDUSTRIAL PARK (BKIP) PENANG, MALAYSIA	Sophia Sheau Wei Than, Chie Tung Lim, Lai Hoong Lee, Wei Huat Khor, Kent Khai Lim, Muhammad Azmin Azizan	Sophia Sheau Wei Than
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36	A82	Energy	GRIZZLY REDUCTION KILN FATIGUE ANALYSIS	Baso Murdin, Asep Suharto, Fahmi Izdiharrudin, Danto Joro1, Muhtar Wahab	Asep Suharto
37	A15	Energy	PENSTOCK REINFORCEMENT LARONA HYDRO POWER PLANT	Baso Murdin, Anom Prasetio, Kiamuddin, Zainuddin, Fahmi Izdiharrudin	Baso Murdin
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INCORPORATING URBAN SUSTAINABILITY PRINCIPLES IN THE DEVELOPMENT OF INDONESIAN NEW CAPITAL NUSANTARA

Danis H Sumadilaga[1], Naufal Azaki[2], and Nazib Faizal[3]

1. Indonesian New Capital Nusantara Construction Task Force, Indonesia
2. Center for Data & Information Technology, Ministry of Public Works and Housing, Indonesia
3. Center for Data & Information Technology, Ministry of Public Works and Housing, Indonesia

E-mail: dsumadilaga@gmail.com, azakinaufal@pu.go.id

Abstract

The Indonesia New Capital Nusantara (IKN) project envisions a modern, sustainable city to replace Jakarta, situated on Borneo. With a $33 billion budget, IKN aims to accommodate Indonesia's economic growth more equally. This research aims to explore the incorporation of sustainable city principles into the planning and development of the proposed new capital city, Nusantara. As a burgeoning urban endeavor, the development of a new capital city presents a unique opportunity to harmonize economic growth with ecological preservation, exemplifying the essence of the sustainable city concept. The study employs a multidisciplinary approach that draws upon urban planning, sustainable development, and governance (public administration) perspectives. It investigates the strategic integration of key sustainable city principles reflected on the Low Impact Urban Design & Development (LIUDD) principles, Green Urbanism framework, and other concepts of urban sustainability such as ecological conservation, green infrastructure, resilience, and compact city into the urban planning design of Nusantara capital city. Through a combination of literature review, case study & benchmarking analysis, and stakeholder consultations, the research seeks the potential benefits and challenges associated with aligning the city's growth trajectory with the sustainable utilization of ecosystems. Contributing to urban sustainability discourse, this research provides insights into practical implications of implementing such principles in planning for future cities contexts. Its findings offer guidance for urban developments worldwide that seek equilibrium between economic progress and environmental care.

Keywords: Indonesian New Capital Nusantara, Sustainable City, Urban Development

1. Introduction

The decision of relocating the capital city of Indonesia from Jakarta to Nusantara, which is located in East Kalimantan, was stated while President Joko Widodo addressing the nation in the State of the Union, 16th August, 2019. The decision considers Jakarta excessive burdens such as flood, congestion, overpopulation due to high urbanization rate, water and air pollution, and an earthquake menace [1]. Borneo Island, the new location of capital city, was chosen by the opposite conditions of Jakarta; geographically located in Central Indonesia hemisphere, low risk of flood, tsunami and forest fire, geostrategically secure, the availability of state's owned land and access to water resources, and also close to existing/built city (Ministry of Development Planning, 2019). Economically, the Government of Indonesia (GoI) believes that the new capital city of Nusantara will bring enormous prosperity for the eastern part of Indonesia by the potential emergence of new economic activity and investment [1]. Despite the controversies surrounding the decision, the new capital city of Nusantara is not only about relocating, but building a new city from scratch; considering that the area chosen (approximately 256.142 ha) as part of Penajam Paser Utara and Kutai Kartanegara Regency in Borneo mainly consists of production forest. Nevertheless, the government of Indonesia (GoI) seeks this as a new opportunity and is willing to have a bold precedent in building a new city that embodies the concept of urban sustainability.

The interpretation of sustainability itself has been developed and applied to diverse areas, such as economics, policy, social, etc [2] and not static but dynamic concept [3,4]. Theoretically, urban sustainability is interpreted in various ways by specific attributes [2]. Sustainable cities are linked to sustainable development which reflected on their position of being the engines of economic growth, urbanization (population growth), resource consumption as well as innovation culture [5]. The terms urban sustainability and sustainable urban development have similar notions [4].

Urban sustainability is also constructed by the set of ecosystems within the city area which includes a greater ecological system and ecology in the city [2]. Sustainable city or urban sustainability itself is often interpreted or manifested by the concept of urban metabolism [6], green urbanism [9], green/sustainable infrastructure [10], resilience city [5,11,12], zero carbon eco city [4,13], and smart city [11]. The sustainable city concept envisions a city that has green growth [5], green landscape or form [5,9], compact city [4], promotes ecological conservation

[15], and inclusive [11]. Besides that, the key of a sustainable city also relies on the efficient use of energy consumption and promoting renewable energies [4,16].

Alongside the the urban sustainability concept, the urban metabolism is now becoming more comprehensive and credible measure for sustainable and adaptive cities rather than a traditional ecological footprint approach because its ability to measure not only environmental aspect but also economic and social dimension of cities [2,5, 17-19]. Urban metabolism is already used as a framework for sustainable city indicators in many large urban development projects like Sustainable Urban Metabolism for Europe, BRIDGE Programme, PIER of California Energy Commission, and World Bank projects [6].

Despite the debates, contradictions, and no consensus that raise the primary definition of sustainable city or urban sustainability [13], therefore, this paper exercises the effort on incorporating urban sustainability principles in urban planning stages from technocratic and academic aspects through analyzing planning documents, legal blankets, policy environment, and research literatures. This research analyzes how urban design and the development of Nusantara city in micro (urban form/interior) to macro planning context can meet the principles of urban sustainability as well as dealing with the challenges because urban sustainability can be seen as place-dependent notion and cannot be generalized from one city to another [14].

2. Urban Sustainability: The Conceptual and Practical Definitions

Good planning practices for sustainable cities reflected on the effort to build compact, mixed-use urban space, affordable and efficient use of energy, and mitigating the occurrence of negative consequences such as widening of social inequalities as well as environmental problems [20]. Therefore, a sustainable city project must be seen as an act of progressive and forward-looking strategy, not a reactive one.

The unprecedented complexity of urban rapid changes needs a new concept to answer the challenge which the traditional approaches of urban planning has already seen incapable of addressing long-term sustainable development [12,19]. Many scholars have developed frameworks on the future of sustainability and sustainable cities [2,15,21]. The foundation of sustainable cities principles primarily emphasizes the integration of environmental, economic, and social objectives [3,5] and ensure the fulfillment of rights for both humans and the environment [2].

One of the popular guidelines on how to incorporate sustainability principles into urban planning is the Low Impact Urban Design and Development (LIUDD) that was developed by Van Roon and Van Roon in 2005 [2]. The LIUDD proposes three hierarchical principles. The primary principle states that urban development must operate in a responsible and respectful manner within natural cycles to mitigate and reduce negative consequences/risks as well as optimizing the ecosystem integrity [15]. The secondary principles seek the minimization of negative impact, efficient use of ecosystem services and infrastructure, and maximizing local resources while reducing possible waste at the same time [15]. The tertiary principles emphasize the efficient use of energy, building compact urban form, green infrastructure that promotes conservation and efficiency, restore and preserve natural biodiversity, reduce waste and contaminants, and naturalization of soil, water, and nutrient cycles [15].

The principles of urban sustainability contained in the LIUDD framework are inherently in tune with many conceptual and theoretical perspectives on green infrastructure, city resilience, as well as urban metabolism. As mentioned earlier, green infrastructure is a term that refers to a sustainable approach on low carbon and pollution infrastructure for climate resilience [22], water resources management to mitigate environmental impacts and infrastructure focused on environmental conservation [23]. Many scholars have defined the tight relationship between green infrastructure and sustainability [22-26] which commonly emphasize the need of constructing infrastructure that preserves the ecological ecosystem through conservation, rehabilitation of green spaces & soil condition, and also maintaining-mitigating natural processes by water quality management and flood mitigation [27].

All principles are interconnected with each other's aspects. For example, in the context of urban mobility, the LIUDD promotes a compact area that eases the mobility of people and goods [15]. Similar to that, in the perspective of environmentalism, many researches show cities with high levels of density (and succeed in controlling urban sprawl) and integrated public transport tend to have lower per capita emissions such as Singapore, Vienna, and Barcelona [5, 28,29]. The criteria of a compact city, the term often used to illustrate the mobility ease in a city, can be seen by how the density is minimum at 40 to 80 resident units per net hectare that makes the neighborhood more interactive and closer, multi-function of land-use, shared-facilities in community/residences, the integration of spatial structure and public transit by transit-oriented development, and short car trip by implementing mix-used urban facilities [4,30].

In the ecological context, the incorporation of sustainability principles is considered using an ecosystem approach which integrates water, land, and resources management by mainstreaming the CBD into decision-making [31]. Sustainable city puts attention on how the citizens use resources in a responsible way, consider the environmental impacts, and generate less waste [2,15]. This can be done for example by building waste containment & processing infrastructure rather than discharging contaminants into the ecosystem [15].

In dealing with climate change, carbon emissions, technological change, as well as managing changing environments, sustainable cities must consider and build a resilience approach which integrates a framework of policy to ensure metabolic flows, governance networks, social dynamics, and the built environment [32]. The urban resilience also has key measures to consider include the progressive paradigm of urban planning, investing in green and disaster-resilient infrastructures (drainage system, earthquake-resistant construction, etc), leveraging ecosystem services, fostering social resilience by strengthening community awareness, and creating mechanisms of risk anticipatory measure [5].

Lehmann [38] also gives a framework for green urbanism; the concept of integrating multi sectoral aspects such as landscapes, transportation network, ecology, sociology, and economy by interacting all these aspects then put together in a planning of a city as illustrated below.

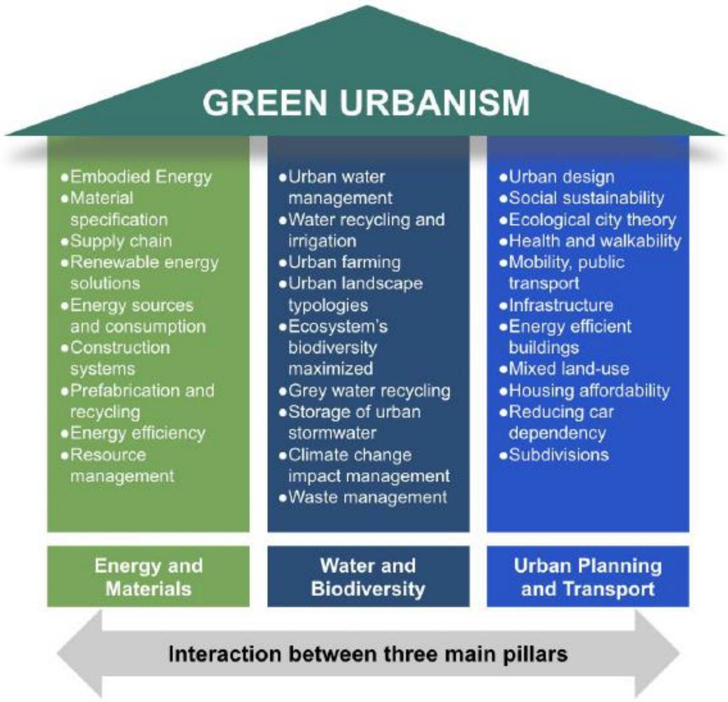


Figure 1. Three Pillars of Green Urbanism and the Interaction Amongst Them. Source: Lehmann, 2006).

Lehmann [38] provides the The Green Urbanism Principles of Sustainability, which are:

a. Climate and Context
b. Renewable energy for zero co2 emissions
c. Zero-waste city
d. Water
e. Landscape, Garden, and Urban Biodiversity
f. Sustainable Transport and Good Public Space-Compact and Poly-centric cities
g. Local and Sustainable Materials with less embodied energy
h. Density and retrofitting of existing districts
i. Green buildings and districts, using passive design principles
j. Livability, healthy communities and mixed-use programs,
k. Local food and short supply chains
l. Cultural heritages, identity, and sense of place
m. Urban Governance, Leadership and Best Practice
n. Education, research, and knowledge
o. Strategies for Cities in developing countries.

3. Methodology

This article uses a qualitative method of research by using secondary data of literature review, project documents/reports analysis, and minutes of meetings (FGD, stakeholders and public consultations). The main basis of theoretical literatures used are on LIUDD Principles, Green Urbanism Principles, and other conceptual framework on urban sustainability given by scholars for exercising Nusantara capital city planning.

4. Results and Discussion

Nusantara, the new capital city of Indonesia, has 256.142 Ha area that divided into three area of planning, namely:

a. Development Area of State Capital City (*Kawasan Pengembangan Ibu Kota Negara/KP IKN)* with an area of 199.962 Ha.
b. State Capital City Area (*Kawasan Ibu Kota Negara/KIKN)* with an area of 56.180 Ha.
c. Central Government Area (*Kawasan Inti Pusat Pemerintahan/KIPP)* with an area of 6.671 Ha.

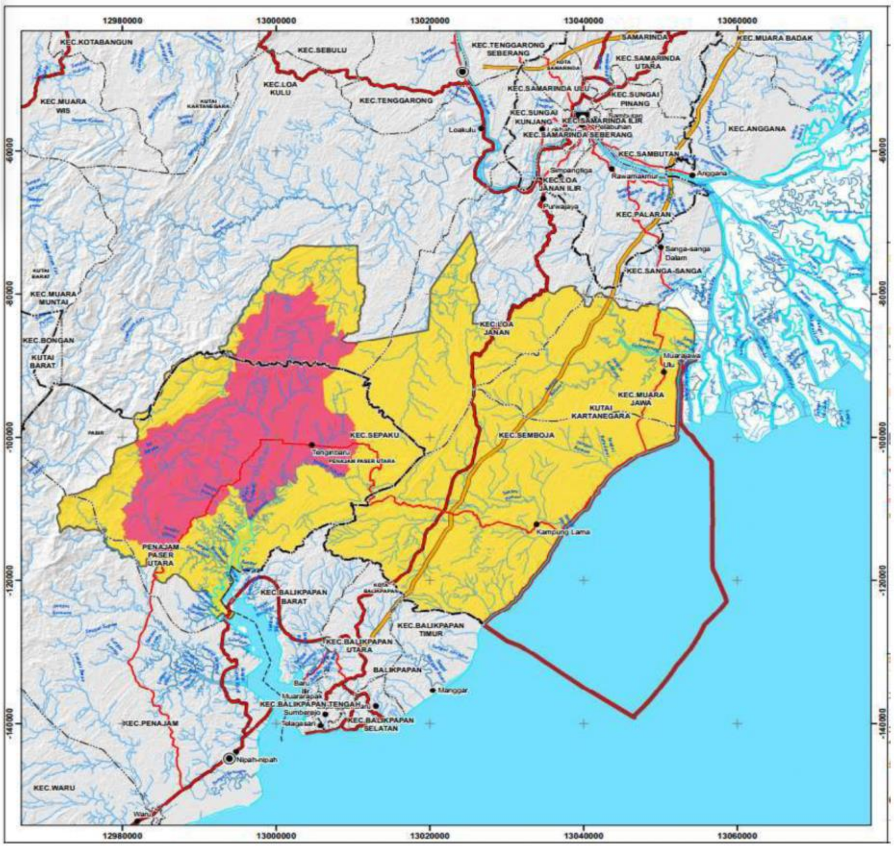


Figure 2. The Development Area of the New Capital City of Nusantara.

Figure 3. Central Government Area

Figure 4. Presidential Palace.

The Master Plan of Nusantara Capital City project envisioned a Global City for All; as identified as a symbol of national identity, global sustainable city, and future engine of growth [32,33]. This paper exercises the effort of strategic integration of sustainable principles as reflected in the LIUDD framework and other theoretical or practical research results into the development planning of Nusantara capital city. The discussion below provides the analysis of feasibility of integrating such principles, framework, as well as best practices from global cities into the detailed planning of Nusantara city.

a. Nusantara Projects: Visions, Foundations, and Strategies

Law on Capital City No. 3 of 2022 and Presidential Regulation on the Detailed Master Plan of Capital City No. 63 of 2022 have already stipulated the adoption of forest city and urban metabolism for Nusantara city project. The Nusantara city planning has incorporated sustainable principles for each area of development: regional, economy, social and human capital, land availability and use, environmental safeguards, to infrastructure construction [1]. In order to maintain the commitment of incorporating such principles, The New Capital City of Nusantara has developed its key performance indicators that manifested the effort of implementing the vision of a global and sustainable city as illustrated below. The discussion in this section focuses the analysis on the urban landscape design and environmental safeguards, green infrastructure, and social-economy side of Nusantara capital city planning.

Table 1. Key Performance Indicators of Nusantara Capital City.

1. Urban design according to natural conditions	**2. Bhinneka Tunggal Ika**	**3. Integrated, Active, and Accessible**	**4. Low Carbon Emission**	**5. Circular & Resilient**	**6. Safe and Affordable**	**7. Livable and Efficient with Technology**	**8. Opportunity for All**
1.1 >75% of 256,000 Ha for green space (65% protected area and 10% food production)	**2.1** 100% integration of all over resident - existing and the new one	**3.1** 80% mobility with public transportations or active mobility	**4.1** Installation of renewable energy capacity will provide 100% IKN energy needs	**5.1** >10% of 256,000 Ha area available for food or consumption production	**6.1** Top-10 EIU Liveable City in world by 2045	**7.1** Reach very high ranking in UN E-Government Development Index	**8.1** 0% poverty rate in Nusantara Capital City by 2035
1.2 100% of residents can access green space recreation within 10 minutes	**2.2** 100% residents can access social services within 10 minutes	**3.2** 10 minutes to important facilities and node public transportations	**4.2** 60% energy efficiency for energy conservation in building	**5.2** 60% waste recycle by 2045	**6.2** The existing and planned settlement in area of 256,000 have access to strategic infrastructures by 2045	**7.2** 100% digital connectivity and ICT for all residents and businesses	**8.2** GRDP per capita equals to high income countries
1.3 100% replacement of green space for every institutional graded building, commercial, and residence (building >4 floors)	**2.3** 100% space public designed considering universal access principle, local wisdom, and inclusivity	**3.3** <50 minutes of express transit connection from KIPP to strategic airport by 2030	**4.3** Net zero emissions for IKN (when operating) in 2045 in area of 256,000 Ha	**5.3** 100% waste will process through waste treatment facilities by 2035	**6.3** Adequate, safe, and affordable housing to meet the balance residence (1:2:3) for luxurious, moderate, and simple houses	**7.3** >75% Business Satisfaction with Digital Services ranking	**8.3** Lowest ratio gini in Indonesia

Source: illustrated from Presidential Regulation No. 63 of 2022.

Urban Landscape Development

The first area of regional development of Nusantara relies on the practical concept of Forest City, Sponge City, and Smart City [1]. Forest city is related to the urban form that not only green landscape but also puts effort into ecological conservation while urban metabolism quantifies city's inputs, outputs, energy storage, materials, nutrients, water, and wastes [6]. The Detailed Master Plan of Nusantara Forest City plan consists of six principles; a) conservation of natural resources and habitat; b) connected with nature; c) low-carbon development; d) availability of water resources; e) anti-sprawl development; and f) public participation. The implementation of forest city is to achieve the goal where >75% of 256,000 Ha Nusantara area is for green space (65% protected area and 10% food production), 100% of residents can access green space recreation within 10 minutes, and 100% replacement of green space for every institutional graded building, commercial, and residence (building >4 floors) as shown in the first key performance indicator (KPI) in Table 1 The landscape design on how to incorporate the forest city concept in Nusantara is illustrated in figure 5 below.

Figure 5. The Master Plan of Nusantara Capital City.

The design of Nusantara Sponge City plans a circular water management system that integrates the architectural, urban form design, infrastructure, and sustainability principles by developing area to absorb rainwater like a sponge then filter it through natural process and release it into dam, drainage, and aquifer [34] as seen in figure 6 below.

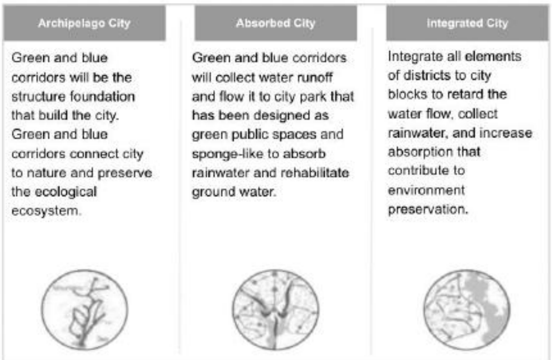


Figure 6. The Plan of Nusantara Sponge City.

Smart City concept in Nusantara capital is designed to prepare and draw up future needs and changing environment which relies on future initiatives of access and mobility, natural environment and climate change, security and safety, public services, urban systems, and livability [34]. One of the initial implementations of smart city in the Nusantara project is the use of Building Information Modelling (BIM) and Geographic Information System (GIS) for the construction phase. BIM provides real time information on construction progress as well as clash detection information as seen in several figures below.

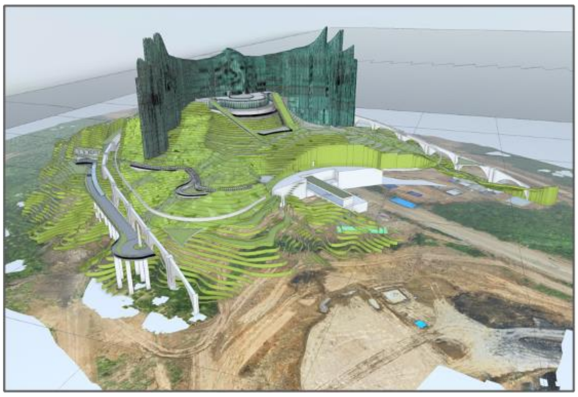


Figure 7. Building Information Management (BIM) in the Nusantara Project.

One of the crucial aspects in urban sustainability is to put concern on environmental safeguards and conservation. In order to make bold commitment for environmental and ecological conservation, the Master Plan of Nusantara capital city is aligned with 6 Principles of Environmental Management and Protection which are:

a) Preserve and improve carrying capacity of environment
b) Avoid the risk of natural damage
c) Optimize ecosystem services
d) Utilize natural potential efficiently
e) Reduce area vulnerability due to climate change as well as helping the reduction of emissions
f) Repair and maintain biodiversity

The 6 Principles above will be integrated into spatial planning with the Go- and No-Go Area approach for example by setting out mangrove forest at Balikpapan Bay and Hitam Kuala Samboja River as Protected Areas. The GoI will also reclaim ex-mining holes and develop tree nursery facilities.

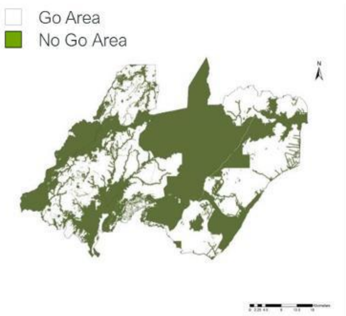


Figure 8. Go and No-Go Area Approach.

To respect biodiversity, the Nusantara capital project will construct animal bridges so that animals like Bekantan monkey can cross through safely.

Figure 9. Animal Bridge Designs.

Green Infrastructure

As part of urban metabolism and the LIUDD concept implementation, green infrastructure plays a significant role. The Nusantara city project has drawn the adoption of green infrastructure approaches in the construction of water resource infrastructures, housing and settlement facilities, waste treatment facilities, mobility and connectivity infrastructures, and energy infrastructure [34,35]. For housing, the city will adopt the green building standard.

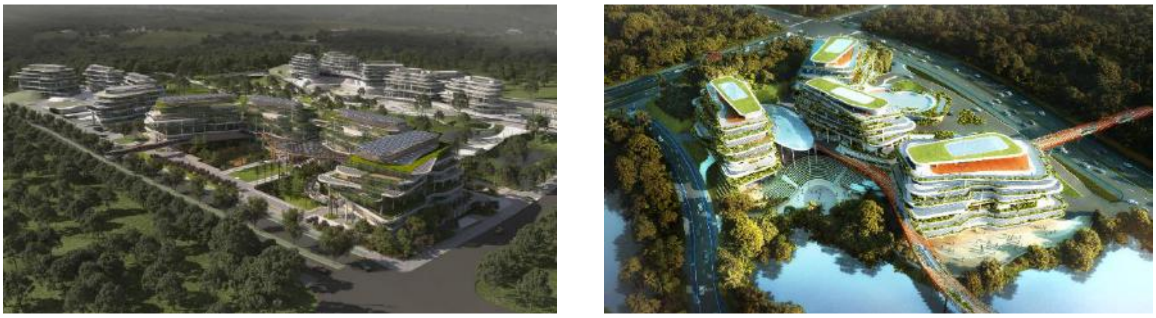


Figure 10. Coordinating Ministry Office.

1) Water resource infrastructures

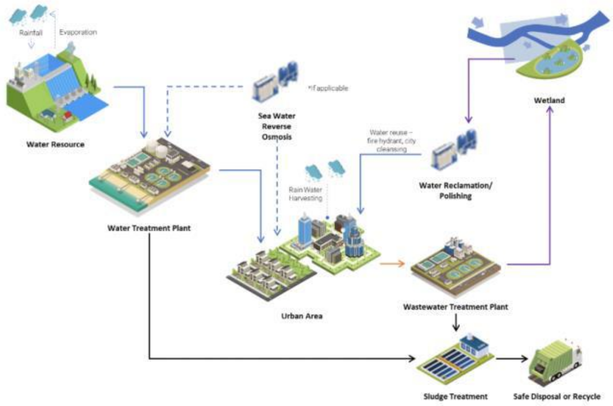


Figure 11. Integrated Urban Water Management (MPWH, 2023).

Sustainable city principles also reflected on the green infrastructure for water resources management. The GoI adopts the principles of Integrated Urban Water Management from upstream to downstream in the Nusantara capital project [35]. At the upstream side, The GoI puts effort on providing raw and clean water by constructing intake facility in Sepaku River with the capacity of 3.000 liter/second, Sepaku Semoi Dam with the capacity of 2.500 liter/second, and Batu Lepek Dam with the capacity of 4.300 liter/second as illustrated in the figure below.

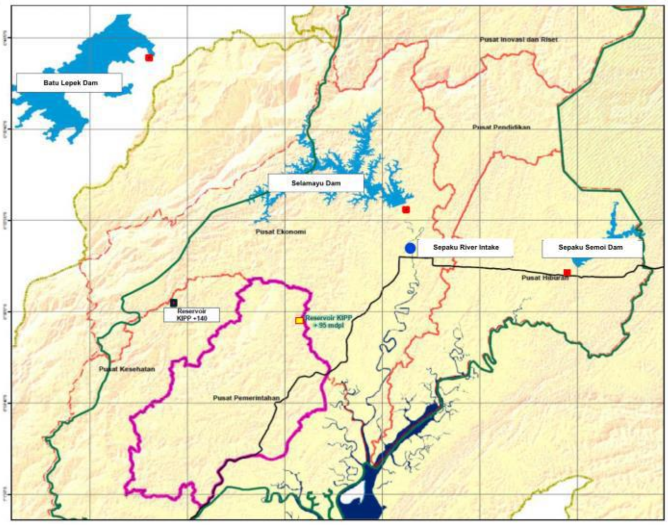


Figure 12. Raw Water Infrastructure on Nusantara New Capital City.

The water system management also adopts the use of smart technologies and systems both on the supply side (water resilience, non-revenue water, and potable water) and the demand side (consumption efficiency) as illustrated in the figure below.

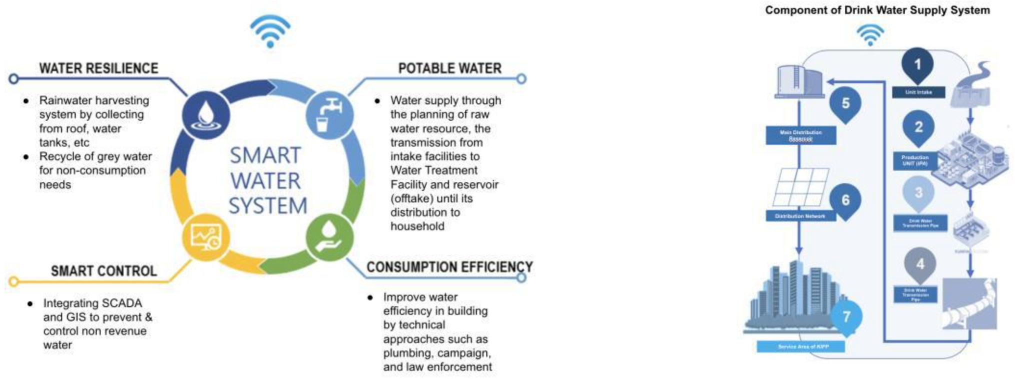


Figure 13. Smart Water Management and Provision System in Nusantara Capital. Source: MPWH, 2023.

Moreover, the project also plans to improve the riverbank areas as well as provide green space. The riparian area of Trunen River at the back of the office area will be transformed into green spaces for physical exercise activities as well as a park for the public as seen in Figure 13. The natural condition will be preserved with various natural-like elements and various landscape beautifications as seen in Figure 14.

Figure 14. Transformation Plan for Trunen Riverside.

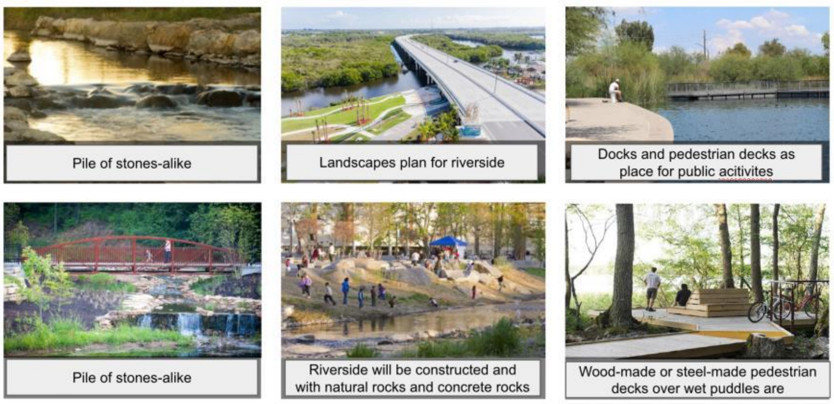


Figure 15. Detailed Landscape Elements for Riverside Improvements.

One of key takeaways of green infrastructure particularly the water resource infrastructure is its role as manifestation of urban resilience in integrating between risk assessment and actionable plans [5]. Nusantara development planning has already adopted the risk assessment approach and delivered it into an action plan particularly for disaster risk management. Nowadays, in the context of disaster risk management, the most critical matter is on the governance and institutional side [7]. Therefore, the Nusantara project also develops the master plan of flood containment particularly in primary drainage of Sangai river side with the early warning system.

The flood containment and management are planned by the integration between green spaces of the capital city, LIUDD concept, and Smart City of Nusantara that are illustrated in figure 15 below. Such early warning system

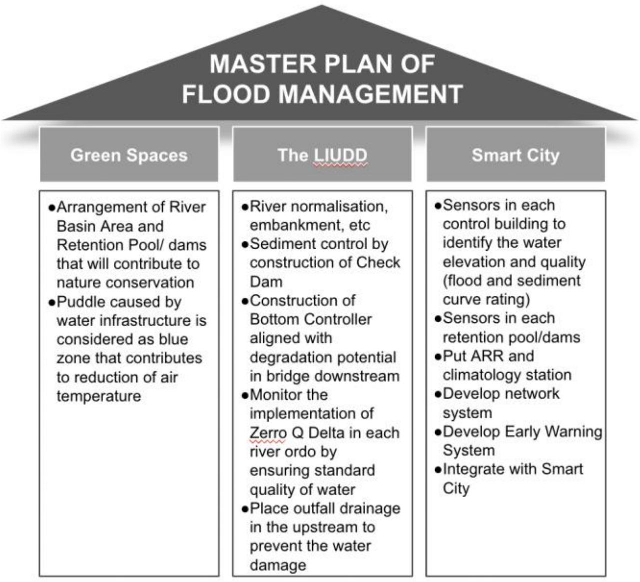


Figure 16. Master Plan of Flood Management in Nusantara Capital. Source: Ministry of Development Planning, 2022.

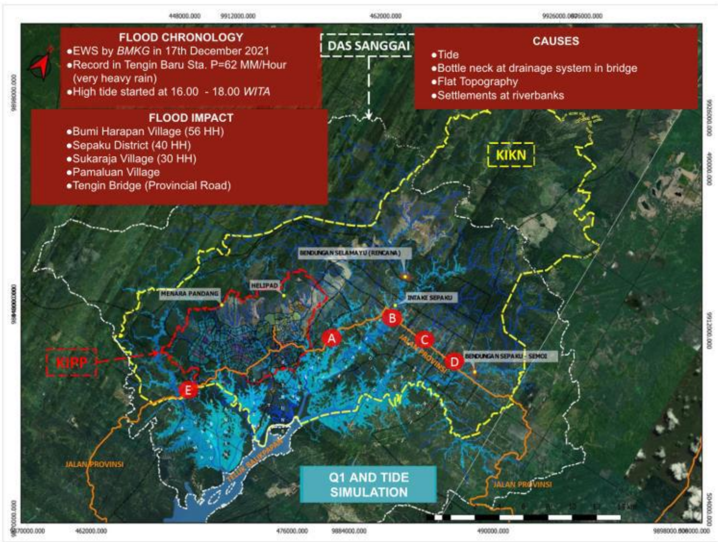


Figure 17. Scenario planning for flood.

In the implementation of the early warning system, building scenarios to identify the potential threat is an integral part of disaster mitigation. Scenario-based planning is really essential because it considers possible outcomes under certain circumstances [8]. Therefore, the Nusantara capital city delivers a scenario-based flood mitigation plan as seen in Figure 16 above. The simulation projects simulation in Q1 and counts tide effect by using flood data history.

2) Waste Treatment

Waste in cities is often produced by public parks, settlements, and areas where public activities happen. The Nusantara capital project plans to build waste treatment facilities that integrate between public areas to final waste treatment/processing sites. Besides that, waste processing will be performed at the initial stage (upstream) by sorting the kind of waste and performing a recycling process [35]. The KPI for waste management is to achieve 60% recycle of solid waste by 2045 with sorting from the initial source and 100% wastewater will be processed through processing facilities by 2035 [34].

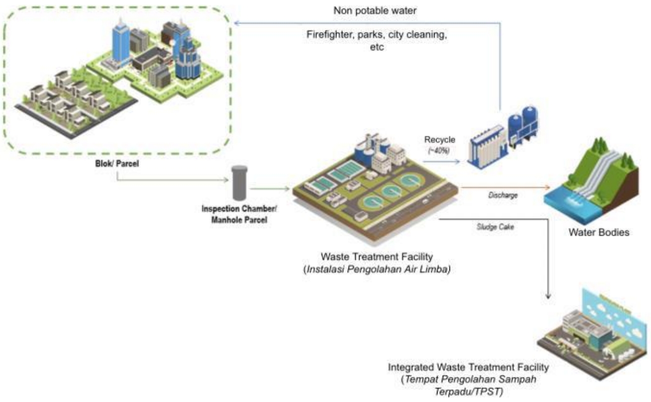


Figure 18. Waste Treatment Process in Nusantara capital city.

3) Connectivity Infrastructure

Green infrastructure principles are also reflected in the construction of connectivity and mobility infrastructures. As part of the implementation of sustainable roads infrastructure as stipulated in the Law Number 2 of 2022 on Roads, the Nusantara capital city will apply the sustainability principles both in access to/from Nusantara city (toll roads), outer ring road, inner ring road, and within the city. As seen in the figure 18 below, the detailed design of roads has adopted the sustainability principles.

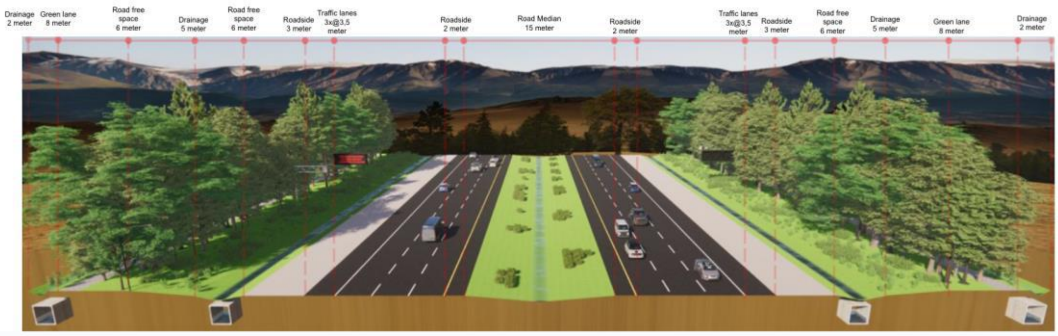


Figure 19. Design of Primary Artery Row 100 - Access to Nusantara city.

Figure 20. Design of Primary Artery Roads.

Figure 21. Design of Secondary Collector Road.

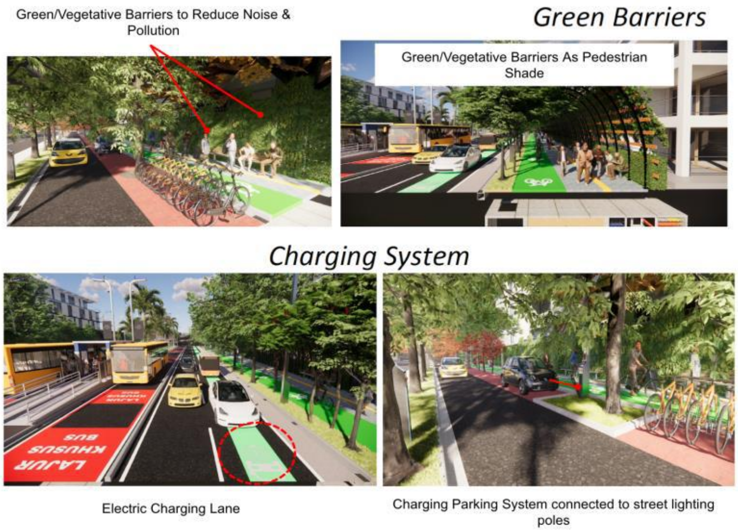


Figure 22. Design of Green Barriers.

The Nusantara capital city project plans achieve 80% of mobility by public transportation or active mobilization, 10 minutes to strategic facilities or public transportation nodes, and <50 minutes of express transit connection from central government area (*KIPP*) to airports in by 2030 as set in KPI 3 [34]. To achieve this, the project uses the following six strategies of mobility.

a) Connected City
Toll road trace with average traveling time from central government area to Balikpapan International Airport in < 50 minutes. Regional roads will connect all directions of regions in East Kalimantan and integrate all activity centres.

b) Compact City
City planning based on transit-oriented development (TOD), *mixed-use*, and vertical housing. 10 minutes of walking to each transportation node.

c) Future City
Future parking with charging stations, optimize the design based on EV/CAV, enhancing the function of pick-up/drop-off zone, and parking zone for all modes of transportation.

d) Sustainable City
High-density area which served by primary transportation corridor and station as mobility hub, competitive traveling time, maximum of 2 transfers of transportation route, ET fuel technology and its charging facilities, and reduction of emission by limitation of private vehicles and the use of non-combustion technology.

e) Active and Pedestrian Friendly City
Active mobility networks with integrated green lanes and main corridors.

f) Efficient and Resilient City
The design of road right-of way accommodates an active mobility, 10 minutes city, and optimization of operational management, traffic signal, communication system, and utilization of Intelligent Transportation System (ITS).

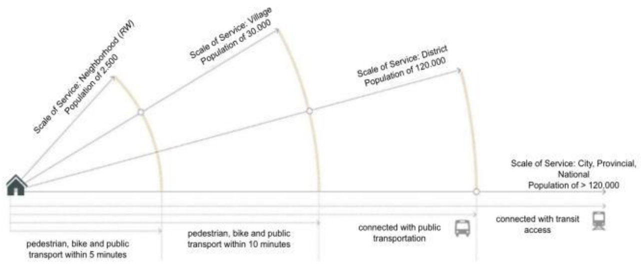
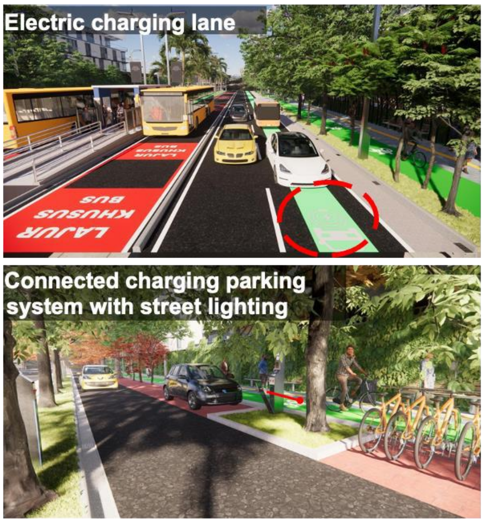


Figure 23. Nusantara compact city planning.

Sustainable and Renewable Energy

For cities that are not energy producers, it's essential to develop policy and regulation that promote integration with renewable energy resources and supply to city grid [5]. The Nusantara capital city plans to have 100% energy consumption from renewable energy sources, 60% efficiency for energy conservation inside buildings, and net zero emissions in 256.142 Ha area by 2045 [34]. The energy in the central government area will be provided by gas insulated substation (GIS) with underground cable (UGC). To achieve the target of 100% renewable energy and net zero emission by 2045, Nusantara capital city plans to develop power plants in the capital city area with an energy saving system, utilization of renewable energy-oriented Kalimantan electricity system, and applying smart grid [34]. For the gas needs, Nusantara capital city plans to consider using the hydrogen and natural gas for city gas supply system [34].



Sumber: Direktorat Jenderal Bina Marga Kementerian PUPR, 2022.

Figure 24. Electric vehicle charging facilities.

c. Challenges and Opportunities

Many believe that cities in the global south have a far more complicated challenge than the global north due to the exponential growth [5]**.** Planning was defined as the art of making social decisions rationally [41] therefore identifying key challenges as well as opportunities are essential for succeeding Nusantara new capital city project. The discussion below reflects the seek of polishing up the project plan from literature review as well as practices in global cities.

1) Policy Environment

Risk Management

Urban form really determines the pattern of future city development particularly in dealing with potential problems such as urban sprawl and high carbon emission [5]. The use of compact city approach is sometimes suitable for some cities but not for the others that arguably doesn't consider the aspects of resident behavior that tends to avoid high-density zones and move to a lower-density area [4,36,37]. Some scholars also argue that the compact city may produce less privacy, more noise and congestion [38]. The other challenge is unfortunately the Nusantara city planning hasn't set out a target of water coverage for its households.

At the micro level, the other challenge is how to minimize the clash of infrastructure/buildings construction because building a city from scratch needs an extra effort to avoid the clash from each construction design. The ability and capacity of planners are very essential to deliver this challenge.

The masterplan of Nusantara capital needs to cover risk management at macro level. For example, in disaster management, floods are already experienced not only in the Nusantara project area but also in surrounding cities. The Master Plan of Nusantara capital has considered the risk of flood, but overlooking the limited capacity of surrounding cities/regencies in disaster preparedness planning could be dangerous because it will only be seen as moving the risk to those cities. Providing technical assistance to those cities/regencies to address the risk have to be taken into action [20].

Institution

On a technocratic level, Nusantara new capital city is the only urban management whose KPI is specifically determined to adopt sustainable city principles through a presidential regulation which is different from most regional/local governments practices. On the one hand, this is a good new precedent. However, what has not yet been discussed is how to elaborate it in the future with the accountability system (*Sistem Akuntabilitas Kinerja Instansi Pemerintah*) and development planning system that is currently in place. The question emerges: will SAKIP in urban governments be influenced by this approach (standardized indicators for urban sustainability)?

The World Bank [8] states that sustainable city can be achieved through enabling sound management of financing to ensure financial sustainability. In investment context, in order to gain massive funding, cities will need to integrate every stakeholder's objective by articulating sustainability initiatives in each interest like revenue and growth for investors, cost-to-serve and intervention targets for the public sector, and well-being for the citizens [5]. For Nusantara, policy as an incentive instrument can be applied for example giving a tax allowance scheme for green investment at micro level/activities. At the initial stage of development, Nusantara relies on a state budget delivered by the Ministry of Public Works and Housing for its water and sanitation access. But many researches show that low-middle income countries in many instances face obstacles in achieving targets of SDGs related to clean water and sanitation [26] and public investment (government spending) will no longer be able to close the funding needs for the provisions [39]. Therefore, Nusantara city has to build a strategy for its sustainable funding.

The Nusantara capital also needs to start preparing a regulation framework for law enforcement related to the effort of ecological preservation for example the limitation of using groundwater and building standards.

Adaptive capacity.

On the other hand, Indonesia has applied the action plan of SDGs for every municipality to control their commitment to sustainable development, so what about Nusantara capital city? How do we know if the city is on the right track of incorporating the sustainable development principles? The answer is to have the same governing system. The development of Nusantara capital city is a great momentum to propose and advocate a more comprehensive framework that becomes the main reference for all Indonesian cities in objectifying urban sustainability. The Melbourne Principles of Urban Sustainability which embodies principles of sustainability is an ideal model that gives a useful framework that all cities can refer to. One of the primary challenges and opportunities is to build an adaptive management system that links between government and scientists to enable the translation of scientific knowledge into practical guidelines and tools [31].

If a city wants to take sustainability more seriously, there is a need to collect urban metabolism data as a priority activity [6]. For example, in ensuring clean & efficient energy consumption, Nusantara could have smart grid technology to monitor resident’s or activities’ electricity consumption and inform the data for better energy management. The goal of this implementation is to enable households and operators of large buildings or public services to change their behavior and reduce energy demand. On the other hand, Nusantara capital represented by the Authority Board of Capital must set up the availability of data and identify quantitative measures to analyze it, for example using Green City Index measurement.

2) People

The World Bank (2013) identifies 3 (three) key challenges in making more sustainable cities which are to address knowledge gaps, foster participation, and seek behavioral change. In the governance context, adaptive policy is essential as failure to mitigate will lead to failure to adapt [40].

Address knowledge gaps

While the development planning system of Indonesia nowadays uses the projection time of 5 to 25 years, cities as permanent places of residence are as old as civilization itself so therefore need a longer perspective of time. To be sustainable, a city should be holistically planned in a participatory way. Design of urban physical characteristics, often termed as urban form, can influence social capital development. That's why it needs a bold collaboration between the engineer and social scientist. The GoI, particularly the Authority Board of Nusantara, has to build an enabling environment that bridges knowledge creation and entrepreneurship, encouraging research to policy making, promoting data transparency, and facilitating the exchange of knowledge at every policy stage.

Foster Participation

Public participation in an ecosystem approach of urban sustainability is viewed by engaging the public in decisions that affect them, exercising equity and environmental justice, and also must go beyond business-as-usual consultation [31]. Many stakeholders (including government officials and the public themself) acknowledge that participatory processes are time-consuming, costly, and distrust often arises between stakeholders. That’s what reflected on some protests among civil society on the Nusantara project even in the initial development phase. The most common thing is the lack of the local capacity (including skilled labor/local experts, local people, and institutional weakness) to critically exercise the planning brought by the government [31]. Therefore, establishing regional centers to provide meaningful workshops in technical skills needed in the context of urban and environment for local people, academia, and practitioners are needed [31]. Promoting transparency and sustainability also matter.

Seek behavioral change

Friedmann [41] stated that planning relies on the attempt to link scientific and technical knowledge into a process of social transformation. Therefore, the Nusantara capital project must be derived into technical behavior change strategies. For example, with middle to high level income/purchasing power and consumption demands projected, Nusantara residents must be directed to low-carbon lifestyles; it means in the supply side the government must selectively provide eco-friendly products and services with a behavior campaign. This includes reducing food and household waste, moving mobility behavior from private vehicles to public transportation modes, less energy consumption, etc. The effort to change behavior is integral within the effort of addressing knowledge gaps and participation which can be delivered not by telling citizen/public what to do but disseminating knowledge and information so people will aware of the importance of sustainable living hood and therefore could create a balanced supply and demand [42].

3) the myth of trickle-down effect

The master plan of Nusantara capital city highlights the concept of a triangle city (Nusantara, Balikpapan, and Samarinda) and cluster-based economy to foster regional growth. Notwithstanding the concept is comprehensive enough to understand, how to ascertain the economic growth and prosperity is perceived by the local community in the short term while the majority has low education and expertise? The Master Plan of Nusantara has mentioned the target of ratio gini (inequality gap) in Nusantara city, but the issue of how to balance the ratio amongst other surrounding cities hasn’t been answered yet. This means that putting focus on secondary cities surrounding the Nusantara capital plays a very important role in keeping the inequality at manageable levels. Notwithstanding their critical contribution to Nusantara capital (in terms of logistics, food, employment, etc), secondary cities/regions are usually overlooked in policy as reflected in ASEAN Sustainable Urbanisation Report [20].

5. Conclusion

The literature discussion before provides the definition of sustainable city that relates to the concept of green urbanism, urban metabolism, green infrastructure, compact city, resilience city, zero carbon city, and city that promotes ecological conservation. By doing analysis on the conceptual and practical background of sustainable city, this article exercises the incorporation of such principles in the Nusantara Capital City of Indonesia project that is undergoing and targeted to be finished by 2045.

The discussion finds that integrating principles of urban sustainability has been performed and delivered in the Nusantara capital city project which reflected on the urban conservation effort of 75% area for green and protected area, the construction of green public infrastructures, and realizing smart governance into the city management. Thus, this article successfully demonstrates the capability of urban planners in the Nusantara city project in implementing sustainability principles.

The analysis still finds various challenges in delivering such principles such as the policy environment and social aspects that need to be considered in short, medium, and long-term. This article also calls for further research on the observation of city governance that fits with Nusantara capital city because it differs from the general local government regime in Indonesia. Furthermore, the effort on how to mainstream the Nusantara visions as a sustainable city to other Indonesia's cities and how to scale up economic growth in the eastern part of Indonesia by the presence of Nusantara must be carried out.

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EXPLORING THE READINESS OF DIGITAL TRANSFORMATION FOR GREEN BUILDING CONSTRUCTION INDUSTRY IN BRUNEI DARUSSALAM

Ir. Chin Lee Tuck[1], Dr. Chan Sai Keong[2], Professor Ir. Dr Tan Chee Fai[2]

[1]Chairman of Engineering Division & Vice President of PUJA(B), Brunei Darussalam
[2]Infrastructure University Kuala Lumpur (IUKL), Malaysia

E-mail: engineerltchin@gmail.com

Abstract

The construction industry often acknowledge as the largest industry and is facing immense technologies changes as well as challenges in application of sustainable practices. In the era of industry 4 with a highly interconnected world and complex digital systems, the building construction industry has gained towards green technology momentum globally. This paper studies, evaluating its current status, challenges, and potential opportunities through a comprehensive literature review of the potential and readiness of digital transformation and the green building construction sector to adopt advanced technologies in Brunei Darussalam. The study examines the correlation between digital transformation and sustainable construction, highlighting key technologies such as Building Information Modeling (BIM), and Internet of Things (IoT), Artificial Intelligence (AI). These technologies whether can offer opportunities to optimize resource efficiency, minimize waste, and enhance building performance. In conclusion, this study underscores the readiness landscape within the green building construction industry. While certain segments have embraced digital technologies, persistent challenges such as cost barriers, expertise gaps, and resistance to change highlight the urgent need for the construction sector to champion readiness for digital transformation. A pivotal aspect of this readiness lies in comprehensive training, particularly in the seamless integration of green technology. These findings by using qualitative method has provide invaluable insights to inform policymakers and stakeholders as they work towards enhancing readiness for digital transformation in Brunei's construction industry.

Keywords: Artificial Intelligence (AI), Building Information Modeling (BIM), Digital transformation, Green building sustainability construction, Internet of Things (IoT),

1. Introduction:

Introduce the concept of digital transformation in the context of the construction industry. The concept of digital transformation has emerged as a conspicuous phenomenon within diverse industrial domains, driven by the accelerated assimilation of digital technologies into the fabric of organizational operations [1].

As scholars have observed, digital transformation in the construction sector stands out for its ability to overhaul conventional practices and workflows, ultimately resulting in enhanced project outcomes and more efficient resource utilization [2]. This transformation harnesses an array of technologies, including Building Information Modeling (BIM), Internet of Things (IoT) devices, drones, and cloud computing, which collectively facilitate real-time data sharing, foster improved collaboration among stakeholders, and enable data-driven decision-making [3].

At present, many business enterprises lack a comprehensive understanding of the profound significance and intricate synergy between digital transformation and green technology innovation. Digital transformation has the potential to significantly advance green technology, yet its supportive role in this context remains underutilized, leading to ongoing financial challenges in the realm of green technology innovation [4]. This underscores the need for a deeper appreciation of the connections between digital transformation and green technology, as digitalization represents not just a technical shift but a fundamental transformation with enduring impacts on businesses.

The potential role of digital transformation in advancing green technology innovation remains underutilized, leading to persistent financial challenges in the green tech sector. It is worth emphasizing that organizations currently have an inadequate grasp of the profound significance and intricate interrelation that exists between digital transformation and the innovation of green technologies [4].

It is widely acknowledged that green building represents an effective approach for addressing sustainability and sustainable development within the construction industry [5][6]. Green building is defined as "the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's lifecycle" [7]. Consequently, the development of green buildings holds the potential to significantly reduce negative environmental impacts and optimize resource utilization [8]. In line with the findings of the literature review [9], the adoption of Green Building Technologies (GBTs) presents a promising avenue for enhancing the sustainability performance of buildings, garnering increased interest within the global construction community. However, barriers to the readiness and adoption of GBTs, such as elevated costs and limited awareness, underscore the necessity for formulating effective strategies to promote wider GBT adoption in building development.

In this context, Xue et al [2] contend that contemporary enterprises often fall short in fully grasping the profound significance and intricate interplay between digital transformation and the innovation of green technologies. This deficiency in comprehension, as elucidated by Xue et al. [4], holds significant implications for the progression of green technology innovation, prompting critical questions regarding the securement of adequate financial support in this critical domain.

However, the construction industry remains conspicuously one of the least digitized sectors worldwide, grappling with the effective adoption of AI and other digital technologies. Existing research suggests that the reluctance to adopt AI can be attributed to a multitude of challenges, encompassing cultural barriers, the substantial initial costs associated with AI-based solutions, issues of trust and security, shortages in skilled talent, limitations in computing power, and constraints in internet connectivity. Nevertheless, it is evident that numerous uncertainties persist in the research landscape concerning AI applications, prospective opportunities, and the impediments to adoption within the construction industry [10].
The transformation of the construction sector hinges on the promotion of advanced digitization, the infusion of manufacturing principles, process automation, data-centricity, the integration of information and communication technologies, and the incorporation of virtual/augmented realities (VR/AR). These elements will reshape the fundamental operations of the industry [11][12]. Consequently, it accentuates the immediate necessity of bridging the existing knowledge gap surrounding the convergence of digital transformation and green technology innovation.

The primary aim of this study is to provide an understanding of the synergistic relationship between digital transformation and green technology innovation and to extend the findings of prior research conducted by Xue et al [4], Gann et al [11], and Yoo et al [12]. Specifically, it seeks to delve deeper into the relationship between digital transformation and green technology innovation within enterprises. This exploration is particularly relevant in the context of Brunei Darussalam, where green building practices and sustainable construction hold significant importance. In light of the nation's commitment to addressing climate change, exemplified by the re-establishment of Brunei Darussalam National Council on Climate Change (BNCCC) and Brunei Climate Change Secretariat (BCCS) in July 2018, and the subsequent release of the Brunei Darussalam National Climate Change Policy (BNCCP), there is a heightened emphasis on addressing climate change impacts through ten key strategies [cite relevant sources if necessary]. Under the BNCCP two of the ten key strategies are to improve power management and climate resilience and adaptation. Energy efficiency falls under both categories to a certain extent [13].

Based on the Choo et al [13] (ASEAN Centre for Energy) According to data from the ASEAN Centre for Energy, Brunei Darussalam had an average annual electricity consumption per capita of approximately 9,000 kWh in 2020, ranking second after Singapore and having the highest consumption in the Southeast Asia region, as indicated in Table 1. It is crucial for Brunei Darussalam to prioritize sustainability in construction as a means of safeguarding the environment, bolstering climate resilience, optimizing resource utilization, fostering economic growth, and enhancing the well-being of its citizens. Such prioritization can significantly contribute to a more environmentally friendly and prosperous future.

TABLE 1: ASEAB Members States (AMS) Electricity Consumption (ASEAN Centre for Energy)[13]

Country	Electricity consumption/(kWh/capita)	Data presented in
Singapore	9100	2020
Brunei	9000	2020
Malaysia	4600	2020
Thailand	2600	2020
Vietnam	2100	2019
Indonesia	970	2020
Philippines	810	2019
Lao PDR	728	2019
Cambodia	600	2019
Myanmar	360	2019

In June 2021, the Ministry of Energy in Brunei introduced a novel regulatory framework known as the Energy Efficiency (Standards and Labelling) Order 2021 (SLO). This standard mandates that manufacturers, suppliers, wholesalers, and retailers operating within Brunei Darussalam adhere to specific guidelines. These guidelines necessitate the importation and sale of electrical appliances that align with the Minimum Energy Performance Standards set to meet consumers' energy efficiency requirements.

2. Industry 4.0/Construction 4.0

The concept of Industry 4.0, also known as the Fourth Industrial Revolution (4IR), gained prominence in 2016 when Klaus Martin Schwab, the founder of the World Economic Forum (WEF), introduced it [14]. Leveraging the capabilities inherent in Industry 4.0, various industries have the potential to enhance their operational efficiency in terms of time, costs, and productivity. The establishment of an Internet of Things (IoT) framework facilitates the development of collaborative platforms through cloud systems among participants in the Supply Chain, enabling the optimization of business processes for improved outcomes [15]. As noted by Lanzolla et al. [16], digital transformation encompasses the integration of digital technologies into organizational structures to redefine products, processes, and value chains, thereby expanding market reach and opening up novel organizational possibilities.

The term 'Construction 4.0,' also referred to as 'Bau 4.0' in German, was initially introduced by Oesterreich and Teuteberg [17] and is closely associated with the influence of the Fourth Industrial Revolution, Industry 4.0, on the construction sector, with its origins dating back to 2009.

The notion of digital transformation, often referred to as "digitalization," is a prominent subject of study. As articulated by Stolterman and Fors [18], digital transformation is synonymous with digitalization. Extensive literature review reveals that digital transformation is commonly portrayed as a social phenomenon [19] or a cultural shift [20][21][22]. In a business context, it represents the evolution or creation of innovative business models [23][24][25][26][27][28[29]. According to Grassmann et al. [29], digital transformation is typically actualized through a process known as digitization, which entails converting existing products or services into digital formats. This transformation offers distinct advantages compared to physical offerings, characterized by the "capacity to transform current products or services into digital counterparts, thereby providing benefits over tangible products."

Digital transformation, as implied by its nomenclature, fundamentally constitutes a metamorphosis resultant from the progression of novel technologies and impelled by technological advancements. This transformation entails the adoption of diverse innovations by enterprises, encompassing internet, analytics, and mobile technologies [23][24][25][26][27][28][29]. Cloud technologies have particularly played a vital role in advancing these components.

This section provided the research study of State of the Art of Construction 4.0 includes the adoption of some of the Industry 4.0 components such as IoT, BIM in the construction industry. Current technologies associated with Industry 4.0 and applied to the construction industry include BIM (Building Information Modelling), virtual reality (VR), augmented reality (AR), mixed reality (MR), cloud computing, mobile computing, and modularization technologies.

The adoption of Green Building Technologies (GBTs) holds considerable promise for enhancing the sustainability performance of buildings, garnering increasing interest within the global construction community [9]. These technologies, for example, solar system technology, green roof and wall technologies, and heat pump technology [30], encompass various approaches applicable throughout the entire building project lifecycle. It is noteworthy that the term "green building" is often used interchangeably with "sustainable building" and "high-performance building" [31] reflecting the evolving discourse within green building research and its future research agenda.

The Internet of Things (IoT) is conventionally characterized as a network that goes beyond traditional computing devices and includes a wide array of physical objects. Within this interconnected network, these entities engage in communication and information sharing, facilitated by established protocols. This interconnectivity serves multiple purposes, including intelligent reconfiguration, positioning, tracking, safety measures, control functions, real-time online monitoring, system upgrades, process control, and administrative functionalities [32][33].

The Internet of Things (IoT) finds practical application in the creation of smart societies and homes. A multitude of electronic devices and HVAC (Heating, Ventilation, and Air Conditioning) systems, such as lights, fans, microwave ovens, refrigerators, heaters, and air conditioners, have been equipped with sensors and actuators. These sensors and actuators enable efficient energy utilization, monitoring and control of heating and cooling processes, and the adjustment of lighting levels. For instance, room lights can detect the presence of occupants and activate when individuals enter a space. Furthermore, in the event of a fire or smoke detection within the home, wireless smoke and carbon monoxide sensors not only sound alarms but also send alerts through phone or email notifications. These IoT-enabled enhancements in daily life contribute to cost reduction and increased energy savings.

In addition to IoT and Building Information Modeling (BIM) as described at below, the construction industry is witnessing the emergence of various other technologies. According to [34], some of these emerging technologies encompass: Additive Manufacturing (AM), Modularization and Prefabrication (M&P), Automation and Robotics (A&R),Human-Computer/Robot Interaction (HCI/HRI),Laser Scanning and Photogrammetry (L&P),Virtual Reality/Augmented Reality (VR/AR),Simulation and Algorithm (S&A),Cloud Computing (CC) Big Data (BD), These technologies collectively represent the evolving landscape of the construction industry, offering transformative potential in terms of efficiency, innovation, and sustainability.

Building Information Modeling (BIM) stands as an advanced information and communication technology with the potential to play a crucial role in streamlining the green building certification process. Essentially, BIM entails the creation and meticulous management of digital representations that encompass both the physical and functional attributes of a building [35]. Within the realm of sustainable construction, BIM offers a multifaceted utility. It empowers comprehensive assessments of passive design strategies, encompassing the effective harnessing of solar and wind resources for heating, illumination, and ventilation purposes. Moreover, BIM proficiently addresses diverse facets such as energy consumption, greenhouse gas emissions, waste generation, life cycle costs, and facilities management. This comprehensive approach contributes significantly to elevating sustainability ratings within the green building paradigm [32].

Building Automation Systems (BAS) represent a significant digital technology employed in the pursuit of energy-efficient green buildings. These systems offer the versatility to integrate with various building services, including HVAC (Heating, Ventilation, and Air Conditioning), lighting, access control, safety and security systems, and transportation infrastructure. This integration enhances operational effectiveness, security, and safety within the building environment. BAS systems are scalable, capable of controlling a single device or scaling up to manage several thousand devices, depending on the specific application.

Numerous studies have identified BAS as a pivotal element in achieving the goals of zero-energy buildings and facilitating the implementation of an effective smart grid. By optimizing the operation of systems linked to BAS, the wear and tear on machinery and appliances are reduced, leading to extended operating lifespans and fewer maintenance interventions. Notably, the global BAS market is projected to reach a substantial valuation of US$8.4 billion by the year 2027, with a compound annual growth rate (CAGR) of 12.4% forecasted over the period from 2020 to 2027 [36]. This underscores the increasing significance and widespread adoption of BAS in the construction industry's digital transformation.

The advent of green building has led to the development of various green certificates, rating systems, labeling programs, and assessment tools aimed at supporting sustainable building practices. Leading among these green building assessment tools are: Leadership in Energy and Environmental Design (LEED) in the United States, the Building Research Establishment Environmental Assessment Method (BREEAM) in the UK, the Green Building Council of Australia Green Star (GBCA) rating system, the Green Mark Scheme in Singapore, the DGNB system in Germany, the Comprehensive Assessment System for Built Environment Efficiency (CASBEE) in Japan, the Pearl Rating System for Estidama by the Abu Dhabi Urban Planning Council, the Hong Kong Building Environmental Assessment Method (HK BEAM), and the Green Building Index in Malaysia.

The emergence of green building practices has led to the development of various green certificates, rating systems, labeling programs, and assessment tools aimed at facilitating and advancing sustainable building initiatives. Among the foremost green building assessment tools are:

- Leadership in Energy and Environmental Design (LEED) - United States
- Building Research Establishment Environmental Assessment Method (BREEAM) - United Kingdom
- Green Building Council of Australia Green Star (GBCA) - Australia
- Green Mark Scheme - Singapore
- DGNB - Germany
- Comprehensive Assessment System for Built Environment Efficiency (CASBEE) - Japan
- Pearl Rating System for Estidama by the Abu Dhabi Urban Planning Council
- Hong Kong Building Environmental Assessment Method (HK BEAM)
- Green Building Index – Malaysia

These tools and programs have been instrumental in advancing sustainable construction practices and promoting environmentally responsible building development.

3. Green Building Construction in Brunei Darussalam

According to a report by the Oxford Business Group in 2014 [37], Brunei Darussalam initiated efforts to promote environmentally friendly development. The government commissioned the construction of the Sultanate's inaugural official green building, the Knowledge Hub, which was completed in January 2010 at a cost of BN$4.8 million (equivalent to $3.77 million USD). Developed by the Brunei Economic Development Board (BEDB), this seven-story building incorporated advanced technologies, including motion sensors for lighting and energy-efficient elevators. Furthermore, it supplemented its electricity consumption by utilizing roof-mounted photovoltaic solar panels.

The Anggerek Desa Technology Park expanded these green building practices with the construction of a sister building during the third and final phase of the BEDB project. Completed in October 2014, this eight-story office building and accompanying car park embraced eco-friendly features such as natural daylight utilization, a rainwater harvesting system for landscape irrigation, and the use of other sustainable materials and techniques. These initiatives aimed to achieve an environmental certification equivalent to Singapore's Green Mark certification issued by the Building and Construction Authority (SBCA).

Furthermore, in 2015, the first LEED Gold award in Brunei Darussalam was conferred upon the NDCO office building [source: https://www.gbig.org/places/95], marking a significant milestone in the country's commitment to sustainable construction. This LEED certification was attained in 2012, underscoring Brunei Darussalam's dedication to environmentally responsible building practices.

The decision to incorporate green building practices ultimately rests with the building owner/stakeholder; however, Brunei Darussalam is actively working to promote the adoption of these practices through the Brunei Green Building Council (BGBC). Established in 2013, the BGBC, which attained emerging member status within the World Green Building Council in the same year, comprises industry stakeholders who have united to advance several key objectives. These objectives include educating construction firms and the general public about the advantages of green building techniques and establishing a set of certification standards akin to those employed internationally.

4. Intersection of Digital Transformation and Green Building

The emergence of digital transformation is increasingly regarded as a pivotal economic advantage, giving rise to the generation of environmental value within the construction sector. In this digital era, construction enterprises are afforded the opportunity to transcend conventional information barriers, swiftly discern prospects for green development, and augment their capacity for innovative green initiatives. Consequently, an exploration of the influence of digital transformation on the green innovation efforts of construction enterprises will facilitate the harmonious advancement of both the digital and green construction industry [38].

While a significant portion of the existing literature on digitalization primarily focuses on technological advancements such as mobile technologies and analytics solutions, it is essential to recognize that the scope of this subject matter is far-reaching. Digital transformation encompasses a broader spectrum of possibilities and warrants examination from diverse perspectives. It is worth noting that both empirical observations and well-established studies from authoritative sources like MIT - Cap Gemini [38] and the IBM Institute for Business Value [39] underscore that digital transformation exerts its impact across all facets of an organization.

The findings derived from the research study [4] underscore the pivotal role of enterprise digital transformation in catalyzing green technology innovation. Importantly, digital transformation permeates every facet of green technology innovation, effectively propelling advancements in this domain [4].

5: Methodology

A comprehensive questionnaire was established by referring to Rahman [35] with modification to the description of questions to suit the topic of this paper. The objective of the questionnaire was to garner insights and perspectives from private sectors players that included building contractors and Electrical works contractor, Mechanical works contractor. Nevertheless, it is crucial to acknowledge the inherent limitations associated with questionnaire methodology. Its applicability may not be universal across all research inquiries, and the quality of the obtained data can be significantly influenced by various factors, including the design of the questionnaire, the phrasing of questions, and the range of response options provided. Therefore, the researchers diligently referred to the questionnaire description delineated by Rahman [35] as a foundational reference and carefully tailored it to align with the specific research context. This methodological refinement aimed to mitigate potential biases and ensure the collection of precise and contextually relevant data, in accordance with the overarching research objectives.

The modality of questionnaire delivery included both in-person visits face to face engagements and telephone engagement.

6. Result and Discussion

This concerted effort culminated in the acquisition of a total of 10 responses due to the facts that the contractor selected are well established contractor at minimum at class 4 above category. All the 10 responses were submitted and while three were only partially completed. The cohort of respondents was focus on upper level of registered contractor, consisting of project manager level, engineer level in the private sector. The collective professional experience of the respondents exhibited an average tenure of 8 to 9 years within their respective domains

The questionnaire inquired about 25 pivotal aspects, soliciting responses in a binary format (i.e., "yes" or "no"). The exhaustive set of questions can be found in the Table 1.

In sum, this rigorous methodological approach not only ensured the comprehensive coverage of pertinent perspectives within the construction industry but also facilitate a robust quantitative analysis of the data, thereby enhancing the reliability and validity of the findings. These findings, as received in Table 1, constitute a valuable contribution to the discourse on Digital Transformation and green technology in the construction sector of Brunei.

There were 10 responds for all the questions. Below is the explanation of each question.

Question 1 was ‘have you heard of Digital Transformation’ : of which 70% said yes, 30% said no. This shows that most of respondents have heard of D.T. This shows that relatively more respondents have heard of BIM.

Question 2 was “Did you know about Digital Transformation before this questionnaire?” Among the 10 respondents to this question, 70% respondents knew about D.T before the questionnaire survey. Thus, most of the respondents knew D.T before the survey study.

Question 3 was “Did you know Heard about Digitisation ad Digitalisation before this questionnaire?” Among the 10 respondents to this question, 10% respondents knew about it before the questionnaire survey but 90% don’t know about it. Thus, most of the respondents did not heard the two words before the survey study.

Question 4 was “Do you know the difference among the Digitisation, Digilisation and Digital Transformation?”. 100% said No.

TABLE 1: Summary of Response Showing Awareness of Digital Transformation and Green Technology

	Description of Question	Yes	No	Sum	Percentage Yes	Percentage No
1	Have you heard of Digital Transformation before? (Only hearing, not knowing what it is)	7	3	10	70%	30%
2	Did you know about Digital Transformation before this questionnaire?	7	3		70%	30%
3	Have you heard of Digitisation, and Digiltalisation ?	1	9		10%	90%
4	Do you know the difference among the Digitisation, Digilisation and Digital Transformation?	0	10		0%	100%
5	Do you know the technologies for Digital transformation ?	partitially				
6	Please list down the technologis that you heard of for Digital Transformation? (if you know: refer to question 5)	partitially				
7	Which technologies that you have any idea how its works? (in term of Technical aspect)	Documents scanning, I.O.T, 3D printing.				
8	Are you aware of the main benefits of Digital Transformation?	4	6		40%	60%
9	Are you aware of what is Green technology product ?	3	7		30%	70%
10	Have you heard of Green Index rating such as Green Mark?	3	7		30%	70%
11	Have you heard of Green Index rating such as GBI?	3	7		30%	70%
12	Have you heard of Green Index rating such as LEED?	1	9		10%	90%
13	Have you heard of Green Index rating such as B.A.G.U.S? (Brunei Accredited Green Unified Seal-(BAGUS)	0	10		0%	100%
14	Have you heard of BIM?	3	7		30%	70%
15	Are you aware that BIM helps to enable sustainability in construction?	3	7		30%	70%
16	Do you have any idea of cost of BIM (e.g high, acceptable, etc)	3	7		30%	70%
17	Do you have any idea about initial investment to kick-start BIM?	3	7		30%	70%
18	Do you think that the implementation of BIM in a construction company would pay off?	3	7		30%	70%
19	Are you aware of any barrier to implementing Digital Transformation ?	7	3		70%	30%
20	Do you agree that implementing BIM requires hands on training on the technologies?	10	0		100%	0%
21	Do you think that clients should sponsor BIM adoption?	10	0		100%	0%
22	Does BIM give more benefits than barriers in the construction industry?	3	7		30%	70%
23	Given the chance and support, will you change from conventional method to digitlisation such as using BIM? 3D printing?	5	5		50%	50%
24	Have you attended any talks on Digital Transformation? in Brunei, or any other country?	0	10		0%	100%
25	As a construction professional, do you feel the need for Digital transformation ?	5	5		50%	50%

Question 5 was “Do you know the technologies for Digital transformation? Among the 10 respondents to this question, all the respondents answered partially knew about the technologies for D.T.

Question 6 was “Please list down the technologis that you heard of for Digital Transformation? (if you know: refer to question 5)?” Among the 10 respondents to this question, hence, all the respondents answered partially.

Question 7 was “Which technologies that you have any idea how its works? (In term of Technical aspect)? Among the 10 respondents to this question, hence, all the respondents answered document scanning, I.O.T, 3D printing.

Question 8 was “Are you aware of the main benefits of Digital Transformation?? Among the 10 respondents to this question, 60% said no, which is more than half of the respondents do not about the main benefits of Digital Transformation.

Question 9 was “Are you aware of what is Green technology product? Among the 10 respondents to this question, 70% said no, which is more than half of the respondents do not aware about Green Technology product. Only 30% of the respondents aware of Green Technology Product.

Question 10, 11, and 12 were "Have you heard of Green Index rating such as Green Mark? GBI? LEED? Respectively, and among the 10 respondents answered to Question 10 is 30% yes, to Question 11 is 30%, and 10% as yes to question 12. In average 23% heard of these 3 green rating tools.

Question 13 was "Have you heard of B.A.G.U.S and the respond is 0% yes. None of the respondents heard of this rating tools.

Question 14 was "Have you heard of BIM?", and 70% said no.

Question 15 was "Are you aware that BIM helps to enable sustainability in construction? Among the 10 respondents to this question, 70% said no, which is more than half of the respondents do not aware about BIM.

Question 16 was "Do you have any idea of cost of BIM (e.g high, acceptable, etc)? Among the 10 respondents to this question, 70% said no. The answered to question 15 and 16 are consistent with question 14 since it is 70% did not heard about it and obviously cannot provide the respond to the ability of BIM.

Question 17 was "Do you have any idea about initial investment to kick-start BIM?" Same answered as Question 14,15,16 respectively with 70% do not know have idea about the investment to kick start of BIM.

Question 18 was "Do you think that the implementation of BIM in a construction company would pay off? Among the 10 respondents to this question, 70% said no, this due to more than half of the respondents do not aware about BIM.

Question 19 was "Are you aware of any barrier to implementing Digital transformation?" Among the 10 respondents to this question, 70% said yes.

Question 20 was "Do you agree that implementing BIM requires hands on training on the technologies?" All the respondent said yes. This indicates that there are less numbers of professionals who know the technical aspect of BIM, and consistent with the previous three questions(Q14,15,16).

Question 21 was "Do you think that client should sponsor BIM Adoption?" 10 respondents all answered with yes.

Question 22 was "Does BIM gives more benefits than barriers in the construction industry?", and 30% said yes and 70% said no.

Question 23 was Given the chance and support, will you change from conventional method to digitalisation? 50% respondent said yes and 50% said no.

Question 24 was "Have you attended any talks on Digital Transformation in Brunei or any other country? The answers is 100% said no.

Question 25 was "As a construction professional, do you feel the need for digital transformation?" 50% of the respondent said yes.

Hence based on the above analysis, 70% of respondents have heard of Digital Transformation before but do not necessarily know what it is. 70% of respondents knew about Digital Transformation before completing the questionnaire. Only 10% of respondents have heard of Digitisation and Digitalisation.
None of the respondents could differentiate between Digitisation, Digitalisation, and Digital Transformation.

Some respondents have an idea of how Document scanning, IoT (Internet of Things), and 3D printing work in technical aspects.40% of respondents are aware of the main benefits of Digital Transformation.

30% of respondents are aware of what Green technology products are.30% of respondents have heard of Green Index ratings such as Green Mark.30% of respondents have heard of Green Index ratings such as GBI (Green Building Index). Only 10% of respondents have heard of Green Index ratings such as LEED (Leadership in

Energy and Environmental Design). None of the respondents have heard of Green Index rating B.A.G.U.S (Brunei Accredited Green Unified Seal).

30% of respondents have heard of BIM (Building Information Modeling). 30% of respondents are aware that BIM helps enable sustainability in construction. 30% of respondents have some idea of the cost associated with BIM. 30% of respondents have some idea about the initial investment required to kick-start BIM.30% of respondents believe that implementing BIM in a construction company would pay off.

70% of respondents are aware of barriers to implementing Digital Transformation.
100% of respondents agree that implementing BIM requires hands-on training on the technologies.
100% of respondents believe that clients should sponsor BIM adoption.30% of respondents believe that BIM gives more benefits than barriers in the construction industry.

50% of respondents are open to changing from conventional methods to digitalization, such as using BIM or 3D printing, given the chance and support. None of the respondents have attended talks on Digital Transformation. 50% of respondents, as construction professionals, feel the need for Digital Transformation.

These findings suggest a disparity in the level of awareness and knowledge among the survey respondents concerning digital transformation and green technology, with certain individuals exhibiting a more comprehensive understanding compared to others. Additionally, there appears to be a mixed sentiment regarding the adoption of technologies such as Building Information Modeling (BIM) within the construction industry.

7. CONCLUSIONS

The study revealed a moderate level of awareness among respondents regarding Digital Transformation, with approximately 70% indicating some level of familiarity with the term. However, there exists a limited understanding of the distinctions between Digitization, Digitalization, and Digital Transformation, as none of the respondents could distinguish between them.

The knowledge of Green technology products and Green Index ratings is relatively low among respondents, ranging from 10% to 30%. Approximately 30% of respondents possess knowledge about Building Information Modeling (BIM), and a similar percentage recognizes the benefits of BIM in the construction sector. There is a substantial consensus among respondents that practical training is essential for the successful implementation of BIM, and they believe that clients should sponsor its adoption.

A significant portion of respondents (70%) is aware of barriers to implementing Digital Transformation.
There is an even split in the willingness to switch from conventional methods to digitalization, with 50% open to the idea.

The results indicate that the construction industry in Brunei generally lacks a profound understanding and comprehensive awareness of digital transformation as a holistic concept. Survey participants had heard of Digital Transformation but possessed only a rudimentary grasp of its technical intricacies and its relevance to the construction sector. While they couldn't precisely enumerate its specific advantages, they did acknowledge its potential to contribute to sustainability in the realm of construction. Although participants remained uncertain about the initial costs associated with digital transformation, they did concede to the indispensability of an initial investment to initiate the adoption process, albeit with concerns about the financial implications.

Despite respondents not being entirely clear on the challenges involved in implementing digitalization and digital transformation, they displayed a strong desire for training and understanding of digital transformation, albeit with apprehensions about the associated financial costs.

In summary, these findings underscore the need for the construction industry to take a pioneering role in fostering readiness and adoption of digital transformation, coupled with comprehensive training to develop the necessary skills, especially in integrating green technology into the construction sector. These initial findings can serve as guidance for decision-makers in formulating policies and guidelines to facilitate the widespread adoption of digital transformation in Brunei's construction industry.

In conclusion, the findings highlight the necessity for increased educational and awareness initiatives regarding Digital Transformation, Green technology, and Building Information Modeling (BIM) among the surveyed group, as knowledge and understanding levels vary significantly. It is noteworthy that respondents acknowledge certain barriers to implementing Digital Transformation, indicating potential challenges in its adoption. However, there is a positive attitude towards hands-on training for technology adoption and client support for BIM implementation. Further research with more respondents include public sector and professional services provider in the construction industry are require to bridge the knowledge gaps and facilitate the readiness and adoption of these technologies and sustainable practices in the construction industry.

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Numerical modeling the effect of extreme temperatures on rooms with mortar foam walls using LISA V.8 FEA

Aco Wahyudi Efendi[1], Novia Safitri[2]

Civil Department, Faculty of Engineering, Tridharma University, Jl. A.W. Syahrani No.7, Batu Ampar, Balikpapan Utara,Balikpapan 76126, Indonesia

Civil Engineering Student at Samarinda State Polytechnic, Jl. Cipto Mangun Kusumo, Sungai Keledang, Kec. Samarinda Seberang, Kota Samarinda, Kalimantan Timur 75242, Indonesia

E-mail: *aw.efendi2018@gmail.com*

Abstract

Mortar foam materials are now widely used as backfill replacement materials and contribute quite well, the use of mortar foam materials contributes to small settlement and stresses on the original soil surface. Mortar foam contributes significantly to the bearing capacity where from the analysis of deformation as well as stresses, the foam mortar material gives a small deformation.
The researchers in this study simulated the flow patterns of extreme temperatures that occur due to and influence in a room measuring 4000x4000 mm with a wall thickness of 200 mm with red brick material, hebel walls and the use of mortar foam, it is hoped that this research can contribute the latest knowledge about the effect of extreme temperatures in the room with these materials so that it becomes one of the alternative materials with the concept of green building.
From the results of numerical analysis research with room modeling given extreme temperature on the outside of the room and normal temperature in the room by providing normal temperature exposure zoning due to air conditioner, it is obtained that the change in the impact of extreme temperature influence dominates the mortar foam wall material with a ratio of 1.000459 against brick wall material. However, in terms of heat flux magnitude, brick wall material dominates with a ratio of 24.896 compared to mortar foam wall material.

Keywords: FEA, Foam, LISA, Mortar, Temperatures.

1. Introduction

A hollow plate burner's flame impinging on a flat plate significantly transfers heat in both industrial and residential heating applications. Inline, star, and staggered hole layouts with three distinct lengths between holes are taken into consideration in this study. The intermediate pitch of 7 mm is the best pitch over the whole mix flow range evaluated in this study [1], [2]. As an example, the heat transfer calculation in a torch furnace is notably uneven. Calculations show that a new furnace is needed to reduce ingot heating unevenness, increase fuel rate, and increase furnace capacity [3].
The results of the fire test show that the temperature at the joints on the sandwich panel's open side is initially lower than the panel itself. The joint temperature increases significantly more quickly than the panel temperature as a result of the substantial radiation in the gap. Even if the panels may be able to achieve a much longer standard fire resistance level, a joint gap of 10 mm or more will cause a joint temperature that is significantly higher than the panel temperature, resulting in a sandwich panel system insulation performance of less than 60 minutes [4].

There was an increase in column temperature with a ratio of 1.062 in both conditions where the temperature of the wall lining the column was 6.28% lower than the temperature of the wall behind the column, while the amount of heat flux that occurred in the simulation of a fire that occurred in the center of the room with two hebel wall installation conditions, namely those that line the columns of the building structure and those behind the columns of the building structure [5].

This study conducted a simulation analysis of extreme temperatures that occur outdoors due to hot temperatures of sunlight with initial wall modeling is a wall with clay material that is frequently called red brick, based on prior research that shows that heat flow patterns can be modeled in numerical analysis programs and provide a hue of coverage and differences in indoor temperature conditions, as well as the impact that occurs on several elements in the room.

Modeling is done using the finite element method program using LISA FEA V.8 (License) by modeling the wall material in the form of mortar foam material and different wall layout patterns in the room are anticipated to be able to convey information about the color of heat flow that affects room temperature conditions due to the influence of extreme temperatures outside the room and hopefully can contribute to reducing the influence of extreme temperatures in the room.

2. Materials and Methods

Heat Transfer. As an inverse quantity, heat transport happens through conduction, convection, and radiation. In solids, free electron energy transport and molecular vibrations work together to transmit heat. The ability of a substance to conduct heat is indicated by its thermal conductivity (k-value). The properties of the building materials' thermal conductivity affect how much energy a building uses. Building materials that reduce energy consumption include wood (0.14 W/m.°K), expanded polystyrene (EPS) (0.03-0.04 W/m.°K), polyurethane (0.02-0.03 W/m.°K), cellulose insulation (0.04-0.05 W/m.°K), cork (0.04-0.05 W/m.°K), and ceramic tiles (1.10 W/m.°K) **[6].**

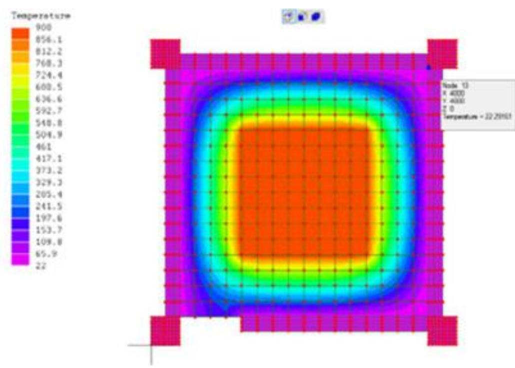

Figure 1. Simulation of temperature contours that occur in the room using LISA [5].

Hebel Brick Mechanical Properties. Hebel brick is a substance that resembles concrete and has the qualities of durability, soundproofness, heat resistance, economy, size uniformity, and environmental friendliness. Hebel bricks come in a range of dimensions, including 600 mm lengths, 200 mm heights, and 75, 100, 125, 150, 175 and 200 mm thick options. Strength and compressive strength are two of the mechanical properties of hebel bricks. These properties are measured by the following formulas: EBH = elastic modulus of hebel bricks (MPa), f'BH = compressive strength of hebel bricks (MPa), f'vH = shear strength horizontal hebel masonry (MPa), P = maximum load (N), A = compression area (mm^2), Pu = maximum shear load (N), W = tool mass (N), Hebel bricks' mechanical properties were ascertained using the destructive test method. Hebel brick size in shear strength test (f'vH) is tested using a Compression Testing Machine (CTM), whereas Hebel brick size in crushing strength test (f'BH) is tested using a Compression Testing Machine and has dimensions of 100 mm × 100 mm x 100 mm **[7].**

Foam mortar is concrete containing heavy aggregate volume equilibrium density, between 1140 and 1840 kg/m3. The advantages of concrete are that it is able to withstand compressive forces well, and has properties resistant to corrosion and decay by environmental conditions, fresh concrete can be easily molded as desired, molds can also be used repeatedly so that it is more economical, fresh concrete can be sprayed on the surface of cracked old concrete or can be filled into cracked concrete in the repair process, fresh concrete can be pumped so that it is possible to pour in places where the position is difficult, and concrete is wear-resistant and fire-resistant, so maintenance is cheaper. Composite materials consist of a mixture of foaming agent, cement, sand and water [8].
The 28-day compressive strength of specimens made using nearby cleaners differed from 4.07-4.82 MPa. It can be seen that all detergent mix designs submitted in this exploratory work resulted in compressive strengths well above the basic prerequisite of 1.38MPa set by ASTM Specifications C796-04 and C 869-91. For example the sample thickness set using local detergents changed from 865-960 kg/m^3[9].

The finite element method (FEM) is a mathematical technique for dealing with specialized examination issues. The restricted component strategy consolidates a few numerical ideas to create straight or nonlinear framework conditions. The number of conditions created is usually very large, reaching more than 20,000 conditions. Therefore, this strategy is very low in value unless a reasonable PC is utilized.
The finite element method uses component discretization to solve the problems of tracking node/association/grid relocation and primary strength. The discrete component condition is linked to the lattice technique for primary examination and the results obtained are indistinguishable from traditional investigations for structures. Discretization should be possible with one-layer (line component), two-layer (plane component) or three-layer (volume/continuum component) components. This approach uses continuum components to determine answers that are close to reality[10]–[16]

LISA FEA V.8. LISA, a numerical analysis testing software, was used to measure the temperature rise for three different intensity exchanger models. The three types of models are, organized by simple modeling, line component model, shell model, and robust model.

The finite element model is a mesh of elements. Each element has nodes that only point to the element. Elements can only be connected to other elements node-to-node. Edge-to-element-node elements have no connection at all. The elements themselves have very simple shapes such as lines, triangles, squares, cubes, and pyramids, seen as figure 2.
Each element is formulated to obey certain laws of science. For example, in static analysis, elements are formulated to relate displacement and stress according to the theory of mechanics of materials. In the case of modal vibration, elements are formulated to follow the shape of deflection and frequency according to the theory of structural dynamics. Similarly, in thermal analysis, elements relate temperature and heat according to heat transfer theory [5], [10], [16]–[24].

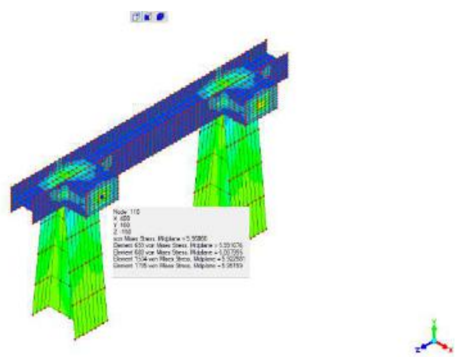

Figure 2. Element modeling in LISA program [18].

3. Results and Discussion

Researchers in this study simulated the flow pattern of the temperature that occurs due to fire in a room measuring 4000x4000 mm with a wall thickness of 200 mm with Hebel / light brick material, red brick and walls with foam mortar material, a floor plate thickness of 120 mm of reinforced concrete material, and a building column structural element size of 400x400 mm with reinforced concrete material, as shown in Figure 3.

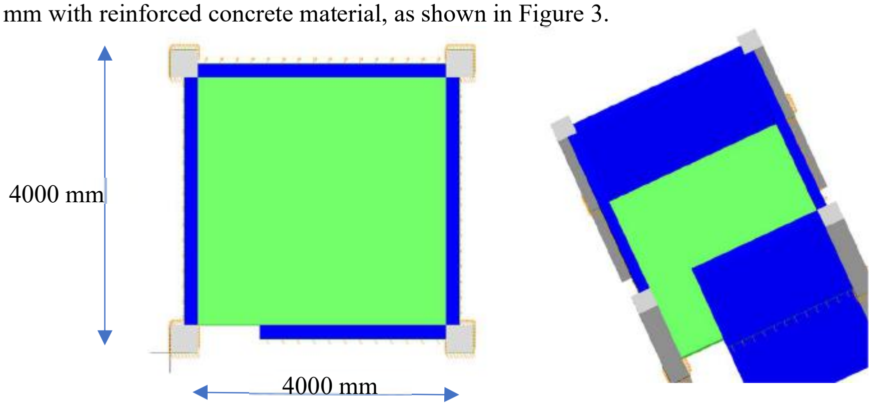

Figure 3. Room modeling.

The American Standard, ASHRAE 55-1999, serves as Indonesia's current thermal standard. In order to achieve thermal comfort, this standard suggests a neural temperature of 24^{o} C, with a comfort range of 22,5^{o} C to 26^{o} C. The results of a study conducted in Makassar in 2005, in which 596 office workers from seven multi-story office buildings participated, showed that these values were relatively too low for the average requirement of Indonesian workers, who were (roughly 95% of the sample population) still at ease within the range temperature of 24,9^{o} C to 28,5^{o} C in terms of air temperature or 25,1^{o} C to 27,9^{o} C in terms of operative temperature [25].
The obtained distributions demonstrate that the April MSA SAT tails are in fact related to ENSO variability. According to both observations and model data, post-El Nino Aprils tend to be hotter than post-La Nina Aprils (Fig. 4) on average. In addition, nearly every April that is hot happens after an El Nino event (80% for GISTEMP, B73% for CRU, and B88% for CESM1-LE post-Nino April extremes have >29 C detrended SAT values). The simulations' excellent representation of this shift in the distribution suggests that ENSO's impact on severe SATs in MSA is robust [26].

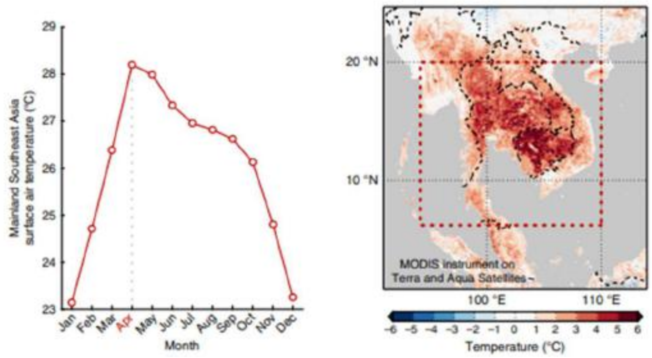

Figure 4. Surface temperatures over Mainland Southeast Asia [26]

Over the weekend, several Southeast Asian towns endured sweltering heat. In certain places, the effects of climate change even led to new high temperatures. Tuong Duong city had record-breaking temperatures on Sunday, according to the National Hydro-Meteorological Forecasting Center of Vietnam. Luang Prabang, a city in Laos, reached a record-breaking high temperature of 43.5° C, according to the Thailand Meteorological Department. The weekend saw a record high temperature of 41° C in Bangkok, the capital of Thailand. The National Environment Agency said that Singapore reached 37° C, matching the previous record established 40 years prior.

From the research above, the most extreme temperature data that will be used in this study is 43.5° C and the most comfortable temperature in the room is taken with a temperature of 24° C. Based on the experimental study that has been conducted, for the material characteristics mentioned in table 1.

Table 1. Thermal Conductivity Material

Material	Density (N/mm^3)	Poison Rasio	Thermal Conductivity W/mm °C
Steel	0.0000785	0.3	0.043
Concrete	0.0000229	0.2	0.00092
Wood	0.0000098	0.3	0.00017
Mortar Foam	0.0000119	0.15	0.00054
Brick	0.00000024	0.21	0.0134

Source: (I. Asadi et al., 2018)

Initial modeling using brick wall material with a Thermal Conductivity value of 0.0134 W/mm °C shown in Figure 5. and entering the ideal room temperature value is 24 °C, the room temperature distribution area adjusts the distribution of Air Conditioner flow with an ideal temperature of 24 °C towards the opening of the room as a door. shown in Figure 6.

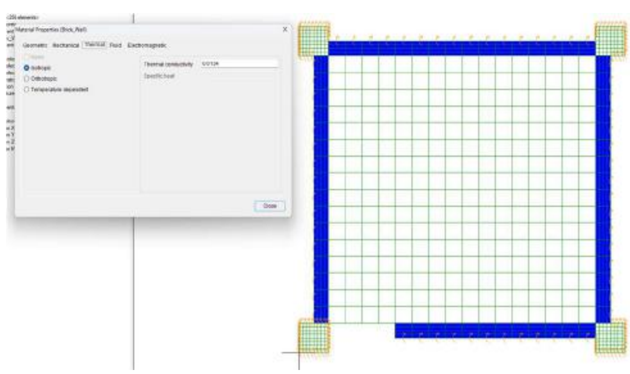

Figure 5. Thermal conductivity of brick wall (LISA, 2023)

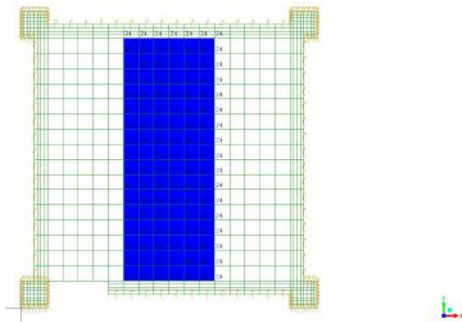

Figure 6. Room temperature (LISA, 2023)

The external temperature value is the extreme temperature that occurs in the ASEAN region according to the previous journal discussion, with the air heat transfer coefficient value of 1 W/mm^2 °C as shown in Figure 7.

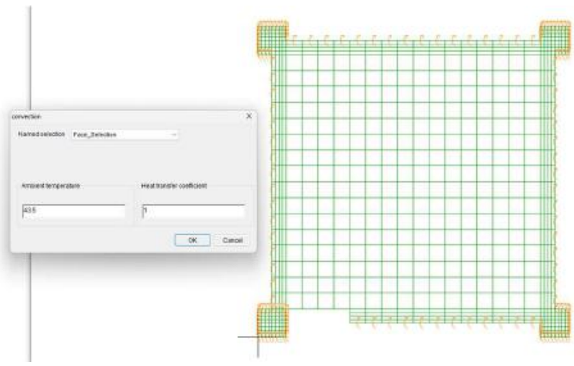

Figure 7. Convection (LISA, 2023)

The hue of the temperature distribution that occurs in the room is more dominantly normal in accordance with the given air temperature of 24 °C, but areas that are not directly exposed to the temperature of the Air Conditioner experience temperature changes around 26.17 °C to 41.35 °C, but in each corner of the room the temperature rises to 43.52 °C, while in the wall elements there is a significant temperature distribution between 34.85°C to 43.52 °C because the extreme temperature that occurs is 43.5 °C and and occurs in the wall opening area which is the location of the room door, as shown in Figure 8.

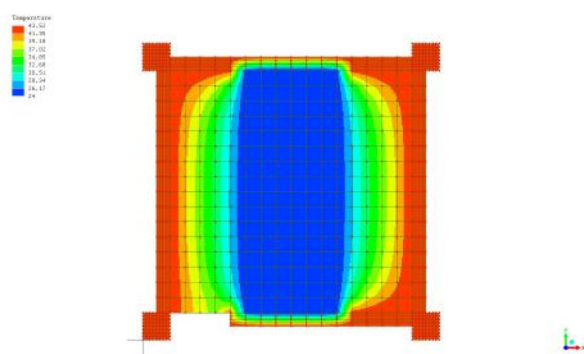

Figure 8. Room temperature with brick wall (LISA, 2023).

While the amount of heat flux that spreads due to temperature tends to be at the location at the back and front of the wall at an ideal temperature distribution of 24 °C with a value of 0.001556 W/mm^2 °C seen in Figure 9.

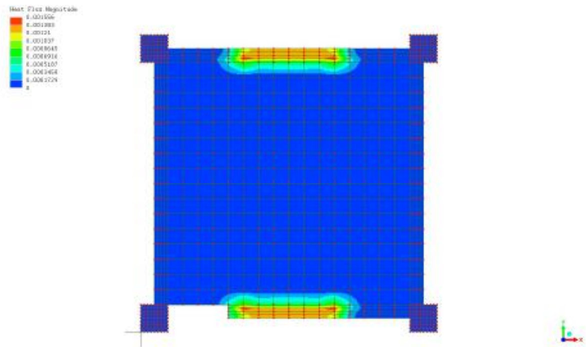

Figure 9. Brick wall heat flux magnitude (LISA, 2023).

Initial modeling using mortar foam wall material with a Thermal Conductivity value of 0.00054 W/mm °C shown in Figure 10. and entering the ideal room temperature value is 24 °C shown in Figure 6.

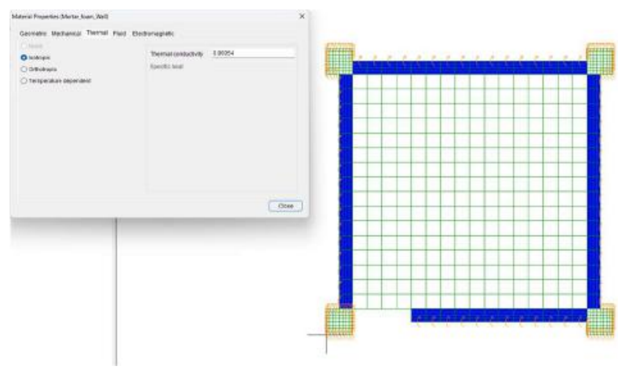

Figure 10. Thermal conductivity of mortar foam wall (LISA, 2023)

The hue of the temperature distribution that occurs in the room is more dominantly normal in accordance with the given air temperature of 24 °C, but areas that are not directly exposed to the temperature of the Air Conditioner experience temperature changes around 26.17 °C to 41.33 °C, but in each corner of the room the temperature rises to 43.5 °C, while in the wall elements there is a significant temperature distribution between 34.83°C to 43.5 °C because the extreme temperature that occurs is 43.5 °C and and occurs in the wall opening area which is the location of the room door, as shown in Figure 8.

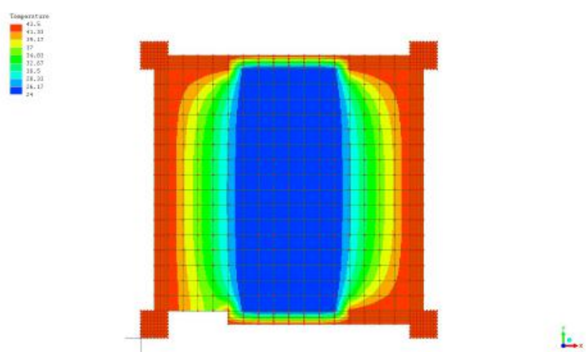

Figure 11. Room temperature with mortar foam wall (LISA, 2023)

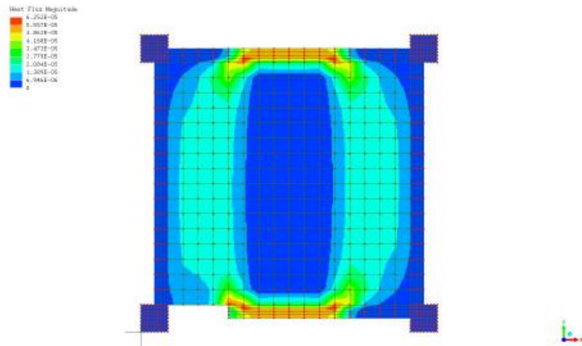

Figure 12. Mortar foam wall heat flux magnitude (LISA, 2023).

While the amount of heat flux that spreads due to temperature tends to be at the location at the back and front of the wall at an ideal temperature distribution of 24 °C with a value of 0.0000625 W/mm^2 °C seen in Figure 12.

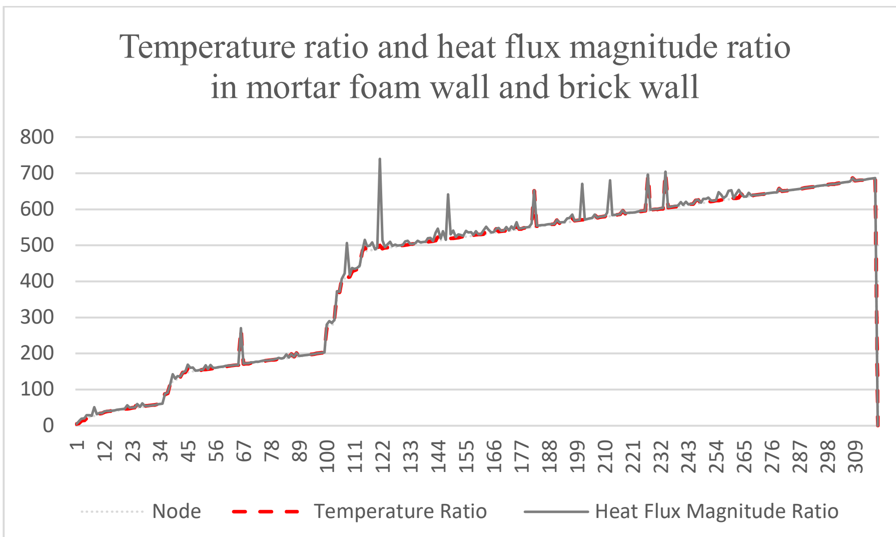

Figure 13. Temperature ratio and heat flux magnitude ratio in mortar foam wall and brick wall

In the graph in Figure 13, it is explained that the pattern of temperature increase tends to be stable without significant spikes at the nodes under review, but in contrast to the behavior of heat flux magnitude, it experiences several spikes in value at several nodes in different brick wall materials and mortar foam walls.

4. Conclusion

From the results of numerical analysis research with room modeling given extreme temperature on the outside of the room and normal temperature in the room by providing normal temperature exposure zoning due to air conditioner, it is obtained that the change in the impact of extreme temperature influence dominates the mortar foam wall material with a ratio of 1.000459 against brick wall material. However, in terms of heat flux magnitude, brick wall material dominates with a ratio of 24.896 compared to mortar foam wall material. It is expected that after this research, experimental and numerical experiments can be carried out with various space and impact models.

Acknowledgement

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DVB-T2 AND DVB-S2 SIMULINK: GREEN MODELS FOR ASEAN ENGINEERS

Ir Jeewa Vengadasalam B.Eng M.Eng MIET C.Eng FIEM PEPC

Institution Engineers Malaysia, jeewa2622@gmail.com

Abstract

Digital Video Broadcast is delivered in ASEAN using satellite and terrestrial platform. The 1st generation DVB-Terrestrial (DVB-T) and DVB-Satellite (DVB-S) systems have been replaced by 2nd generation DVB-T2 and DVB-S2 which carry more payload and more energy efficient. 1st generation DVB-T used 16-QAM whilst DVB-S used QPSK to transmit Standard Definition TV. However, DVB-T2 and DVB-S2 utilises advanced forward error correction technique with Low Density Parity Check (LDPC) coding that enable the transmission of modulated data over noisy channel. DVB-T2 uses 256 QAM whilst DVB-S 2 uses 8PSK resulting in the attainment of High Definition TV delivery over channels requiring high bit rates. Hence, transmitters are consuming less energy with reduced carbon footprint and can be considered as part of green technology. This paper uses Matlab/Simulink software to analyse the performance of DVB-T2 and DVB-S2 under different configuration modes. Both practitioner and academician can conduct research in the laboratory in order to improve field performance. The DVB-T2 and DVB-S2 Simulink software can be regarded as Green models as the laboratory tests reduces manpower and energy consumption compared to testing at the transmitter sites.

Keywords: DVB-T2, DVB-S2, LDPC , 8PSK , 256 QAM

1. INTRODUCTION

Analogue Switch Off (ASO) of terrestrial TV signals have occurred internationally and a number of ASEAN member nations namely Brunei, Singapore, Malaysia, Vietnam and Thailand have stopped transmission before 2020, which was in accordance to the timeline agreed by ASEAN [1] . On 2 November 2022, Indonesia ceased transmission of analogue PAL Colour TV and implemented Digital Switch Over (DSO) of Digital Terrestrial TV [2]. It must be noted that terrestrial transmission cannot provide full coverage in countries such as Indonesia, Philippines or Malaysia. Indonesia and Philippines consist of many islands whilst Malaysia is geographically separated by the South China Sea, into Peninsula Malaysia and East Malaysia. The Digital Video Broadcast-Terrestrial-2 (DVB-T2) network is linked with Digital Video Broadcast-Satellite-2 (DVB-S2) network to overcome the barriers of providing cost efficient and full coverage of DTV even in remote areas [3]. In Malaysia, DVB-T2 transmitters have been installed in Peninsula Malaysia, Sabah and Sarawak but Digital TV signals are relayed from Kuala Lumpur to Kota Kinabalu (Sabah) and Kuching (Sarawak) utilising DVB-S2 signals via MEASAT 3d space satellite with C band transponders.

1st generation DVB-T used a Forward Error Correction (FEC) subsystem consisting of Reed Solomon concatenated with Convolutional codes, 64 QAM modulation and 8K OFDM carriers [4]. DVB-S used the same FEC subsystem but with QPSK modulation [5]. However, 1st generation systems had limited payload and could only deliver Standard Definition TV (SDTV) and have been replaced by 2nd generation systems which carry more TV channels and are more energy efficient.

DVB-T2 uses FEC subsystem consisting of Bose Chaudhuri Hocquenghem (BCH) code concatenated with Low Density Parity Check Code (LDPC) enabling the extension of modulation order from 64-QAM to 256-QAM and increase from 2K to 32K OFDM carriers [6][7][8] .DVB-S2 also incorporates similar Forward Error Correction (FEC) subsystem enabling almost error free operation of higher level Multi Phase Shift Keying (MPSK) constellation such as 8PSK 16 Amplitude PSK (APSK) and 32 APSK [9]. The improvements have enabled the transmission of High Definition TV (HDTV) and UHDTV (Ultra High Definition TV).

The recent Digital Switch Over in ASEAN has created a demand for engineers who have the technical knowledge in implementing DVB systems with the various configuration modes. It is a daunting task for ASEAN engineers, who have to analyse the signal flow process and thus specify the correct mode of operation in the field. Therefore, it is indeed timely to introduce training courses using Matlab/Simulink models to create more effective the learning process of new engineers.

The green advantages of DVB-T2 and DVB-S2 are electrical power savings, more efficient audio and video compression techniques using High Efficiency Video Coding (HEVC)/H265 and smaller carbon footprint [10]. Additional savings are realised from reduction in facility space, cooling, construction and maintenance costs

2. LITERATURE REVIEW

The performance of 2nd generation DVB systems have been a subject of research by several engineers. In 2013, an Egyptian study was conducted with DVB-T2 Simulink but the research was confined to 16K OFDM subcarriers and 64 QAM [11]. In 2022, research was conducted in Indonesia using DVB-T2 Simulink designed with 32K subcarriers and 64 QAM [12].The project also examined transmission over Rayleigh and AWGN channel with various LDPC code rates. The main limitation of this project was that 64 QAM could only be used for SDTV and hence the study should have been extended to 256 QAM which is necessary for HDTV transmission.

In 2012, a Malaysian study was conducted with DVB-S2 Simulink using constellation modes of QPSK, 8PSK, 16 Amplitude PSK and 32 APSK [13]. It is noteworthy to mention that 16 APSK and 32 APSK constellation modes are to be used in Digital Satellite News Gathering (DSNG) and conforms to ITU Recommendations BO 1784-1 [14]. 16 APSK and 32 APSK were found to be more susceptible to noise and should not be used for direct broadcasting. In 2019, a study in Pakistan was conducted with DVB-S2 Simulink using 8 PSK and the number of LDPC iterations was counted [15]. The limitation was that comparison of QPSK and 8PSK was not undertaken.

There haven't been any papers published on the joint research of both systems which is necessary as they share common FEC subsystem. It is more effective for ASEAN engineers to learn both the terrestrial and satellite system as part of a combined training course, reducing the number of learning hours and leading to the engineers' better understanding of the concept of the FEC subsystem.

Till now, there has been no Simulink analysis of DVB-T2 performance with 32 K carriers and 256 QAM over various propagation channels. A proper analysis is needed as there is fixed as well as mobile reception of DVB-T2 signals. In addition, there are hardly any papers published on the High Power Amplifier (HPA) performance based on Saleh or Rapp model [16].

Hitherto, there has been no comparatively analysis of DVB-S2 performance between QPSK 8PSK and 16 PSK using Matlab simulation. Although the previous Malaysian project studied various constellation modes, it did not include 16 PSK, which is more suitable for direct broadcasting instead of 16 Amplitude PSK.

3 PROBLEM STATEMENT:

Economical methods of analysing the performance of the various configuration of DVB systems are needed. In addition, testing of DVB signals must not cause interference to viewers, adjacent satellites and to other ASEAN member countries as there is overlap of terrestrial TV coverage at each country's border.

Simulink models can provide less complex method of analysing the performance of DVB. Separate Simulink models have been designed to record the response of the DVB-T2 and DVB-S2 under different code rates and constellation modes. Past research on DVB-T2 was mostly confined to 2K, 8K, 16 K subcarriers, 64 QAM and simplified propagation channel. Designing a model with 32 K subcarriers, 256 QAM and propagation channels, which better represent multipath behaviour is more complicated because the parameters must be tuned for optimum performance. In the case of DVB-S2, research was mostly confined to QPSK and 8 PSK constellation. Thus, the DVB-S2 model has been modified to simulate system behaviour to include 16 PSK [17].

4. METHODOLOGY

The research strategy undertaken is based on the simulation of DVB system under various configuration modes and measuring the performance with various tools such as Spectrum Analyzer and Constellation Diagram.

The DVB-T2 Simulink programme consists of an end to end transmitter receiver chain with a switchable HPA representing either the Saleh or Rapp model. The technical parameters measured are Signal to Noise Ratio (SNR) and Bit Error Rate (BER). The DVB-S2 Simulink model was modified to allow for the extension of constellation modes to 16 PSK. The technical parameters measured are Bit Error Rate (BER), Packet Error Ratio (PER) and

Number of Iterations needed by the LDPC decoder. If PER $<10^{-7}$, the target of Quasi Error Free (QEF) performance is achieved. The number of iterations indicates the performance of the LDPC decoder under increasing noise level and DVB-S2 standard specifies maximum iterations to be 50.

5. DVB Simulink Models

Simulink models were designed based on DVB-T2 and DVB–S2 technical specifications and run under various configuration modes as discussed in the next two subsections

5.1. DVB-T2 Simulink Model

The Simulink model capable of simulating the various configurations is illustrated by Fig 1. For clarity, the transmitter chain is shaded in cyan and receiver chain is shaded in yellow. The data from the transmitter and receiver are compared for Bit Error Rate (BER) calculation.

At the transmitting front end, a Random Integer Generator acting as video/audio data source delivers 1504 integers which can be regarded as an MPEG-2 Transport Stream. The 1504 integers are converted into 31584 bits and padded to 32220 bits which act as the data field for the formation of Baseband Frame. The samples per frame =50000 samples and the sample time = 2*1.385e-08s setting the spectrum at 5MHz, which is the video transmission bandwidth of the DVB-T2 signal in Malaysia.

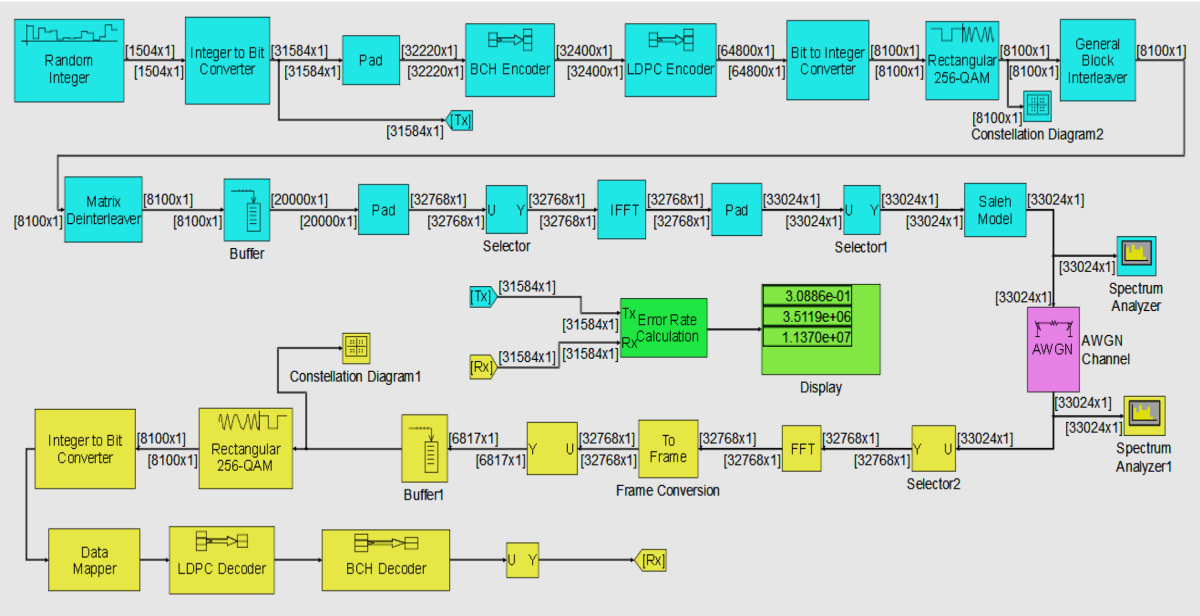


Fig 1: Block diagram of the DVB-T2 Simulink Model

The Baseband Frame of K_{BCH} = 32220 bits that was formed, is processed by the Forward Error Correction (FEC) subsystem with a code rate CR =1/2. It consists of an Outer Coder which is a BCH (N_{bch} = 32400, K_{bch}= 32220) encoder concatenated with an Inner Coder comprising a LDPC (N_{ldpc}= 64800, K_{ldpc}=32400) encoder. The data are time, frequency interleaved and modulated with 256 QAM constellation order. The combined signal is then processed by the 32K IFFT which acts as the OFDM modulator. The OFDM signal is passed to the HPA which can be based on Saleh or Rapp model. The resulting signal is transmitted over a propagation channel which can be selected from Additive White Gaussian Noise (AWGN), Rician or Rayleigh channel. The AWGN channel represents the direct path from the transmitter station to the home. The Rician channel represents a combined direct and reflected path from the transmitter to the receiver. The Rayleigh channel usually represents a mobile channel, where there is no direct path from transmitter to receiver but only reflected paths or multipath. The receiver decodes the error corrected signal and retrieves back the data.

5. 2 DVB-S2 Simulink Model

The Matlab/Simulink programmme capable of simulating various configuration is explained simply by Fig 2. At the transmitting end, a Random Data Generator acting as the signal source, delivers 188 bytes which can be regarded as an MPEG 2 Transport Stream. These packets act as the data field consisting of 1504 bits for the formation of Baseband Frame.

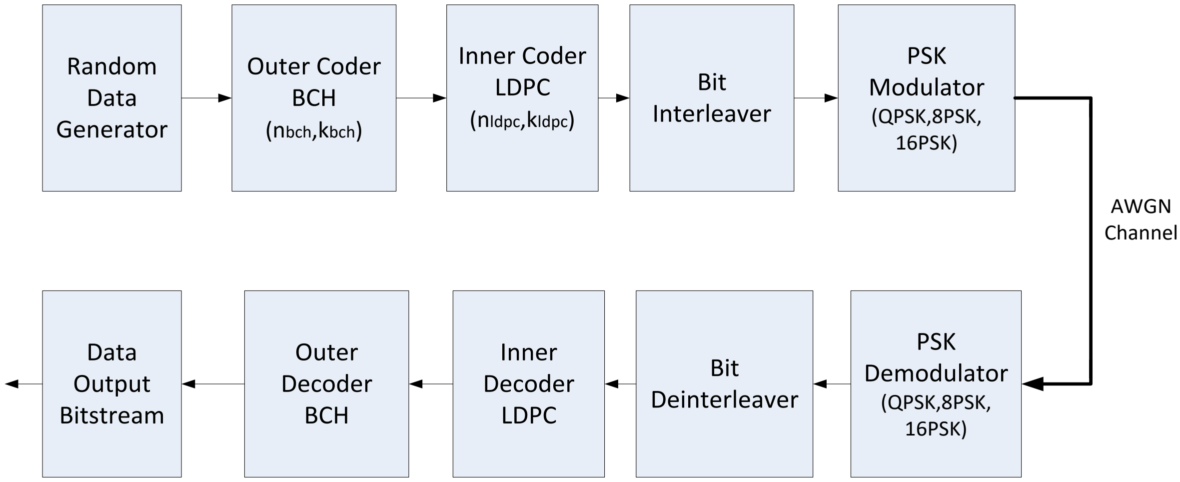


Fig 2: Functional block diagram of the Matlab DVB-S2 System Simulation

If a code rate =1/2 is chosen, a Baseband Frame of K_{BCH} = 32208 bits is formed and processed by the Forward Error Correction (FEC) subsystem consisting of an Outer Coder which is a BCH (N_{bch} = 32400, K_{bch}= 32208) encoder concatenated with an Inner Coder comprising a LDPC (N_{ldpc}= 64800, K_{ldpc}=32400) encoder. The frames are interleaved and modulated with a QPSK/8PSK/16PSK constellation and transmitted over an Additive White Gaussian Noise (AWGN) channel. The AWGN channel represents the uplink path from the earth station to the space satellite and the downlink path to the small parabolic antenna at the home.

6. SIMULATION RESULTS & DISCUSSION

The comparative performance of each DVB System is analysed separately and discussed in two subsections.

6.1 DVB-T2 Model

The selection of AWGN, Rician and Rayleigh propagation channels as well choice of Saleh or Rapp HPA model affects overall performance. Table 1 shows the result obtained using the 3 different propagation channels and both HPA models.

Table 1: Performance of 32 K DVB-T2 256 QAM Code Rate:1/2 with High Power Amplifier based on Saleh and Rapp model over AWGN, Rician and Rayleigh channels

Signal to Noise Ratio SNR (dB)	High Power Amplifier - Saleh model			High Power Amplifier -Rapp model		
	Rayleigh Channel Bit Error Rate (BER)	Rician Channel Bit Error Rate (BER)	AWGN Channel Bit Error Rate(BER)	Rayleigh Channel Bit Error Rate (BER)	Rician Channel Bit Error Rate (BER)	AWGN Channel Bit Error Rate (BER)
0	1.9832e-01	1.9831e-01	1.9832e-01	1.9832e-01	1.9833e-01	1.9833e-01
10	1.9827e-01	1.9825e-01	1.9825e-01	1.9831e-01	1.9830e-01	1.9821e-01
20	1.9814e-01	1.9805e-01	1.9802e-01	1.9826e-01	1.9822e-01	1.9821e-01
30	1.9769e-01	1.9736e-01	1.9730e-01	1.9808e-01	1.9795e-01	1.9792e-01
40	1.9629e-01	1.9543e-01	1.9522e-01	1.9748e-01	1.9705e-01	1.9696e-01
50	1.9437e-01	1.9407e-01	1.9403e-01	1.9583e-01	1.9499e-01	1.9477e-01
60	1.9407e-01	1.9407e-01	1.9407e-01	1.9435e-01	1.9426e-01	1.9426e-01
70	1.9411e-01	1.9412e-01	1.9412e-01	1.9431e-01	1.9435e-01	1.9436e-01
80	1.9410e-01	1.9409e-01	1.9409e-01	1.9426e-01	1.9416e-01	1.9414e-01
90	1.9409e-01	1.9409e-01	1.9409e-01	1.9411e-01	1.9409e-01	1.9409e-01
100	1.9409e-01	1.9409e-01	1.9409e-01	1.9409e-01	1.9409e-01	1.9409e-01

Fig 3 below illustrates the graph plotted from the data obtained from Table 1. DVB-T2 performance over the three different propagation channels decreases in the following order from AWGN, Ricean to Rayleigh. The decrease in performance over the Rayleigh channel shows mobile TV reception is not as good as fixed reception. The Rapp class of HPA model considers only AM/AM distortion whilst the Saleh class considers AM/AM as well as AM/PM distortion. It should be noted that slight distortion occurred and pre-distortion techniques were introduced to correct the signal. It can also be deduced that HPA based on the Saleh model performs better than the Rapp model because the Saleh model represents the non-linearity of the Solid State HPA more accurately.

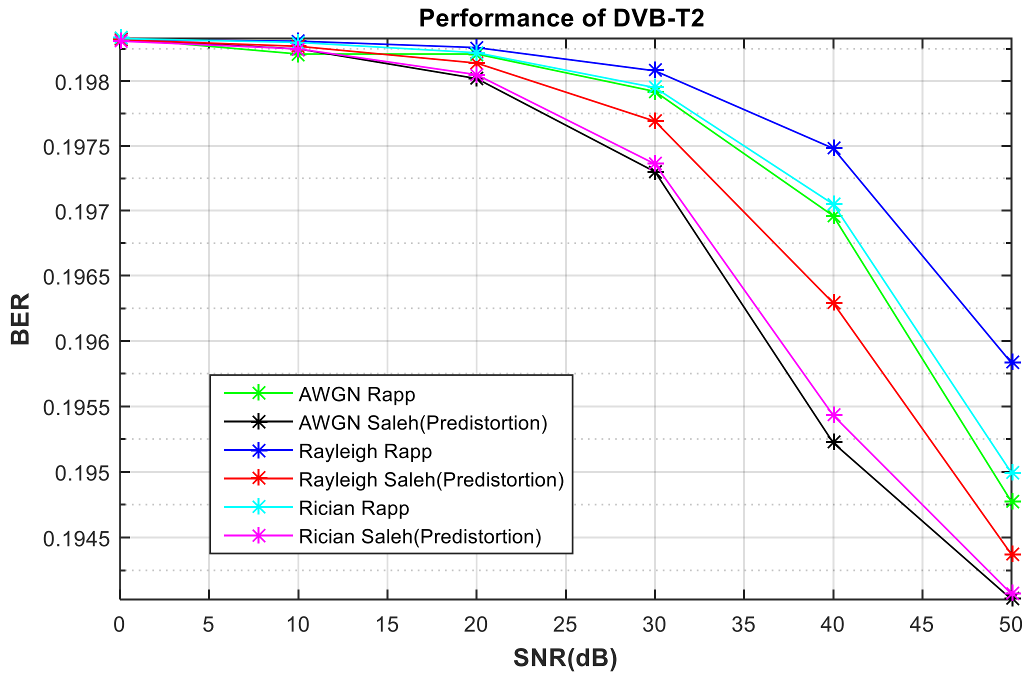


Fig 3 : Performance of DVB-T2 over various propagation channels

Figure 4 below shows the 256 QAM constellation taken at the transmitter and whilst Figure 5 shows the display taken at the receiver. Although slight distortion is evident, the FEC subsystem has corrected most errors.

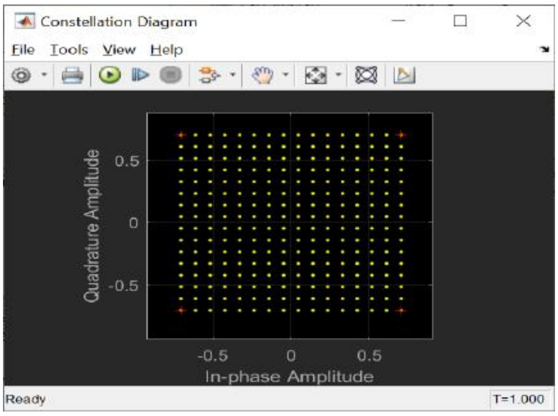


Fig 4: 256 QAM display at Transmitter

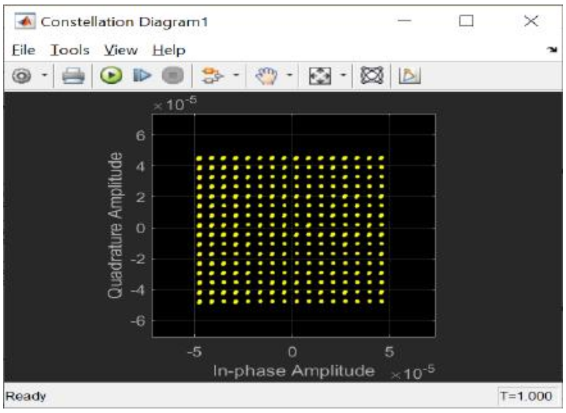
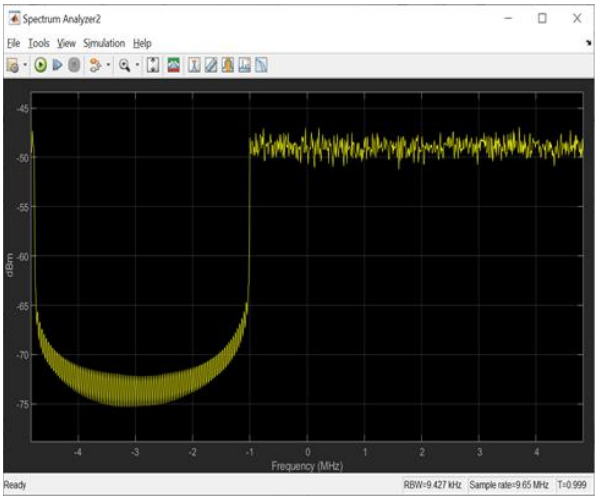


Fig 5: 256 QAM display at Receiver

The OFDM spectrum with a bandwidth of 5 MHz is shown by Figure 6 for the transmitter output and by Figure 7 for the receiver input. Results from AWGN and Rician channels are not shown as space is limited. As expected, there is a loss of amplitude of the OFDM signal as it propogates along the Rayleigh channel.



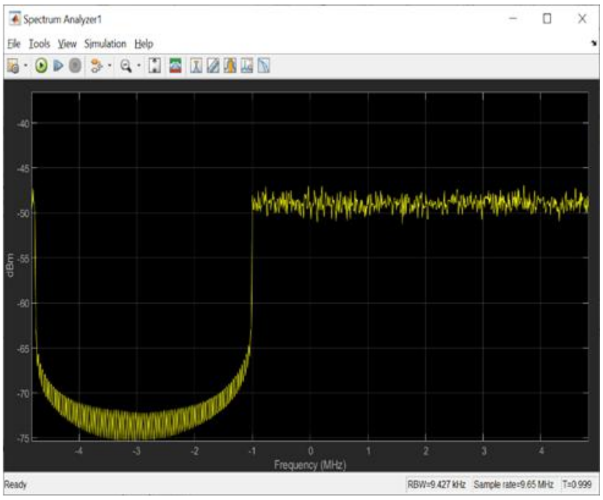


Fig 6: OFDM spectrum at Transmitter **Fig 7: OFDM spectrum at Receiver**

6.2 DVB-S2 Model

As space is limited, only simulation results of certain configuration such as QPSK 9/10 and 3/4, 8 PSK 1/2 and 16 PSK 1/2 are shown in the following pages. Changes in the code rates are met by adjusting the N_{bch}, K_{bch} and K_{ldpc} parameters and are reflected in the output of the respective Outer and Inner Coders. These parameter changes provide easily understood explanation for the operation of the Baseband Frame stage and FEC subsystem. The selection of QPSK, 8PSK or 16 PSK affects overall performance and is easily visualised through the constellation display. Data shown are the BER at the demodulator output, the BER at the LDPC decoder output, and the PER of the end-to-end system together with the measured Signal to Noise Ratio (SNR) at the receiver input.

Table 2a : DVB-S2 Configuration Mode : *QPSK* , *Code Rate : 9/10* ,
K_{bch} = 58192, N_{bch} = 58320 , K_{ldpc} = 58320, N_{ldpc} = 64800

Es/No dB	Demodulator Output BER	LDPC Decoder Output BER	Number of Iteration	Packet Error Ratio (PER)	Signal to Noise Ratio (SNR) dB
0.0	1.58e-01	1.58e-01	50	1.00e+00	0.01
0.5	1.45e-01	1.45e-01	50	1.00e+00	0.51
1.0	1.31e-01	1.31e-01	50	1.00e+00	1.00
1.5	1.17e-01	1.17e-01	50	1.00e+00	1.50
2.0	1.04e-01	1.03e-01	50	1.00e+00	2.00
2.5	9.09e-02	9.09e-02	50	1.00e+00	2.51
3.0	7.89e-02	7.87e-02	50	1.00e+00	3.00
3.5	6.73e-02	6.72e-02	50	1.00e+00	3.49
4.0	5.63e-02	5.58e-02	50	1.00e+00	4.00
4.5	4.70e-02	4.55e-02	50	1.00e+00	4.49
5.0	3.75e-02	3.48e-02	50	1.00e+00	5.01
5.5	2.99e-02	2.45e-02	50	1.00e+00	5.50
6.0	2.30e-02	1.25e-02	50	1.00e+00	6.01
6.5	1.73e-02	0.00e+00	12	0.00e+00	6.50
7.0	1.26e-02	0.00e+00	6	0.00e+00	7.00

Table 2b : DVB-S2 Configuration Mode : ***QPSK*, *Code Rate : 3/4*,**
K_{bch} = 48408 , N_{bch} = 48600 , K_{ldpc} = 48600, N_{ldpc} = 64800

Es/No dB	Demodulator Output BER	LDPC Decoder Output BER	Number of Iteration	Packet Error Ratio (PER)	Signal to Noise Ratio (SNR) dB
0.0	1.59e-01	1.30e-01	50	1.00e+00	0.00
0.2	1.53e-01	1.18e-01	50	1.00e+00	0.20
0.4	1.48e-01	1.05e-01	50	1.00e+00	0.40
0.5	1.45e-01	9.55e-02	50	1.00e+00	0.49
0,6	1.42e-01	7.87e-02	50	1.00e+00	0.60
0.8	1.37e-01	2.61e-04	35	3.57e-02	0.80
1.0	1.31e-01	0.00e+00	31	0.00e+00	1.0
1.2	1.25e-01	0.00e+00	21	0.00e+00	1.19
1.5	1.17e-01	0.00e+00	18	0.00e+00	1.50

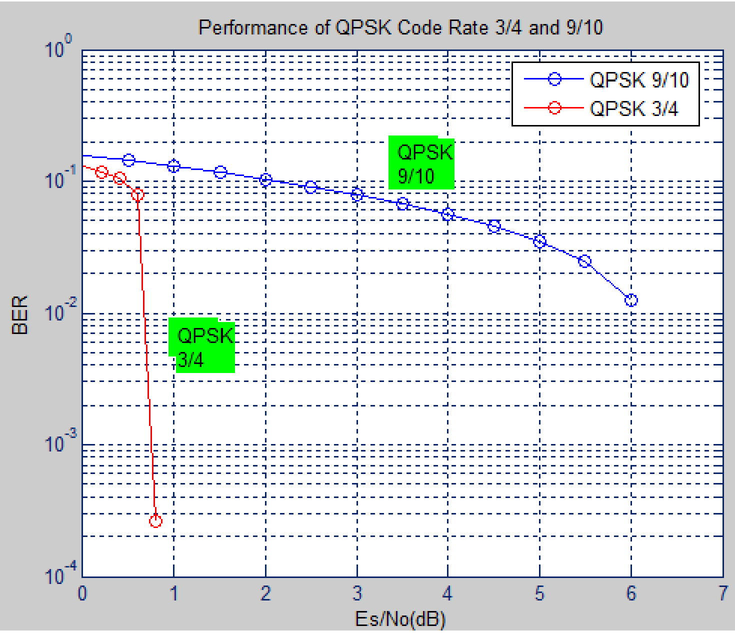


Fig 8a: DVB-S2 QPSK BER Performance

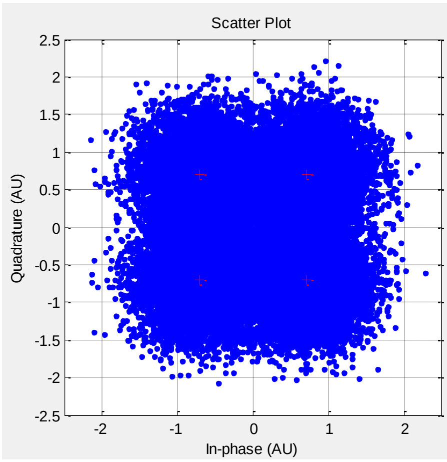


Fig 8b: QPSK Scatterplot

Data analysis from Table 2a & b indicates that QPSK performs better with a lower code rate ratio (CR) as BER reaches zero value faster if CR= 3/4 instead of CR=9/10. The results conform to theory as QPSK 3/4 is a stronger signal with more error correction capability although it can carry lesser payload. The BER plot of Fig 8a indicates that the LDPC has a waterfall region where the error curves drop steeply. The LDPC Inner Decoder does most of the error correction, leaving the BCH Outer Decoder to operate in the error floor region where the LDPC code cannot reach. Fig 8b shows the QPSK signal with its 4 constellation points which can still operate in such a noisy environment.

Table 3a: DVB-S2 Configuration Mode : 8PSK , Code Rate : 9/10 ,
K_{bch} = 58192, N_{bch} = 58320 , K_{ldpc} = 58320, N_{ldpc} = 64800

Es/No dB	Demodulator Output BER	LDPC Decoder Output BER	Number of Iteration	Packet Error Ratio (PER)	Signal to Noise Ratio (SNR) dB
0.0	2.41e-01	2.46e-01	50	1.00e+00	0.00
0.5	2.28e-01	2.34e-01	50	1.00e+00	0.50
1.0	2.16e-01	2.21e-01	50	1.00e+00	1.00
1.5	2.03e-01	2.08e-01	50	1.00e+00	1.50
2.0	1.90e-01	1.95e-01	50	1.00e+00	2.00
2.5	1.77e-01	1.82e-01	50	1.00e+00	2.51
3.0	1.65e-01	1.69e-01	50	1.00e+00	3.01
3.5	1.52e-01	1.56e-01	50	1.00e+00	3.50
4.0	1.41e-01	1.44e-01	50	1.00e+00	4.00
4.5	1.28e-01	1.32e-01	50	1.00e+00	4.51
5.0	1.17e-01	1.20e-01	50	1.00e+00	5.00
5.5	1.06e-01	1.09e-01	50	1.00e+00	5.51
6.0	9.56e-02	9.83e-02	50	1.00e+00	6.01
6.5	8.58e-02	8.81e-02	50	1.00e+00	6.50
7.0	7.62e-02	7.83e-02	50	1.00e+00	7.00
7.5	6.72e-02	6.87e-02	50	1.00e+00	7.49
8.0	5.86e-02	5.98e-02	50	1.00e+00	7.99
8.5	5.00e-02	5.04e-02	50	1.00e+00	8.51
9.0	4.25e-02	4.19e-02	50	1.00e+00	9.00
9.5	3.54e-02	3.30e-02	50	1.00e+00	9.51
10.0	2.90e-02	2.38e-02	50	1.00e+00	10.00
10.5	2.33e-02	1.27e-02	50	1.00e+00	10.50
11.0	1.83e-02	0.00e+00	14	0.00e+00	11.00
11.5	1.41e-02	0.00e+00	7	0.00e+00	11.49

Table 3b : DVB-S2 Configuration Mode : 8PSK , Code Rate : 3/4 ,
K_{bch} = 48408 , N_{bch} = 48600 , K_{ldpc} = 48600, N_{ldpc} = 64800

Es/No dB	Demodulator Output BER	LDPC Decoder Output BER	Number of Iteration	Packet Error Ratio (PER)	Signal to Noise Ratio (SNR) dB
0.0	2.41e-01	2.57e-01	50	1.00e+00	0.00
0.5	2.29e-01	2.44e-01	50	1.00e+00	0.50
1.0	2.16e-01	2.30e-01	50	1.00e+00	1.01
1.5	2.03e-01	2.17e-01	50	1.00e+00	1.51
2.0	1.91e-01	2.04e-01	50	1.00e+00	2.00
2.5	1.77e-01	1.90e-01	50	1.00e+00	2.51
3.0	1.66e-01	1.78e-01	50	1.00e+00	3.00
3.5	1.53e-01	1.64e-01	50	1.00e+00	3.51
4.0	1.41e-01	1.52e-01	50	1.00e+00	4.01
4.5	1.29e-01	1.39e-01	50	1.00e+00	4.50
5.0	1.17e-01	1.26e-01	50	1.00e+00	5.00
5.5	1.06e-01	1.13e-01	50	1.00e+00	5.51
6.0	9.59e-02	1.00e-01	50	1.00e+00	6.01
6.5	8.62e-02	8.62e-02	50	1.00e+00	6.49
7.0	7.60e-02	7.13e-02	50	1.00e+00	7.01
7.5	6.69e-02	4.32e-02	50	1.00e+00	7.50
8.0	5.83e-02	0.00e+00	20	0.00e+00	8.00
8.5	5.02e-02	0.00e+00	12	0.00e+00	8.49

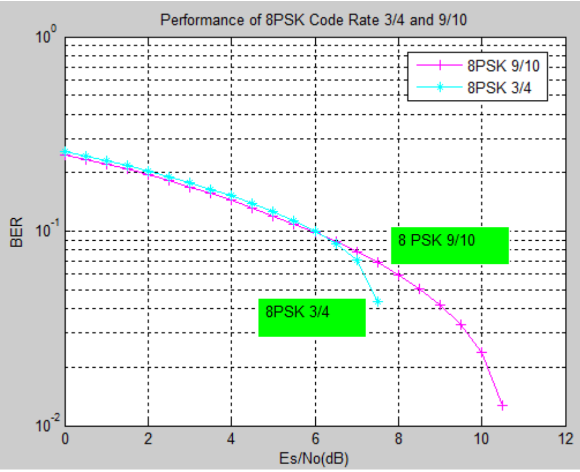


Fig 9a: DVB-S2 8PSK BER Performance

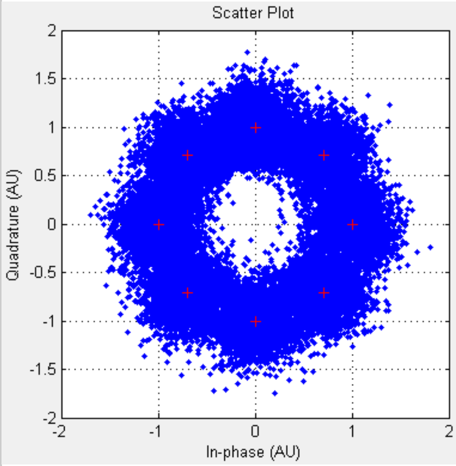
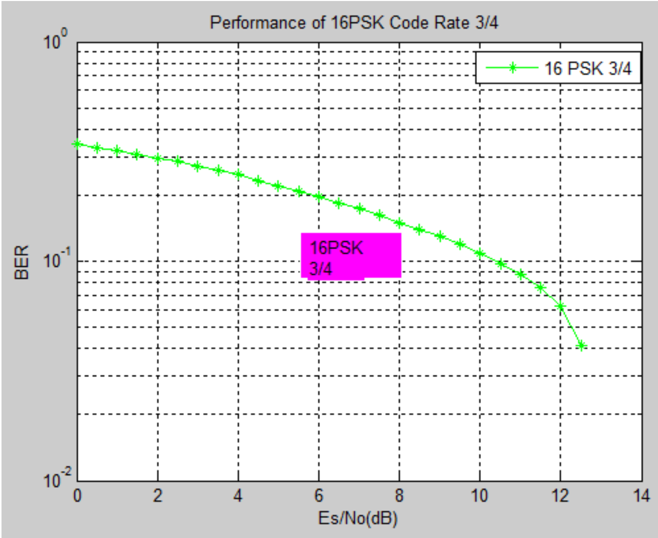


Fig 9b: 8PSK Scatterplot

From Table 3a & b, 8 PSK does not perform as well as QPSK as it requires higher Es/No for better BER performance. In spite of this, 8 PSK can be used as the LDPC decoder is capable of correcting errors, even at low signal power. Fig 9a indicates that both 8 PSK 3/4 and 9/10 give almost similar performance at low Es/No but at higher signal energy, 8PSK 3/4 gives better improvement. Fig 9b shows the 8PSK constellation points indicating that the signal is delivering the data transmitted to the receiver without significant errors.

Table 4 : DVB-S2 Configuration Mode : 16 PSK , Code Rate : 3/4 ,
K_{bch} = 48408 , N_{bch} =48600 , K_{ldpc} = 48600, N_{ldpc} = 64800

Es/No dB	Demodulator Output BER	LDPC Decoder Output BER	Number of Iteration	Packet Error Ratio (PER)	Signal to Noise Ratio (SNR) dB
0.0	3.41e-01	3.41e-01	50	1.00e+00	0.00
0.5	3.30e-01	3.30e-01	50	1.00e+00	0.49
1.0	3.19e-01	3.19e-01	50	1.00e+00	1.00
1.5	3.08e-01	3.08e-01	50	1.00e+00	1.51
2.0	2.96e-01	2.96e-01	50	1.00e+00	1.99
2.5	2.85e-01	2.85e-01	50	1.00e+00	2.49
3.0	2.72e-01	2.72e-01	50	1.00e+00	3.00
3.5	2.60e-01	2.60e-01	50	1.00e+00	3.51
4.0	2.48e-01	2.48e-01	50	1.00e+00	3.99
4.5	2.34e-01	2.34e-01	50	1.00e+00	4.51
5.0	2.21e-01	2.21e-01	50	1.00e+00	5.00
5.5	2.09e-01	2.09e-01	50	1.00e+00	5.51
6.0	1.97e-01	1.97e-01	50	1.00e+00	5.99
6.5	1.84e-01	1.84e-01	50	1.00e+00	6.51
7.0	1.73e-01	1.73e-01	50	1.00e+00	7.00
7.5	1.62e-01	1.62e-01	50	1.00e+00	7.50
8.0	1.51e-01	1.50e-01	50	1.00e+00	8.01
8.5	1.40e-01	1.40e-01	50	1.00e+00	8.50
9.0	1.30e-01	1.30e-01	50	1.00e+00	9.00
9.5	1.21e-01	1.19e-01	50	1.00e+00	9.50
10.0	1.11e-01	1.08e-01	50	1.00e+00	10.01
10.5	1.02e-01	9.78e-02	50	1.00e+00	10.50
11.0	9.33e-02	8.66e-02	50	1.00e+00	11.00
11.5	8.50e-02	7.57e-02	50	1.00e+00	11.49
12.0	7.74e-02	6.21e-02	50	1.00e+00	11.99
12.5	6.91e-02	4.13e-02	50	1.00e+00	12.50
13.0	6.15e-02	0.00e+00	24	0.00e+00	12.99



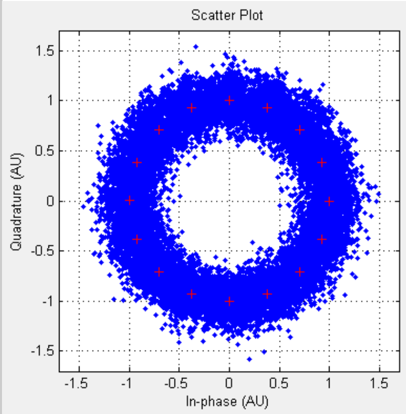


Fig 10a: DVB-S2 16 PSK BER Performance **Fig 10b: 16PSK Scatterplot**

As expected, data from Table 4 confirms that higher signal strength is needed for 16 PSK mode to achieve a BER of zero value. 16 PSK requires Es/No = 13 db to achieve error free operation when compared to 8 PSK which only needs 8 db. Fig 10a shows the steady decline in BER as signal strength gathers whilst Fig 10b indicates that 16 PSK operation can be sustained at reasonable field strength. Only 16 PSK with code rate 3/4 is shown so as to reduce publication space.

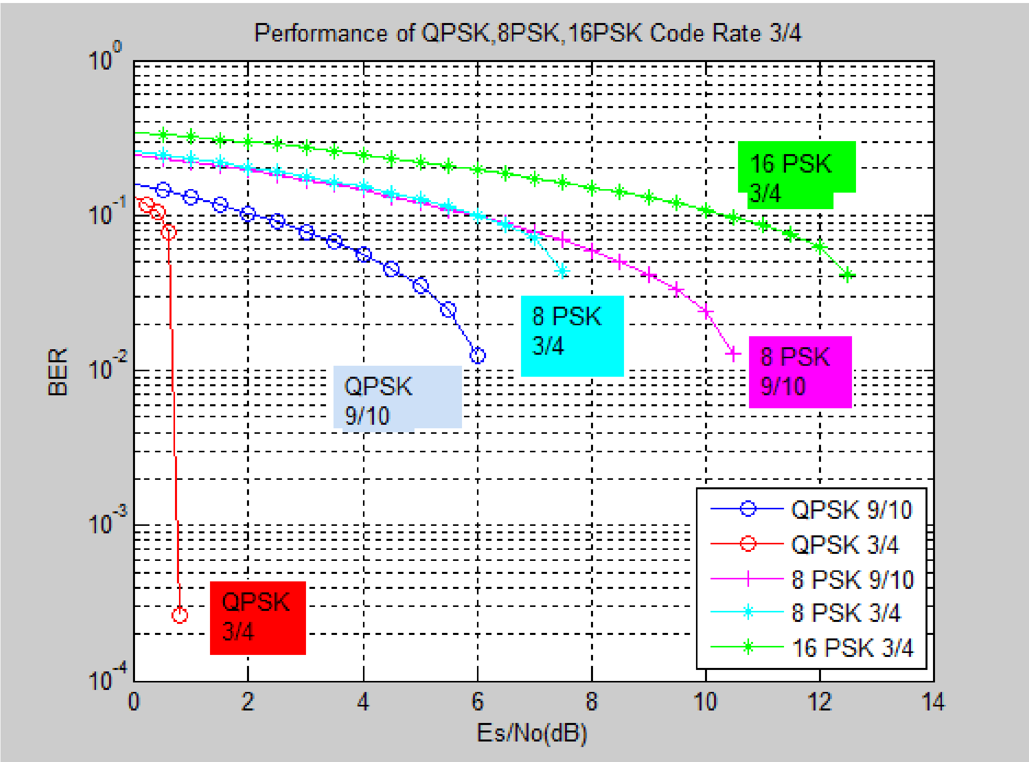


Fig 11 : Comparison of QPSK, 8PSK and 16 PSK BER Performance

Comparative analysis of all the configuration modes are laid out in Fig 11 for the sake of convenience. Simply put, the progress from a lower constellation mode to a higher constellation mode requires higher signal power. This is caused by the shrinking in distance of the constellation points from each other, which would result in the points not being detected accurately especially when noise is becoming troublesome. The change in code rate also substantially influences the BER as a received MPSK signal with CR= 3/4 has more robust error correction capability compared to a signal with CR= 9/10.

The main limitation of this paper is that not all ASEAN countries have chosen DVB-T2 as the digital terrestrial TV standard. Brunei, Singapore, Indonesia, Malaysia, Vietnam, Thailand Cambodia and Myanmar have selected DVB-T2. Philippines have selected the Brazilian standard Integrated Services Digital Broadcasting (ISDB-Tb) whilst Laos have selected the Chinese standard Digital Terrestrial Multimedia Broadcast (DTMB)[18]. Hence, engineers in Laos and Philippines may not be able to utilise the DVB–T2 Simulink model. However, ASEAN countries including Philippines and Laos can utilise the DVB-S2 Simulink, as all ASEAN members use the same Satellite standard. Nevertheless, the majority of ASEAN countries use DVB-T2 and hence this paper should provide a valuable resource for the region's engineers.

Future work should be conducted on the utilisation of Amplitude Phase Shift Keying (APSK) for DVB-S2X which is an extension to the DVB-S2 standard. Although DVB-S2X is to be utilised for Digital Satellite News Gathering only, the ASEAN engineer can gain additional skills in using a suitable DVB-S2X Simulink model. The recommended configuration by the DVB organisation are 32APSK, 64APSK, 128 APSK and 256APSK [19].

7. CONCLUSION

The Simulink model programme can be used during training sessions in the field of Digital Broadcasting. It is essential that engineers comprehend the advanced FEC subsystem and the theory behind Shannon's Theorem, relating the maximum capacity that can be achieved over a given channel with certain noise characteristics and bandwidth. Since DVB-T2 can cater for both fixed and mobile reception, engineers should comprehend the different performance of DVB-T2 over AWGN, Rician and Rayleigh channels. High Power Amplifiers also introduce non-linearities into the signal and hence suitable classes of models such as Rapp or Saleh should be studied. The performance of DVB-T2 is remarkable, as low BER is achieved even at low signal to noise ratio making the use of 256 QAM a feasible choice. HDTV services require much higher bitrates compared to SDTV and cannot be met by using the present 64 QAM mode.

Overall the performance of DVB-S2 is remarkable, as low BER is achieved even at low signal strength making the use of 16 PSK a feasible choice. UHDTV services require much higher bitrates compared to HDTV and cannot be met by using the present 8PSK mode. Therefore, communication engineers have to incorporate higher constellation modes in their design.

It is essential that ASEAN engineer acquire skills in both DVB-T2 and DVB-S2 as it is rather risky for a country to rely on a single platform to deliver TV signals to the public. It must be also noted that DVB-S2 using Ku band cannot provide reliable reception to homes during cloudy weather. The public also has to pay to subscribe to satellite TV channels whereas terrestrial TV channels are free. Satellite transmission cannot provide mobile reception whereas DVB-T2 can reach car receivers and mobile phones. The advantages of DVB-S2 are that the signals can reach distant regions and UHDTV is a practical proposition.

Both DVB-T2 and DVB-S2 networks are linked to each other to provide cost effective and disruption free service to the public. Both are green technology as they consume less energy and have lower carbon footprint than analogue transmitters. Higher Signal/Noise ratio is required at the receiver as there is no error correction of signals from the analogue transmitters resulting in the transmitters having much higher power ratings The smaller Digital Terrestrial TV infrastructure emits lesser carbon and renewable energy can be used for low power transposers in remote regions. Hence, ASEAN can benefit from both digital systems in terms of cost and green technology.

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Implementation of Green Building for Energy Savings Potential in Nipah Mall Building

Muh. Agung Triady Putra[a,d,e], Nurul Asmarani[b,c,e]

a) PT. Bumi Karsa, Makassar City, South of Sulawesi, Indonesia
b) Natural Resources and Environmental Management, Bogor Agriculture Institute, Bogor, West Java, Indonesia
c) Ministry of Energy and Mineral Resources, Jakarta, Indonesia
d) Institution of Indonesia Engineers, Indonesia
e) Environmental Engineering, Hasanuddin University, Makassar, Indonesia
agung.triady@gmail.com

Abstract

Makassar's population growth has spurred a significant increase in economic activities, leading to a notable surge in energy demand. The building sector, responsible for nearly 40% of the national energy consumption, plays a central role. Achieving the 2025 goal of 23% new and renewable energy (NRE) utilization necessitates a meticulously designed renewable energy plan, with a specific focus on the building sector. Energy consumption within this sector contributes significantly to carbon emissions and greenhouse gases, emphasizing the urgency of transitioning to sustainable development through green building principles. Nipah Mall and Office Building in East Indonesia exemplify this commitment, earning the Green Building Council Indonesia's (GBCI) Gold Certificate for their wholehearted embrace of green building principles. Natural lighting and ventilation potential further enhance their environmental performance.Research, employing quantitative and qualitative methods, meticulous observations, and data collection, finds that Nipah Mall & Office consumes approximately 70.5 kWh/m2/year of electrical energy, roughly 0.2% of the annual energy consumption standard. Impressively, it earns 15 out of 16 points in the GBCI EEC1 category, confirming compliance with electrical energy standards. This study aims to elucidate the potential benefits and outcomes of green building practices, particularly in energy conservation, contributing to a sustainable future.

Keywords: Carbon emissions , Energy efficiency, Energy savings, Green building, Renewable energy

1. Introduction

Nipah Mall & Office Building, as an environmentally friendly and open-space shopping center, has achieved the Green Building Gold Certificate from the Green Building Council Indonesia. It stands as the sole mall in the Eastern Indonesia Region (Kawasan Timur Indonesia, KTI) to have attained this distinction. Approaching its fourth year of operation, Nipah Mall & Office Building embraces the theme "Energy of Nature," emphasizing its connection with natural elements such as water, wind, fresh air, and sunlight, which symbolize both natural energy and the essence of life and balance.

Nipah Mall & Office Building is fully committed to incorporating every aspect of green building principles into its construction, especially given its urban location. Obtaining green certification for Nipah Mall & Office Building is not an easy feat, as it involves a comprehensive process, spanning from the design phase to the building's operational phase. Key prerequisites, including building comfort, health, and safety, must be met in accordance with established standards and regulations. In the assessment and review of the building's design, benchmarks in the form of rating tools serve as reference points. These benchmarks are issued by independent institutions with the authority, capability, and recognized presence. In Indonesia, such an institution is the Green Building Council Indonesia (GBCI).

The achievement of these benchmarks aims to ensure that the building optimizes land use, energy, water, and materials, providing comfort to its occupants and adhering to energy-saving practices during construction, thereby offering energy users savings and efficiency. The benchmarks or categories for achieving recognition include Appropriate Site Development (ASD), Energy Efficiency and Conservation (EEC), Water Conservation (WAC), Material Resource and Cycle (MRC), Indoor Health and Comfort (IHC), and Building Environment Management (BEM). The process of obtaining Greenship certification is notably lengthy, but Nipah Mall has successfully navigated several stages, particularly in the areas of energy conservation and building design.

Hence, there is a need for an analysis of the impact of implementing green building concepts on energy efficiency. This analysis serves as an effort by the author to identify the alignment of energy-efficient design in Nipah Mall & Office with Green Building and IKE (Energy Consumption Intensity) standards.

2. Literature Review

Green Building Green Building was introduced in 1993 by the US Green Building Council (USGBC) with the aim of transforming the construction industry into a more environmentally friendly activity. Beginning in the mid-1990s, with financial support from the United States Department of Energy, USGBC developed an assessment and evaluation system for what constitutes green building practices (Pamulasaki, 2017).

Managing a building with an environmental commitment, such as Nipah Mall, undoubtedly requires special and comprehensive attention. This encompasses activities, management aspects, and, importantly, the involvement of building managers and users as individuals. Humans play the most critical role in the sustainability of a green building and environment because the results ultimately benefit them.

Standar IKE (Energy Consumption Intensity) The IKE standard, or Energy Consumption Intensity, is a standard for energy-efficient buildings used to determine the extent of electricity consumption in a given system or building (Santosa, 2017). IKE serves as a reference point to ascertain whether a building is energy-efficient or not. According to research conducted by ASEAN-USAID in 1987, with the report published in 1992, the target Energy Consumption Intensity (IKE) for shopping centers in Indonesia is set at 330 kWh/m2 per year.

The formula for calculating IKE is as follows:

$$\text{IKE} = \frac{Energy\ Used\ ({}^{kwh}/_{year})}{Building\ (m^2)}$$

$$\text{IKE \%} = \frac{IKE\ Bangunan\ Nipah\ Mall\ Building\ IKE}{Shopping\ Center\ Standart\ IKE}$$

Standar GBCI GBCI (Green Building Council Indonesia) is a non-governmental and non-profit green building standard used to assess whether a building qualifies as a green building. GBCI standards include several classification assessments, one of which is the EEC 1 assessment or Optimized Efficiency Building Energy Performance, which evaluates a building based on standardized data on electricity consumption (kWh) and is calculated using the IKE standard.

3. Research Methodology

The research methodology employed in this study utilizes a quantitative-qualitative approach, involving the collection of documents from Nipah Mall & Office, specifically pertaining to energy consumption over the past year. These data were then tested for compliance with environmentally friendly and green building standards, using quantitative, measurable, and mathematical methods to obtain valid and precise information.

Mathematical Calculations Measurements were conducted by gathering existing data, which were subsequently assessed using energy-efficient building standards, namely the IKE (Energy Consumption Intensity) and GBCI (Green Building Council Indonesia) standards.

Research Description and Location
Nipah Mall, officially opened in late 2018, brought a fresh ambiance to the city of Makassar. This was primarily due to the fact that the mall marked the first green commercial area in East Indonesia to implement green building concepts. The mall covers an expansive area of 3.5 hectares (ha) with a total building area of 121,426 square meters. It was designed by the architectural firm PT. Urbane Indonesia.

Nipah Mall is situated in Urip Sumoharjo, Panaikang, Panakkukang, in the city of Makassar. It stands as the largest mall in Makassar, occupying 3.5 hectares of land. The mall boasts five floors, a basement level, and a 10-story office building. Situated on 3.5 hectares of land, the total building area encompasses approximately 121,426 square meters. The architectural design features elements of industrial style and is complemented by the natural greenery of trees. Nipah Mall, officially opened at the end of 2018, introduced a new atmosphere to the city of Makassar. Notably, it became the first green commercial area in East Indonesia to embrace sustainable architectural concepts. Nipah Mall prioritizes environmental considerations in its construction and building design. The mall incorporates the efficient use of resources, materials, and energy. With its open-concept design, it reduces the need for indoor cooling systems. The mall features wastewater treatment installations, addressing various aspects of eco-friendly facilities from every perspective within the building. Lush green ornamental plants adorn both the front and rear areas of the mall, harmonizing with its architectural concept. Void corridors enhance air circulation, providing freshness, coolness, brightness, and spaciousness. The water management system captures water for use in ponds and plant irrigation. Additionally, waterfalls and cascades contribute to air moisture retention. Daud Rianto adds that the semi-outdoor concept facilitates excellent air circulation, supported by greenery in all public areas, reducing energy consumption in terms of lighting and air conditioning.

4. Results and Discussion

Nipah Mall is a family-oriented shopping center designed as an open-air concept to provide all family needs in one place. Beautiful Green Open Spaces (GOS) are available on almost every floor. The semi-outdoor concept facilitates excellent air circulation, further enhanced by the presence of plants in all public areas, which reduce energy consumption in terms of both lighting and air conditioning.

Officially opened at the end of 2018, Nipah Mall introduced a new atmosphere to the city of Makassar as the first green commercial area in East Indonesia to embrace green architectural concepts. Environmental considerations were paramount in Nipah Mall's construction and building design. The mall's efficient use of resources, materials, and energy was a key focus. Its open-concept design minimizes the need for indoor cooling systems, such as Air Conditioning (AC). Void corridors enhance air circulation, providing a fresh, cool, bright, and spacious atmosphere. Waterfalls and cascades contribute to air moisture retention, and the semi-outdoor concept facilitates excellent air circulation. This is further supported by the presence of plants in all public areas, reducing energy consumption in terms of both lighting and air conditioning. Plantings along pedestrian walkways serve as protection from the heat caused by solar radiation, and vegetation in outdoor spaces and mall corridors enhance the overall aesthetics.

The open spatial planning concept, which serves as a source of air circulation, features various green plants that grow and adorn the entire mall area, contributing to air circulation and making the mall clean, comfortable, and fresh. The mall's architectural appearance prominently showcases exposed materials, including concrete, wood, brick, and terracotta, which combine to create Nipah's distinctive atmosphere. Nipah Mall's roof structure remains uncovered, utilizing materials that mitigate the sun's effects, including membrane materials with insulation.

Nipah Mall's steps toward Energy Conservation and Efficiency include: designing and installing insulation to reduce heat transfer and thermal bridging, minimizing energy consumption related to heating and cooling systems, reducing energy consumption through interior and exterior lighting, and reducing consumption of nonrenewable energy resources by installing and operating sustainable energy generation systems. The entire building is equipped with solar panels to generate its electricity. Additionally, Nipah Mall employs energy-efficient LED lighting with extended lifespans. The implementation of Energy-Efficient Architectural Design in Nipah Mall responds effectively to the local climate conditions. By optimizing site potential, such as wind direction, building orientation, and the reduction of sunlight through canopy reflection systems, it achieves thermal comfort and sufficient lighting, reducing the need for indoor cooling. Moreover, the materials used in the roof structure, including membrane materials with insulation, align with sustainability criteria.

Electricity Usage Over the Past Year The data on the electricity consumption of the Nipah Mall & Office building over the past year is as follows:

Table 1. Electricity Usage Over the Past Year in Indonesian Rupiah (Year 2022)

PERIODE THN 2022	ENERGY CONSUMPTION	UNIT	GFA (m2)	EEI based NLA (kWh/m2)
JANUARI	672.560	kWh	103.425	82,79
FEBRUARI	600.960	kWh		
MARET	676.480	kWh		
APRIL	673.360	kWh		
MEI	710.160	kWh		
JUNI	685.360	kWh		
JULI	747.200	kWh		
AGUSTUS	746.480	kWh		
SEPTEMBER	754.960	kWh		
OKTOBER	769.440	kWh		
NOVEMBER	749.360	kWh		
DESEMBER	776.320	kWh		
TOTAL	**8.562.640**	**kWh**		

The average electricity consumption for the Nipah Mall & Office building over the past year was 8,562,640 kWh. The calculation of the building's energy conservation/efficiency level is determined using the IKE (Energy Consumption Index) standard method. The target IKE for a mall building is 330 kWh/m2 per year. The calculation for the IKE of the Nipah Mall & Office building is as follows:

$$\text{IKE} = \frac{Energy\ Used\ \left({}^{kwh}/_{year}\right)}{Building\ Area\ (m^2)}$$

$$\text{IKE} = \frac{8.562.640\ \left({}^{kwh}/_{year}\right)}{121.426\ (m^2)}$$

$$\text{IKE} = 70{,}5\ \text{kWh/m}^2\text{/year}$$

Percentage of energy consumption efficiency for the building:

$$IKE\ \% = \frac{Nipah\ Mall\ Building\ IKE}{Shopping\ Center\ Standard\ IKE}$$

$$IKE\ \% = \frac{70{,}5\ kWh/m2/year}{330\ kWh/year} \times 100\%$$

$$= 0{,}2\%$$

Therefore, the Nipah Mall & Office building utilizes approximately 70.5 kWh/m2/year, which is about 0.2% of the standard energy consumption in one year according to the IKE standard.

GBCI Standards GBCI applies green building standard points with established classifications. These points can be observed as follows:

Table 2. GBCI EEC1 Standard Points at Nipah Mall & Office, 2023

Classification	Description	Point	Max Value
Energy Eficiency	Furthermore, if the building's electrical IKE exceeds the reference electrical IKE standard and is less than or equal to 120% of the building's electrical IKE in the last 6 months, then each 5% reduction earns an additional 1 point, up to a maximum of 8 points.	4 - 8	8
	In the event that the building's electrical IKE falls below the reference electrical IKE standard in the last 6 months, each 3% reduction will receive an additional 1 point, up to a maximum of 16 points.	9 - 16	7
Total			15

Source : Author, 2023

From the table, it can be concluded that the obtained points amount to 15 points. According to the GBCI classification, the maximum points for the Optimized Efficiency Building Energy Performance (EEC 1) classification is 16 points, indicating that the Nipah Mall & Office building already meets the GBCI EEC 1 classification standard.

5. CONCLUSION

The conclusion drawn from this written work is that the Nipah Mall building, in terms of energy conservation, meets the standards. The building's electricity consumption is very low, utilizing only 70.5 kWh/m2/year, or approximately 0.2% of the standard energy consumption over the past year according to the IKE standard. It has also earned 15 out of 16 points in the GBCI EEC1 category, affirming compliance with electrical energy standards. The Nipah Mall building in Makassar is an exemplar of sustainable architectural design. With a land area of 121,426 m2 and an annual energy consumption of 8,562,640 kWh/year, energy efficiency measures are not only aimed at conserving energy but also creating a favorable microclimate and comfort for users/visitors.

Nipah Mall appears to employ passive design principles and an open roof with membrane materials. Their functions include reducing energy consumption related to lighting and aiding in thermal energy use. Nipah Mall also utilizes central air conditioning and chimneys, each with their respective functions for the distribution of cold and warm air, helping to facilitate the circulation of air entering or leaving the building.

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ESTIMATION OF BIOMASS CONTENT AND CO_2 UPTAKE IN THE MANGROVE FOREST CONSERVATION AREA SERIBU CEMARA BEACH CSR PROGRAM PT PLN (PERSERO) UIP KALBAGBAR

Widyanto Hadi Prasetyo[1], Pradita Teguh Irawan[1] and Dhio Dwinofiansyah Putra[1]

[1]UPP Kalbagbar 3, PT PLN (Persero) UIP Kalbagbar, Jl. Letjen Suprapto No.50 G, Pontianak, 78111, Indonesia

E-mail: widyantohadiprasetyo.whp@gmail.com

Abstract

Corporate Social Responsibility Program for Mangrove Forest Conservation in Seribu Cemara Beach by PT PLN (Persero) Unit Induk Pembangunan Kalimantan Bagian Barat (UIP Kalbagbar) is a form of company contribution and commitment to supporting the Sustainable Development Goals (SDGs) program launched by the government, especially the pillar of environmental development. The Seribu Cemara Bearch Mangrove Forest Conservation Corporate Social Responsibility Program is located on the shoreline of 1,7 Ha. The mangrove conservation Corporate Social Responsibility Program is expected to preserve the environment with its ecological function as a producer of natural biomass and absorber of carbon dioxide (CO_2). This study aimed to determine the total content of biomass, carbon stock, and CO_2 absorption produced by the Seribu Cemara beach mangrove forest conservation. The method used in this study is the survey method with the determination of stations using the purposive sampling method. Carbon storage in mangrove stems using a non-destructive sampling method with allometric equations. The research results obtained found 1 type of mangrove, namely *Rhizopora Mucronata*. The estimated yield of the average mangrove biomass is 91,11 tons/ha, the average mangrove carbon stock is 42,82 tons/ha, and the average amount of CO_2 uptake is 157,01 tons/ha and the results between stations were significantly different ($\rho<0,05$). The results showed that the potential of mangrove biomass is directly proportional to carbon stock and CO_2 uptake. The density of mangroves affects biomass, mangrove carbon stock, and CO_2 absorption and has a strong influence.

Keywords: CSR, Conservation, Mangrove, Biomass, CO_2 uptake

1. Introduction

The issue of global warming is a topic and concern of many parties around the world. The issue of global warming is related to climate change that affects life on Earth. One of the causes of global warming is the increase in the concentration of greenhouse gases in the Earth's atmosphere. Efforts to reduce greenhouse gas concentrations are by reducing carbon emissions, maintaining existing carbon stocks, and increasing carbon absorption through forest conservation programs including mangrove forest ecosystems. Mangroves are one of the coastal ecosystems that have an important role in the life of living things. The important role of mangroves consists of ecological and economic aspects. Mangroves also function as carbon sinks in the atmosphere and are part of the blue carbon concept, which stores carbon in tissues and sediments [14].

Mangroves as a component of the coastal ecosystem have an important role, both from an ecological perspective, namely their role in maintaining water productivity and in supporting the economic life of the surrounding population [8]. According to [18], the ecological function of mangroves is to absorb and store carbon in efforts to mitigate global warming. Mangroves in the coastal areas of the Indo-Pacific region, which only have 0.7% of the forest area, can store around 10% of all emissions including carbon [19]. Carbon storage in mangrove forests is higher than carbon storage in other forest types [3]. The biological aspects of mangrove ecosystems play a role in maintaining the stability of productivity and bioavailability of coastal areas as breeding and spawning areas. Capability in chemical processing and recovery, namely as an absorbent for pollutants, especially organic matter, as well as a supplier of organic matter for the aquatic environment. Mangroves can absorb carbon in the atmosphere and store it in biomass and sediment, so mangroves play an important role in mitigating global climate change [2].

From 2000 – 2005, the area of mangrove forests decreased by around 1.6% or 50 thousand hectares [5]. The decline in mangrove areas is largely due to community activities that convert mangrove forest areas excessively, fishing that is not environmentally friendly, weak governance, lack of coordination between government and community institutions, and weak law enforcement in coastal and marine areas [6]. The loss of mangrove forests contributes 42% of carbon dioxide gas (CO_2) emissions into the atmosphere due to damage to coastal ecosystems, including swamps, mangroves, and seaweed [13].

PT PLN (Persero) Unit Induk Pembangunan Kalimantan Bagian Barat (UIP Kalbagbar) as a unit of BUMN companies participates in sustainable development in line with government programs namely Sustainable Development Goals (SDGs) always holds programs or activities in the form of Corporate Social Responsibility (CSR) to realize or improve the Sustainable Development Goals (SDGs), especially in the work area or around the transmission or generation project location. The Mangrove Forest Conservation CSR Program is one of the programs of PT PLN (Persero) UIP Kalbagbar which focuses on preserving mangroves as an effort to mitigate global warming carbon emissions, this program is also in line with the company's contribution and commitment to supporting the Sustainable Development Goals (SDGs) program which proclaimed by the government, especially the pillars of environmental development. According to Law Number 24 of 2007, the notion of mitigation can be defined as a series of efforts to reduce disaster risk through physical development and awareness and capacity building in dealing with disaster threats [15].

Mangrove Forest Conservation CSR activities are located in Seribu Cemara Beach, Seruyan Regency with an area of around 1.7 Ha. It is hoped that the change or increase in area as a result of the CSR program for mangrove forest conservation can add or increase the biomass content in the Seribu Cypress beach area to preserve or increase the standard of living of marine biota and increase carbon stocks and carbon dioxide (CO_2) absorption to reduce global warming.

Information regarding the value of biomass, carbon stock, and CO_2 absorption of mangrove ecosystems around Seruyan District, Central Kalimantan Province, especially in the mangrove forest conservation area of the CSR program of PT PLN (Persero) UIP Kalbagbar Seribu Cemara Beach, Sungai Bakau Village, is currently not available. Based on this, it is necessary to do research on the amount of additional value of biomass, carbon stock, and CO2 absorption as a result of mangrove forest conservation activities, the CSR program of PT PLN (Persero) UIP Kalbagbar. This study was to determine the relationship between the value of mangrove biomass with the value of carbon stock and CO_2 uptake, the relationship between mangrove density with the value of biomass, carbon stock, and CO_2 uptake and to find out the average added value of biomass, carbon stock and CO_2 uptake around Seribu Cemara Beach. as a result of the CSR Program of PT PLN (Persero) UIP Kalbagbar mangrove forest conservation.

2. Methods

Time and place. This research was conducted in July 2023 in the Mangrove Forest Area of PT PLN (Persero) UIP Kalbagbar Corporate Social Responsibility (CSR) Program in Seribu Cemara Beach, Seruyan Regency, Central Kalimantan Province, the location can be seen in Figure 1.

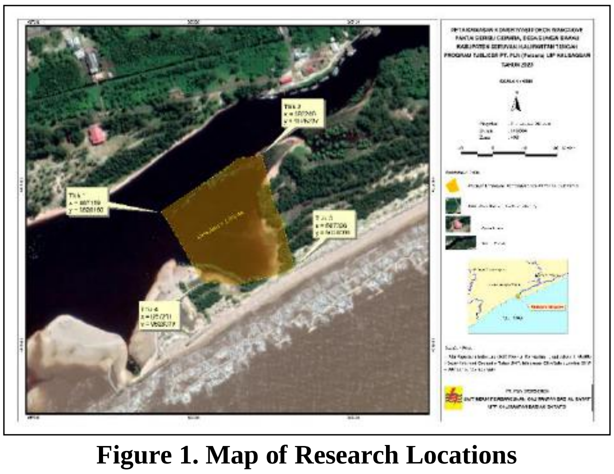

Figure 1. Map of Research Locations

Data Retrieval Method. The method used in this study is a survey method, namely observation and sampling carried out at the research location. Determination of station points was carried out purposively, namely determining locations deliberately by paying attention and taking into account the conditions at the research location [1]. These considerations include station I, the location is close and there is a river flow at the estuary of the mangrove river. Station II is located close to the community plantations of Sungai Bakau Village where the utilization of mangrove forests is relatively minimal and far from the currents of the river estuary and the waves of the Java Sea. Station III, Location directly facing the Java Sea.

Mangrove sampling used the 5 m x 5 m quadrant plot transect method. According to [10], mangrove data collection uses a 20 m x 20 m plot for tree stands, a 10 m x 10 m transect for the pole level, a 5 m x 5 m transect for the sapling level, and a 2 m x 2 m transect for the seedling level. Mangrove size at seedling level (stand height < 1.5 m), sapling level (height > 1.5 m and stem diameter < 10 cm), pole stage (trunk diameter 10-20 cm), and tree stage (diameter > 20 cm). The distribution map of stations and sampling in the CSR mangrove forest area of PT PLN (Persero) UIP Kalbagbar Seribu Cemara Beach can be seen in Figure 2.

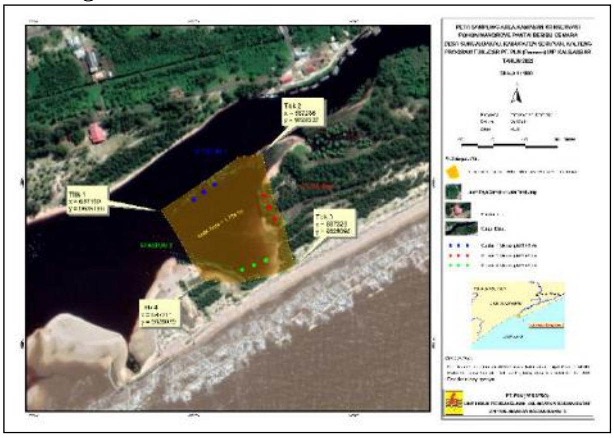

Figure 2. Map of Station Distribution and Sampling

Mangrove Density

Mangrove density (density) is calculated using a formula that refers to [16] as follows:

$$K = \frac{I}{L\ plot} \quad (1)$$

Information:

K = Density (individual/m^2)

I = Number of Individuals

L plot = The area of the entire plot (m^2)

Mangrove Biomass

The calculation of mangrove biomass in this study used the allometric equation method. The allometric equation for determining the value of mangrove tree biomass is presented in Table 1.

Table 1. Calculation of Mangrove Biomass Allometric Equations

Mangrove Types	Allometric Equations	Research Resources
Rhizophora mucronata	$B = 0{,}1466\ (D)^{2{,}3136}$	[4]
Nypa fruticans	$B = 0{,}222\ (D)^{2{,}7048}$	[20]
Avicennia alba	$B = 0{,}079211\ (D)^{2{,}470895}$	[22]
Avicennia marina	$B = 0{,}1848\ (D)^{2{,}3524}$	[3]
Sonneratia spp	$B = 0{,}299\ (D)^{2{,}300}$	[11]

Note: B = Mangrove Biomass (kg/ind) ; D = Diameter of tree tunk (cm)

Carbon Stock Mangrove

Calculation of mangrove carbon stocks uses a formula that refers to [9]:

$$Cb = B \times \%\ C\ Organik \quad (2)$$

Information :

Cb = Mangrove carbon stock (Kg)

B = Mangrove Biomass (kg)

%C Org = Carbon content percentage value (0.47)

CO_2 Uptake

According to [9], to convert carbon to CO_2 absorption (kg) a relative atomic mass of C (12) and CO_2 (44) is required, formulated as follows:

$$CO_2\ Uptake = \frac{Mr\ CO2}{Mr\ C} \times Cb \quad (3)$$

Information :

CO_2 Uptake = CO_2 Uptake (kg)

Cb = Biomass Carbon Stock (kg)

Mr. CO_2 = 44 gr/mol

Mr. C = 12 gr/mol

3. Results And Discussion

Vegetation Composition and Density of Mangrove Stands. The mangrove vegetation found at the research station consisted of 1 species, namely: *Rhizophopra mucronate*. Mangrove type, number of individuals, mangrove density, and average diameter of mangrove stems at each station and plot can be seen in Table 2.

Table 2. Types of Mangrove, Mangrove Diameter, and Density

Stasiun	Plot	Mangrove Type	D average (cm)	Number of Individuals Per Plot	Density (Ind/Ha)
1	I	RM	7,57	17	6.800
	II	RM	6,78	14	5.600
	III	RM	7,46	16	6.400
Average			**7,27**	**15,67**	**6.266,67**
2	I	RM	8,25	17	6.800
	II	RM	7,13	18	7.200
	III	RM	8,44	16	6.400
Average			**7,94**	**17,00**	**6.800,00**
3	I	RM	7,57	14	5.600
	II	RM	6,33	13	5.200
	III	RM	5,43	14	5.600
Average			**6,44**	**13,67**	**5.466,67**

Source: Survey and research results (2023)

Biomass, Carbon Stock, and CO_2 Uptake. Based on the results of the research that has been carried out, the results obtained are biomass, carbon stock, and CO_2 absorption which can be seen in Table 3.

Table 3. Biomass Value, Carbon Stock, and Mangrove CO_2 Uptake

Stasiun	Biomass (Ton/Ha)	Carbon Stock (Ton/Ha)	CO_2 Uptake (Ton/Ha)
I	91,49	42,99	157,66
II	120,36	56,57	207,42
III	61,47	28,89	105,94
Average	**91,11**	**42,82**	**157,01**

Source: Survey and research results (2023)

Relationship between Mangrove Density and Biomass, Carbon Content and CO2 Uptake. Mangrove density influences the content of biomass, carbon stock, and CO_2 absorption in mangrove forests. To find out how strong the relationship is, it is necessary to do a regression test between mangrove density and biomass, carbon stock, and CO_2 absorption, which can be seen in Figures 3, 4, and 5.

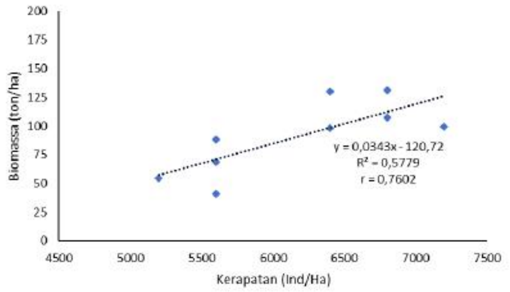

Figure 3. Relationship of Density to Mangrove Biomass in the Seribu Cemara Beach Mangrove Conservation

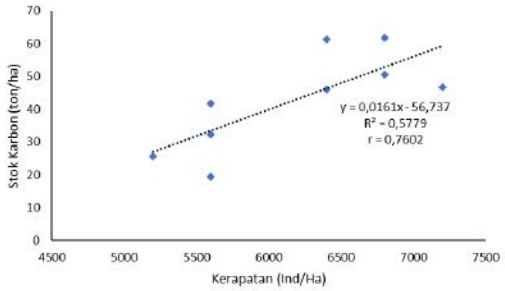

Figure 4. Relationship of Carbon Stock to Mangrove Biomass in the Seribu Cemara Beach Mangrove Conservation

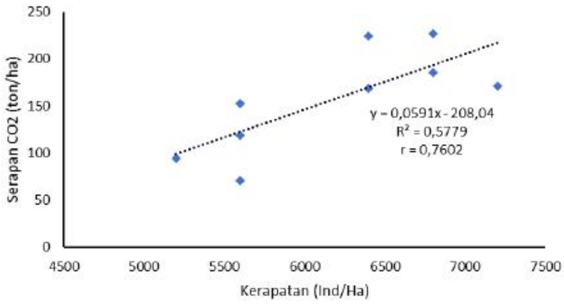

Figure 5. Relationship of CO_2 Uptake to Mangrove Biomass in the Seribu Cemara Beach Mangrove Conservation

Mangrove Density. Based on the data in Table 2, it can be seen that the station which has the highest average density is at the station which has the highest density of mangroves at station 2, which is 6,800 ind/Ha with a diameter range of mangrove stems of 7.94 cm, while the lowest mangrove density is at station 3, namely 5,466.67 ind/ha with a diameter range of 6.44 cm mangrove stems. Based on the results of the ANOVA test, it can be concluded that the density of mangrove stands between stations shows a value of $\rho = 0.03$ ($\rho < 0.05$), which means that the density of mangroves between stations is significantly different.

The density at station 2 is higher than that at station 1 and station 3 due to the different characteristics of the three areas. Station 2 is close to the plantations of the people of Sungai Bakau Village where the use of mangrove forests is relatively minimal and far from river estuary currents and the waves of the Java Sea so that the seedlings live well. Station 3 is beside the Java Sea where the Java Sea waves are strong so several seedlings fall and drift away, this causes station 3 to be lower than stations 1 and 2. Station 1 is close to the estuary of the mangrove river, due to the currents of the estuary. which resulted in a lower density of station 1 compared to station 2. [21] stated that the low density of mangroves in an area is due to the large anthropogenic influences that change mangrove habitat for other purposes, such as clearing land for settlements and others so that the mangrove ecosystem experiences pressure and decreases in area.

Biomass, Carbon, and CO_2 Uptake. Based on the data in Table 3, the results of calculating mangrove biomass at the three research stations show that the highest biomass value is found at station 2, namely 120.36 tons/ha, the lowest biomass value is at station 3, namely 61.47 tons/ha and the average value of biomass in mangrove forest conservation locations is 91.11 tons/ha. The highest carbon stock value was found at station 2, which was 56.57 tons/ha, the lowest carbon stock was found at station 3, which was 28.89 tons/ha and the average carbon stock value in mangrove forest conservation locations was 42.82 tons/ha. Ha. The highest CO_2 uptake value was at station 2, which was 207.42 tons/ha, the lowest CO_2 uptake was at station 3, which was 105.94 tons/ha and the average CO_2 uptake value in mangrove forest conservation locations was 157.01 tons/ha. Ha. Based on the results of the ANOVA test, it can be concluded that the mangrove biomass between stations showed a value of $\rho = 0.04$ ($\rho < 0.05$), which means that the mangrove biomass between stations was significantly different. Likewise, with mangrove carbon and CO_2 uptake, the test results showed significantly different results between stations. The difference in the amount of biomass is due to differences in the density and diameter of the mangroves at each station.

From the results of this study, it was found that each addition of biomass content would be followed by an addition of carbon content. Carbon and biomass have a positive correlation, if there is an increase or decrease in biomass it will cause an increase or decrease in carbon content. The percentage of carbon stock increases in line with the increase in biomass, carbon stock is directly proportional to the biomass content. The results of calculating the CO_2 absorption value of mangroves at the three research stations showed that the highest CO_2 uptake value was at station 2, namely 207.42 tons/ha, the lowest CO_2 absorption value was at station 3, namely 105.94 tons/ha and the average value CO_2 absorption in mangrove forest conservation locations is 157.01 tons/ha. The amount of CO_2 absorbed by mangrove forests increases along with the amount of biomass in these trees so the carbon content they have also increases. The carbon content in mangrove plants illustrates how much these plants can bind CO_2 from the air [7].

Relationship between Mangrove Density and Biomass, Carbon Content and CO_2 Uptake. Based on Figures 3, 4, and 5, the results of the linear regression test can be concluded that the relationship of density to the three variables (biomass, carbon stock, and CO_2 uptake) in the mangrove conservation area in Seribu Cemara Beach has the same correlation value of 0.7602, which means it has a level strong correlation. According to [20] the density of mangroves is directly proportional to the amount of biomass, carbon stock, and CO_2 uptake, so there is a need for regulations to preserve mangroves so that air quality can be maintained properly.

The coefficient of determination for the three variables is 0.58, meaning that 58% of the variation in biomass, carbon stock, and CO_2 uptake can be explained by the density variable, while the remaining 42% is influenced by other factors. According to research [17], stand density has a strong positive correlation with carbon storage and biomass, although it is not significant. Other factors that affect variations in biomass, carbon stock, and CO_2 uptake are tree diameter. The larger the diameter of the tree, the greater the biomass, carbon stock, and CO_2 uptake. This shows that the variations in these three aspects are not only influenced by the level of density, but there are other factors such as the diameter of the mangrove trees [1]. This significant correlation between diameter and biomass is thought to be related to the rate of carbon absorption and the physiological process of plants, namely photosynthesis, the greater the biomass produced from the photosynthesis process will affect plant growth, both primary and secondary growth [12].

4. Conclusion

The Corporate Social Responsibility Program of PT PLN (Persero) UIP Kalbagbar in the form of mangrove forest conservation on Seribu Cemara Beach is an effort to support the government's Sustainable Development Goals (SDGs) program, especially the pillars of environmental development. From the results of the study, it was found that the values of biomass, carbon stock, and CO2 absorption at station 2 which is close to community plantations are greater than station 1 which is near the estuary of the Bakau River, and station 3 which is beside the Java Sea. From the results of the ANOVA test, mangrove density, biomass values, carbon stocks, and CO_2 uptake between stations showed a value of $\rho < 0.05$, which means that the results between stations had significantly different results. The CSR program of PT PLN (Persero) UIP Kalbagbar mangrove forest conservation provides an additional average value of mangrove biomass is 91.11 tons/ha, carbon stocks is 42.82 tons/ha and CO_2 absorption is 157.01 tons/ha in the surrounding area. Thousand Cemara Beach. Based on the results of the analysis, the amount of CO_2 absorbed by mangrove forests increases along with the amount of biomass in the trees so that the carbon content and CO_2 absorption also increase. Mangrove density affects biomass, mangrove carbon content, and CO_2 uptake and has a strong relationship with a correlation value of 0.76.

It is hoped that there will be further research on the potential for organic carbon in mangrove species based on their depth and research related to the relationship between the size of the mangrove diameter and the value of biomass, carbon stocks, and CO_2 absorption at the Seribu Cemara Beach mangrove forest conservation program PT PLN (Persero) UIP Kalbagbar CSR program.

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TREATMENT OF SULLAGE WATER USING CDS TECHNOLOGY - A CASE STUDY OF TIONG NAM URBAN AREA SULLAGE WATER TREATMENT PLANT (SWTP), KUALA LUMPUR UNDER PHASE 2 RIVER OF LIFE PROJECT

Yale Wong*, Chow Hock, Lim **
*Author and Co-author** from EcoClean Technology Sdn. Bhd., Kuala Lumpur, Malaysia
yalewong@ecoclean.com.my

Abstract

The Kuala Lumpur City Hall was responsible for the Phase 2 River of Life Project which included the construction of several underground sullage water treatment plants (SWTP). EcoClean Technology Sdn Bhd had won on an alternative design and build basis as a sub-contractor to carry out the work of collecting the sullage water from the Tiong Nam urban sub-catchment and treating it to the river Water Quality Index (WQI) of Class 2B. In this project, we used a CDS-GSS (Continuous Deflective Separation - Gross Screen Separator) to replace the client's primary and secondary screening processes based on the conventional plant design. The CDS-GSS is an innovative non-blinding screening technology for the separation of solids from liquid stream by working in conjunction with hydraulic principles of balancing of high flow, carrying particles across the face of the screen resulting in the removal of all the solids. The next process involves coagulation and flocculation where the superfine particles will accumulate and become flocs and the heavy flocs then will undergo a secondary vortex process where the flocs will settle down inside the CDS. This is followed by the biological treatment consisting of suspended cultured bacteria in the biological oxidation tank. After this final treatment, the treated sullage water effluent with a Water Quality Index (WQI) of Class IIB will be finally discharged into the adjacent Gombak River.

Keywords: EcoClean Technology, Continuous Deflective Separation - Gross Screen Separator, non-blinding screening technology, sullage water treatment plant, and sullage water effluent.

1. Introduction

Water pollution is a crucial problem in the Kuala Lumpur Metropolitan City due to the frequent discharges of pollutants into the river arising from the rapid housing and commercial developments and the existing squatters staying along the riverbanks. The accumulation of pollutants will deteriorate the river water quality and deplete dissolved oxygen in the river through algae growth. Pollutants from the various sources of the catchment will stick and gather with sediment at the riverbeds, hence aggravating the degradation of river water quality. This in turn will also pollute the seas and oceans, endangering the marine ecosystems. Besides the issue of pollution, frequent flash flooding may also happen partly due to the shallowing of riverbeds caused by the sediments.

Apart from installing various types of trash traps along rivers and more than 300 gross pollutant traps within the drainage system to improve the water quality of the Klang and Gombak rivers under Phase 1 of the River of Life (ROL) project, the Federal Government had allocated additional fund to construct about 20 numbers of sullage water treatment plant (SWTP). Hundreds of kilometers of drainage interceptors in the form of pipelines were built to collect and channel the sullage water to the SWTP for treatment before releasing the treated effluent to the Klang and Gombak rivers.

The SWTPs were constructed in different parcels with different stages of completion, all of which were aimed at raising the river water quality from the current Class III and Class IV (both not suitable for body contact) to Class IIB (suitable for body contact and recreational usage). The general rating scale for the Water Quality Index is shown in Table 1.

Table 1: General Rating Scale for the Water Quality Index

WQI	Status	Class	Uses
80-100	Clean	I	Conservation of the natural environment Water Supply I – Practically no treatment necessary Fishery I – Very sensitive aquatic species
		IIA	Water Supply II - Conventional Treatment Fishery II-Sensitive aquatic species
		IIB	Recreational use suitable for body contact
60-79	Slight Polluted	III	Water supply III- Extensive treatment required Fishery III - Common of economic value and tolerant species; livestock drinking
0-59	Very Polluted	IV	Irrigation
		V	None of the above

EcoClean Technology Sdn. Bhd. had been awarded the sub-contract to construct the Sullage Water Treatment Plant (SWTP) at the Tiong Nam urban area for Package 3 of the Phase 2 River of Life Project. The target effluent was to achieve the Water Quality Index (WQI) of class IIB. The location of the Tiong Nam SWTP in the upper Klang River catchment is shown in Figure 1.

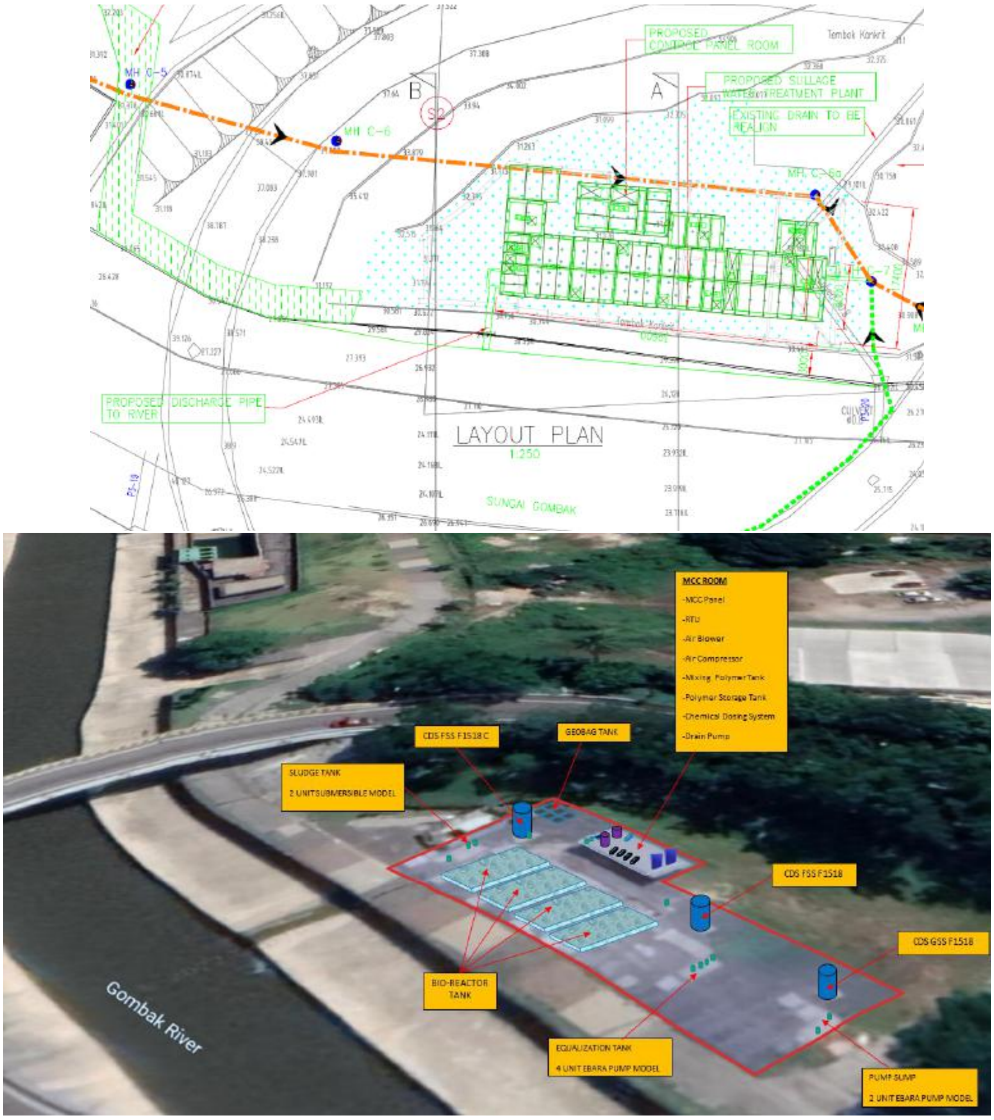

Figure 1: Location Plan for Tiong Nam SWTP

The conventional design was carried out by a local consultant who had earlier designed some 13 numbers of sullage water treatment plants under the Phase 1 River of Life. In terms of the mode of operation, they were designed in some ways similar to the conventional wastewater treatment plant by diverting the sullage water into a channel with primary and secondary raking screens followed by pumping the water for a fixed flow rate to a series of concrete tanks. The tank bottoms were lined with air diffusers for introducing oxygen to rakes of hanging long plastic brushes. By applying the principle of an Integrated Fixed Activated Sludge (IFAS) system comprising multiple types of biological carriers in the biological oxidation tank in long-hanging brush forms, microbacteria will eventually enable the growth and generation of biofilm which perform the task of nutrient and pollutant removal.

The influent and effluent of the SWTP are sampled and recorded weekly to determine the water quality. Constant evaluation of the river water quality was carried out to ensure the plant operates and performs in a good and sustainable manner.

The target of the effluent is to achieve the Water Quality Index (WQI) class IIB. The parameters to be tested for each influent and effluent are the Dissolved Oxygen (DO in unit mg/L), Temperature (°C), pH (unitless), Biochemical Oxygen Demand (BOD in unit mg/L), Chemical Oxygen Demand (COD in mg/L), Total Suspended Solid (TSS in unit mg/L), Ammoniacal Nitrogen (AN in unit mg/L) and Escherichia-Coli (E-coli in unit Most Probable Number; MPN).

EcoClean Technology as a design and build sub-contractor had proposed an alternative design to the conventional and confirming design and it was accepted by the main contractor.
The alternative design and construction of the plant were carried out by the in-house team from EcoClean Technology Sdn Bhd with input from local consultants for certain detailed engineering processes. It was a challenging task as the plant had to be constructed totally underground and operated via a SCADA system. EcoClean had proposed to the client adding an AI-IoT smart monitoring system as well as a Bio UV disinfection system before the effluent is used as non-potable water for irrigating the vegetation at the ground level as part of the recreational open space.

The completed sullage water treatment plant was tested and commissioned just before the outbreak of Covid 19 in the early part of 2020. The water quality sampling was carried out by an independent team from the Department of Irrigation and Drainage and the testing was by an independent laboratory; whilst EcoClean continued to operate the plant via the SCADA system during the Covid lockdown period.

After 6 months of operation with weekly Lab results done on the water quality of the effluent, these results were averaged out and submitted to the authority regularly. The client which is City Hall of Kuala Lumpur, together with the SO from the Department of Irrigation and Drainage had accepted the water quality index results which were consistent with Class IIA, a standard achieved beyond the targeted result of Class II B. The influent samples taken from the equalising tank remained unchanged at WQI of Class 4 to 5 with blackish colour and bad odour.

The plant operationally started from the primary screening at the intake sump followed by the mixing process in the equalizing tank. A series of submersible pumps were used to draw water from the equalizing tank to feed directly into a CDS-GSS unit. The CDS Technology is quoted in the 'Fifth Edition Wastewater Engineering Treatment and Resource Recovery' by Metcalf & Eddy/AECOM as a Grit Separator for Combined Wastewater and Stormwater. It is the first time it has been used in Malaysia.

The second process started after the CDS-GSS separation involved flocculation whereby the sullage water which had been treated by the CDS-GSS unit with 70% Total Suspended Solids (TSS) removed will go through the flocculation process. Here further reaction will occur whereby the remaining fine particles will form flocs and will be further trapped by the next CDS-FSS unit which has a finer separation screen than the first CDS-GSS unit. The trapped flocs residue will be purged when full at the sump below the screen to a separate Dee Bag Sludge Treatment process unit.

The flow which by now with most of the fine TSS removed, will continue to reach the following detention tank for the biological treatment. The inside of this tank consists of suspended Bio-fibre cords in submerged cages with cultured bacteria. Below these cages is the network of aeration piping with fine bubble diffusers. This is an aerobic process to enable attached growth on the Biofibre chords to form a biofilm colony. Biofilm will consume the nutrients (organic and inorganic) from the sullage water.

With the expectation of biomass formation and shaken off as suspended biomass in the bioreactor tank under the constant supply of air, the fully treated sullage water is pumped through and further purified via the last unit of Hybrid CDS-FSS-IPC Inclined Plate Clarifier and stored in a clear water tank to be overflown out constantly to the adjacent Gombak River.

2. SWTP Tiong Nam Treatment Process

Sullage water encompasses all wastewater generated from all residential, commercial and industrial buildings without fecal contamination. In conjunction with the River of Life (ROL) Phase II Project, EcoClean Technology Sdn Bhd has introduced a unique and efficient sullage water treatment plant using a combination of EcoClean CDS unit (trash and sediment removal), flocculation unit (biochemical treatment) and bio-reactor (biological treatment), and collectively named as the *Advanced Flocculation Bio-Reactor* (AFBR) system. Figures 2 and 3 below show the overview and the isometric view of the sullage water flow treatment process for the Tiong Nam SWTP. Table 2 contains the list of inventory for the whole SWTP.

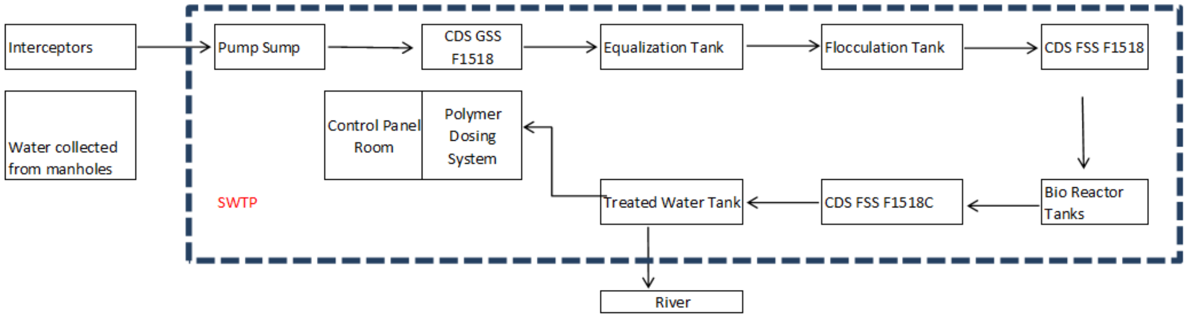

Figure 2: Overall Tiong Nam SWTP Flow Process designed by EcoClean Technology

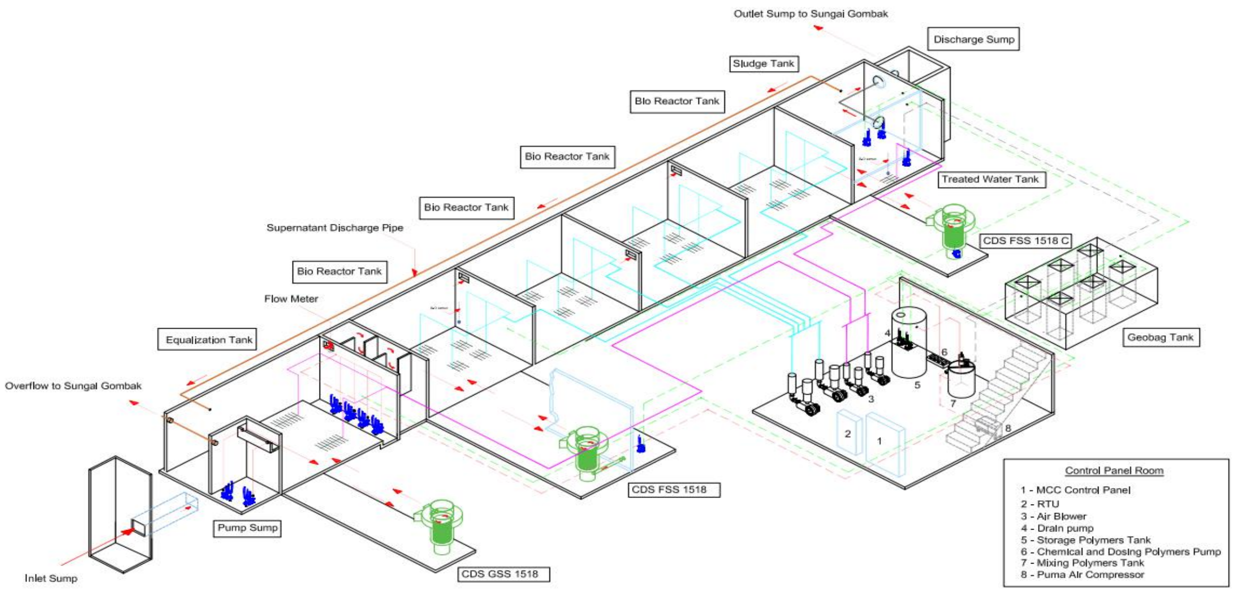

Figure 3: Isometric Overview of Tiong Nam SWTP Flow Processes

Table 2: Inventory List for Tiong Nam SWTP

Compartment	Inventory Lists
Pump Sump	• Transfer Pump (TP1, TP2) • Ultra level Sonic Sensor • Float Switches (L1,L2,L3,L4)
Clarifier 1 Tank	• GSS CDS F1518
Equalization Tank	• Transfer Pump (TP3,TP4,TP5,TP6) • Tube Diffuser (32sets) • Float Switches (L1,L2,L3,L4,L5,L6) • Flow meter • Dissolved Oxygen Sensor
Clarifier 2 Tank	• FSS CDS F1518 • Sludge Pump (SP1)
Bioreactor Tank	• Biofibre (370m3) • Tube Diffuser (128 SETS) • Dissolved Oxygen Sensor (DO2)
Clarifier 3 Tank	• FSS CDS F1518C • Sludge Pump (SP2)
Treated Water Tank	• Treated Water Tank Pump (TWT1) • Dissolved Oxygen Sensor (DO1) • Tube diffuser (8 SETS)
Sludge Holding Tank	• Sludge Pump (SP3, SP4
Geobag Tank	• Deebags (6 SETS)
Control Panel Room	• SCADA system • Fire Alarm System • MCC Panel • Polymer Dosing System • Air Blowers (AB1, AB2, AB3, AB4) • Ventilation System • Drain Pumps (DP1, DP2)

The sullage water treatment process starts from the inlet sump then the water will go to the pump sump via gravity. At the pump sump, the water will be pumped into CDS-GSS (Gross Solid Separation, Model F1518). The purpose of CDS-GSS as shown in Figure 4 is to remove any gross pollutants that were washed into the sullage treatment plant. Besides that, CDS Technology is based on using established hydraulic principles and indirect screening filtration, and it is designed to capture over 99% of waterborne solid pollutants down to less than 1mm in size, and a large proportion of smaller particles (>200 microns), sediments and oil. The unique features of CDS are: i) having full bypass flow capacity, ii) guaranteed non-blocking screen, iii) 'self-cleansing' screen, iv) durable material construction, and v) storage facility for settling pollutants.

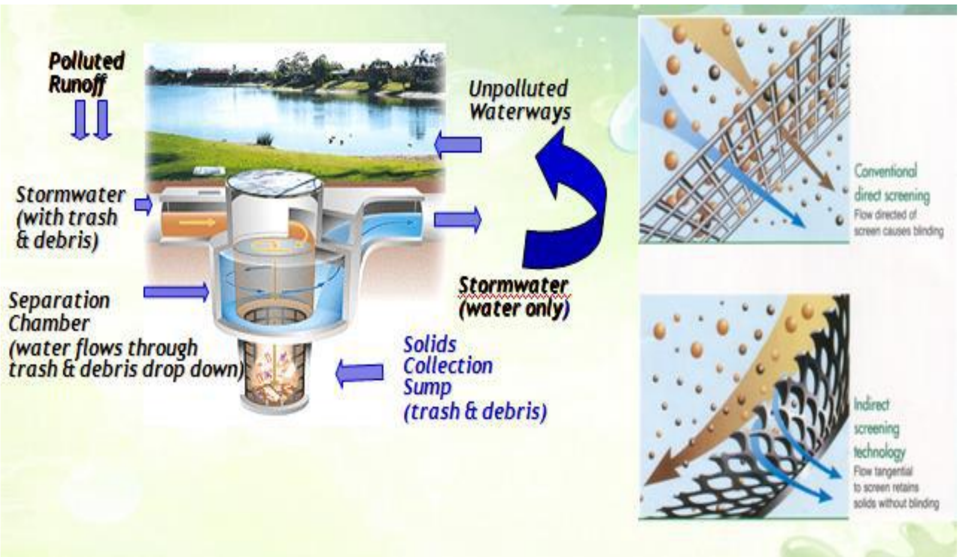

Figure 4: Illustration of CDS Technology and the Indirect Screening

The treated sullage water from CDS-GSS will then be transferred to the equalization tank. This equalization tank serves the purpose of reducing the peak flows (acting as a buffer). Here, the sullage water will be dosed with polymer through an auto-injection system. The pre-screened sullage water will react with polymer to form flocs and it will pass through the flocculation tank and then through the next CDS-FSS for the flocs separation and removal. The vortex of CDS will encourage the flocs to settle down at the bottom of CDS and the clear treated sullage water will then go into the following bioreactor tanks which have cages of suspended string-like biofibre chords to undergo biological treatment (see Figure 5 below).

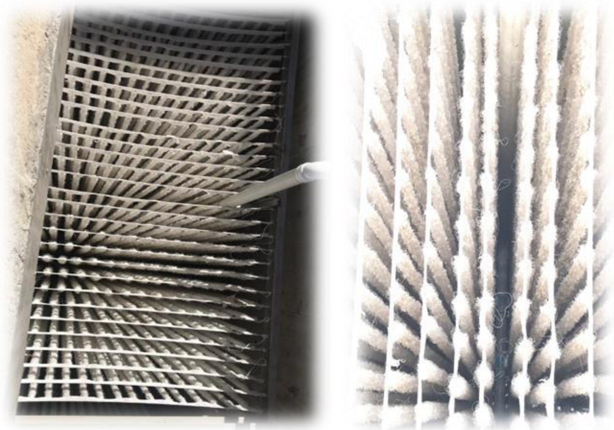

Figure 5: Biofibre Chords in Bioreactor Tanks

The submerged biofibre chords provide large surface areas to allow the micro-organisms to attach and grow. As the influent flows across the surface area, the micro-organisms uptake the substrate such as the ammoniacal nitrogen. The submerged biofibre can allow excessive bio-growth to build up and yet it will not clog. Sufficient air and ideal conditions are needed in order for these microorganisms to survive and consume the wastes. The air is delivered to non-clog fine bubble air diffusers by air blowers. The air diffusers are systematically arranged and installed at the bottom of the bio-media cages to ensure a uniform supply of oxygen throughout the tank. The operation of the air blower is controlled by dissolved oxygen (DO) sensors in the reactor tank to maintain the desired dissolved oxygen level.

The sullage water that has been undergoing biological treatment then will go to the final clarifier process which is at the Hybrid CDS-FSS-IPC Model F1518C. In this unit, all the bio-solids and any fine particles resulting from the biological treatment will settle down here till the bottom collection sump is full before being purged to the Dee Bag sludge management process unit. The final treated water will then be detained in a clear water tank and allowed to overflow to the adjacent Gombak River. In this tank, final aeration is also will be provided via a tube diffuser.

3. Water Sampling and Monitoring

The targeted effluent water quality is Class IIB which is safe for body contact and recreational usage. Table 3 below shows the parameters to be achieved after undergoing the treatment process.

Table 3: Parameters to be achieved after undergoing the treatment process

Parameters	**Treated Water Quality (Class II B)**
Ammoniacal Nitrogen (mg/l)	0.3
Biological Oxygen Demand (mg/l)	3
Chemical Oxygen Demand (mg/l)	25
Dissolved Oxygen (mg/l)	5 – 7
pH	6 – 9
Total Suspended Solid (mg/l)	50
Oil and grease (mg/l)	N. A

The duration required for the data samplings of the influent and effluent for the SWTP is shown in Table 4.

Table 4: Duration for data sampling

Duration
August 2021 till September 2021
September 2021 till October 2021
October 2021 till November 2021

The parameters to be tested for each influent and effluent are Dissolved Oxygen (DO in unit mg/L), Temperature (°C), pH (unit less), Biochemical Oxygen Demand (BOD in unit mg/L), Chemical Oxygen Demand (COD in mg/L), Total Suspended Solid (TSS in unit mg/L), Ammoniacal Nitrogen (AN in unit mg/L) and Escherichia-Coli (E-coli in unit Most Probable Number; MPN).

The sample is stored in a sterile 1500 ml polyethylene bottle before instantly being transferred to the analytical laboratory for water quality parameters according to standard methods. The most essential method to classify river water quality is the WQI index and National Water Quality Standards (NWQS). These are the common regulations for all common water guidelines in Malaysia. The NWQS defined classes I to V, which referred to the classification of rivers or river segments based on the descending order of water quality; with Class I being the best and Class V being the worst.

The WQI is calculated using six parameters WQI: DO, BOD, COD, TSS, AN, and pH with the inclusion of intermediate sub-indices. Calculations are performed on the water quality parameters to find individual sub-indices. The sub-indices are named SIDO, SIBOD, SICOD, SIAN, SISS and SIPH. The best-fit equations used for the assessment of the six sub-indices are shown below.

$$WQI= (0.2 \times SIDO) + (0.19 \times SIBOD) + (0.16 \times SICOD) + (0.15+SIAN) + (0.16 \times SISS) + (0.12 \times SIPH)$$

Table 5: Water Quality Index Classification

Parameter	Index Range		
	Clean	**Slightly Polluted**	**Polluted**
WQI	81-100	60-80	0-59

4. Results and Discussion

Table 6 provides the results of the water quality from the outlet sump of Tiong Nam SWTP.

Table 6: The Results for WQI Parameters

Duration	Results of the 6 Parameters					
	pH	**DO (mg/L)**	**BOD (mg/L)**	**COD (mg/L)**	**TSS (mg/L)**	**AN (mg/L)**
August 2021 till September 2021	7.9	7.7	28.4	48	13	4.37
September 2021 till October 2021	7.9	7.7	0.6	23	2	0.04
October 2021 till November 2021	8.1	7.6	0.6	6	2	0.07

According to the results, from August to September was the first month of full commissioning of the Tiong Nam SWTP. The biological treatment as in the bacteria cultured still has not yet matured. In the first month, the microorganism will attach and grow on the bio-fiber to form bio-film to break down the contaminants. Once all bio-fiber surfaces have formed the bio-film and are fully utilized, it will effectively remove BOD, nitrogen as well as phosphorus by nitrification and denitrification.

In the second month, it proved and showed that the BOD value had drastically reduced by 97% due to biological treatment. The nitrification process was successfully reduced by 99% in the 2nd month. The COD result hah been reduced by 52% whereas total suspended solid TSS has been reduced by 85%. The TSS reading being drastically reduced was due to CDS clarifier functionality. The CDS has previously been proven by performance report from UNITEN University together with the top management team from the Drainage and Irrigation Department which concluded that CDS functions not just as a gross pollutant trap, but at the same time also performs other treatment functions by removing a large amount of BOD, COD and TSS (Lariyah et al.,2014[a]). The summary of the results of the study is that the CDS unit has the highest treatment efficiency as published in the ICUD paper by Lariyah et al., (2014)**.**

Table 7 shows the water quality index (WQI) obtained for each sampling period.

Table 7: The result of WQI for each sampling duration

Duration	Water Quality Index (WQI)
August 2021 to September 2021	56.52
September 2021 to October 2021	90.28
October 2021 to November 2021	92.01

The WQI result on 1st month of operation of Tiong Nam SWTP is 56.52 which falls under the polluted category as shown in Table 5. However, in the following 2nd and 3rd months, the WQI has significantly fallen under the clean category which is 90.28 and 92.01 each. This proves that the CDS units with integrated Tiong Nam SWTP treatment system have been effective and efficient in treating the polluted sullage water quality within a month of its commissioning.

Apparently, the water quality was consistently maintained thereafter till it went into the Covid lockdown whereby no water sampling was further conducted.

Figure 6 shows the photo taken at the site where the water sampling exercise was conducted by an Independent 3rd party and witnessed by the client and their consultants.

Figure 6: Water samples taken at the intake (influent) and after the outlet discharge (effluent)

5. Conclusion

We believe this is one of the first of its kind in the world where a sullage water treatment plant as designed by EcoClean Technology was implemented making use of the CDS technology to treat dirty and smelly sullage water of river water quality index of class IV & V to reach Class IIA. The project was based on a design and build basis with the condition that it has to be cheaper than conventional plants using the standard wastewater direct screening technology. This cost-saving requirement was complied with even though Ecoclean provided extra processes of polymer dosing, flocculation unit, and sludge management which were absent in the normal conventional plant as stipulated in the confirming tender.

A water quality computer simulation model was applied to determine and confirm the expectation that the improvised sullage water treatment system using the EcoClean Technology could improve the worst case of the river water quality index of class V to reach a required level of class IIB.

An innovative idea of a Hybrid- CDS-FSS-IPC with inclined plate clarifier (IPC) must have added further enhancement to the water quality and could be a contributing factor to the system meeting and even exceeding the target river water quality index of class IIB, more likely to be at Class IIA instead.

Since the water quality of class II is considered rcreatede except for some traces of E-Coli where further treatment like ozonation or UV disinfectant could be applied, we would consider that we have closed the stormwater loop and created a circular economy by making the effluents reusable for non-potable uses. Hence, the way forward for the nation is to seriously look at how sullage water treatment plants can be re-engineered to become a source of resource recovery to reclaim wastewater for non-potable usage.

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Title

"Prospects of Low Head Dam schemes implementation along Ayeyarwady River"

by

Engr, Kyi Thar (Councilor, Myanmar Engineering Council, Retired Managing Director,
Ministry of Electric Power No.1)

Abstract

Ayeyarwady River which is the principle river of Myanmar, Running 1350 miles in length, flow wholly within the territory. Total drainage area of Ayeyawady is 158,7000 square miles.

Due to monsoonal rain which occurred Mid-May to Mid-October, Ayeyarwady and it's tributaries varies greatly through the year and in summer melting of snow and glaciers in northen Myanmar added to the volume.

Totally 32 High-Head Hydropower Projects are planning along Ayevarwady sub-basin with 24,605 MW installed capacity.

Also Low Head Dam schemes along Ayeyarwady of 16 places with totally 2,880 MW, are under investigation.

Sedimentation will be biggest risk to implementation, since Ayeyarwady is the 5th largest sediment load of river on earth.

Keywords: Low Head Dam, Hydropower, sediment load, bulb type turbine.

Introduction:

Myanmar is a country of 678,500 square kilometers and population of about 55 millions. Agricultural base economy and normal GDP of 2021 was 78.02 million US Dollar.

Hydropower Potential of greater than 10MW was 46,099.3 MW and less than 10 MW was 231.25 MW. Totally 46,330.55 MW, Myanmar is rich in hydropower potential.

TABLE I. HYDROPOWER POTENTIAL
(STATE AND REGION-WISE)

Sr. No	State / Region	Numbers of Potentials		Capacity (MW)
		>10MW ≤50 MW	>50 MW	
1	Kachin State	5	14	18,744.5
2	Kayah State	2	3	954.0
3	Kayin State	1	8	7,064.0
4	Sagaing Region	2	4	2,830.0
5	Taninthayi Region	5	1	711.0
6	Bago Region	4	4	538.0
7	Magway Region	2	3	359.0
8	Mandalay Region	3	6	1,555.0
9	Mon State	1	1	290.0
10	Rakhine State	3	3	764.5
11	Shan States			
	East	1	3	719.8
	South	3	5	7,569.5
	North	-	5	4,000.0
12	>10 MW	32	60	46,099.30
13	<10MW	210		231.25
	Total	302		46,330.55

The Ayeyarwady River that flow from north to south through Myanmar is country's largest river and most important commercial waterway. It is about 1350 miles long, flow wholly within the territory of Myanmar, total drainage area is about 158,7000 sq-miles. It begin where the N' Mai and Mali river join together the confluence is the start of Ayeyarwady.

Fig - 1

Fig - 2

The Ayeyarwady have five major tributaries, these rivers goining with Ayeyarwady and flows from north to south are as follows.

(1) Taping Rivers
(2) Shweli Rivers
(3) Myitnge Rivers
(4) Mu Rivers
(5) Chindwin Rivers

The Ayeyarwady is identify by five basins, these are as follows.

(1) Ayeyarwady Headwater.

From its source in mountains bordering PR China to the confluence of M Mai and Mali at Myitsone in Myikyina district. It's drainage area is 47,557 km2 (11.5% of the total Ayeyarwady basin drainage area.)

Fig - 3

(2) Middle Ayeyarwady from Myitsone to the confluence of the Chindwin River. It's drainage area is 132,195 km2 (the remaining 11% is in PRC). The middle Ayeyarwady is including the area is PRC represents 32% of the total Ayeyarwady basin drainage area.

(3) Chindwin – a major tributary of Ayeyarwady River. It is in Myanmar consider as a Main river basin, but in the context of this analysis, we have taken it to be a tributary feeding it's development environmental impacts into the Ayeyarwady. Its drainage area is 114,687 km2 (28% of the total ayeyarwady basin drainage area.)

Fig - 4

Large areas of the Chindwin Basin's forests are being lost to gold mining. Photo: Wichai Juntavaro / SEI

Fig - 5

(4) Lower Ayeyarwady – from Chindwin River confluence to the delta at a small village called Ngapiseik.

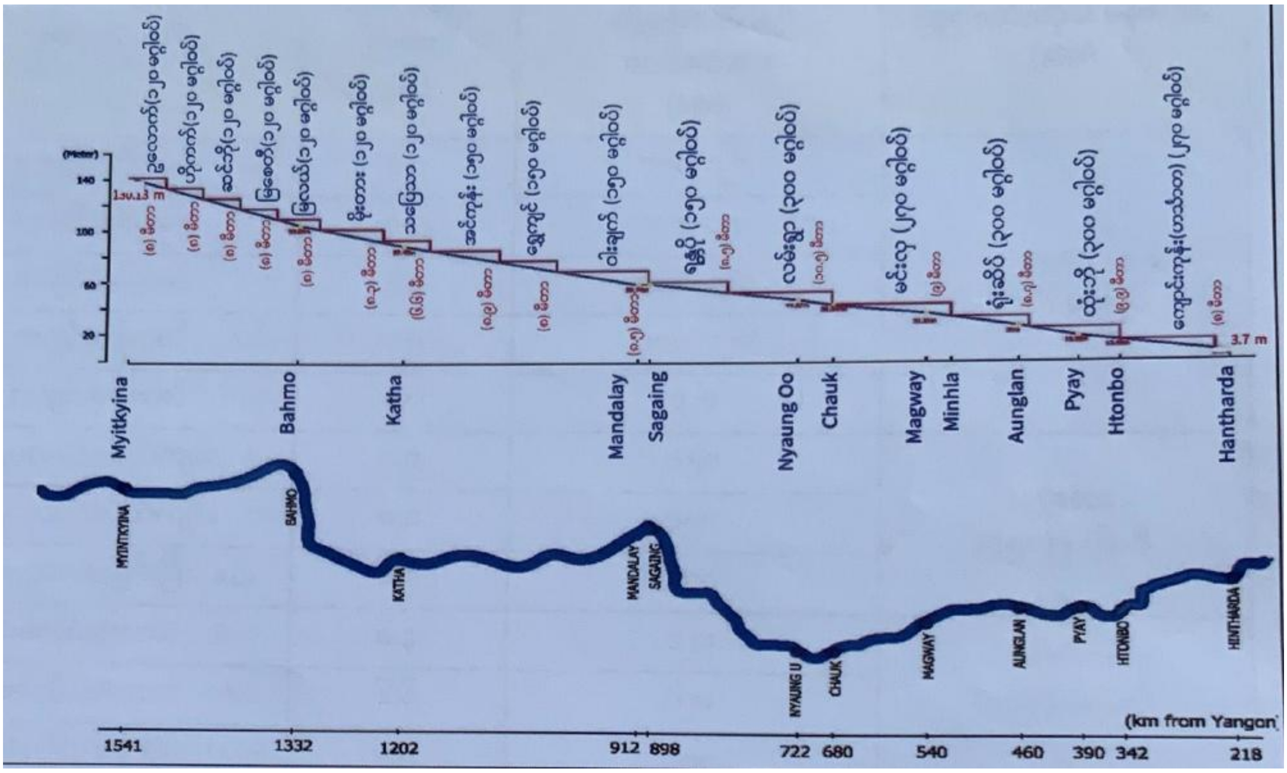


Fig - 6

(5) Delta – The delta start about 93km upstream of Hinthada, the tidal influence 9.42 and to the tour of Myan Aung. The Delta cover an area of around 31,000km2 with coastal front of 260km. The Ayeyarwady River is the only large river left in Asia, where it is possible to develop and implement a well thought out integrated plan for the management of both the surface and underground resources of the basin. It is a unique opportunity for Myanmar to learn form the mistakes of other and to develop in a suitable way.

The implementation of a program of low head dams (LHD) without a better understanding of the and consequences could the overall benefit available from the water related developments in this basin.

It is likely that a dramatic improvement is navigation of the river can the achieved by building and coordinating hydropower development to regulate water from wetter months to the dryer months. This is a natural outcome of the construction of storage backed hydropower in the upper needs of the basin. This together with strategic investments in the river channel improvement will deliver a munch needed increase in navigation at a fraction of the cost of LHD's and can be achieved much more quickly.

The Ayeyarwady carries the 5th largest sediment load of any river on earth, 261 million ton of sediment annually. It is the 3rd larges of any-river that still reaches the sea and maintains an active delta. By sedimentation effect delta area expand 200ft every year and 3.79 miles every 100years. From the preliminary evidence sediment load are increasing and management of sediment will be deposit within the wear pools. When the next monsoon event occurs this sediment will impact on flow and result in further bank erosion and in some circumstances results in river flooding and or the river changing cowise.

A series of LHD's will have a dramatic impact on the amount and distribution of sediment to the delta. It is currently impossible to predict the impact this will have, but given the Mekhang delta experience it is likely to be very significant.

Services of Low Head Dams implementation along Ayeyarwady River, was planned.

At Ayeyarwady Head water region these are planned 13 hydropower projects totally 20,495 MW installed capacity. These projects are dam height 42 to 223 meter and storage volume 3,233,393 (hm3).

Middle Ayeyarwady region have 11 hydropower projects totally 2,146MW installed capacity. The dam heights are 27 to 160 meter and storage volume is greater than 1,240 (hm3).

Chindwin basin have 6 projects totally 1,807MW installed capacity and dam height are roughly 242meter and storage volume is 22,565 (hm3).

Lower Ayevarwady have 2 projects totally 168MW installed capacity and dam height not yet decided and storage capacity many greater than 721(hm3).

Totally Ayeyarwady basin have 32 hydropower projects totally 24,605MW installed, not included low head dams scheme which we are now planning.

After standing geography, topology, coil conditions we have found that 16 low head dams may be possible to implement along Ayeyarwady river, expected total installed 2880MW.

Table – (2)
"Low Head Dam Scheme Potential for Hydropower Along Ayeyarwady River"

Sr.	Division Township	Location	River width (meter)	Above Mean seal Level (meter)	Water Discharge per second	Dam Height (meter)	Backward water Length (km)	Estimated Hydropower Potential (MW)	Remarks
1	Kachin / Waimaw	Aulauk	770	139	1422	8.0	46	120	
2	Kachin / Waimaw	Hukat	1110	131	1290	8.0	46	120	
3	Kachin / Bhamo	Simbo	630	123	1378	8.0	46	120	First defile of Ayeyarwady
4	Kachin / Bhamo	Myagedi	760	115	14523	8.0	46	120	Second Defile of Ayeyarwady
5	Kachin / Bhamo	Myale	1000	107.8	10738	8.0	46	120	Second Defile of Ayeyarwady
6	Sagaing / Katha	Motar	720	99.8	25908	8.3	79	120	
7	Sagaing / Katha	Thapyetha	1750	91.5	12688	6.6	58	120	
8	Mandalay / Thabeikkyin	Inngone	950	84.9	17234	8.9	86	150	Third Defile of Ayeyarwady
9	Mandalay / Thabeikkyin	Shwekyin	700	76.0	14308	8.0	71	150	Third Defile of Ayeyarwady
10	Sagaing / Sagaing	Waschit	1340	68.0	16300	8.5	113	150	
11	Mandalay / Myingyan	Yandapone	760	59.5	19120	8.5	94	150	
12	Magwe / Chauk	Lanywar	1050	57.0	26510	10.5	124	300	
13	Magwe / Minhla	Minhla	1170	40.5	22883	9.0	142	270	
14	Magwe / Aunglan	Yongseik	1310	31.5	28724	8.7	92	300	
15	Bago / Padaung	Htonebo	700	22.8	27333	9.9	100	300	
16	Ayeyarwaddy / Hinthada	Kyaung Gone	1060	12.9	10795	8.0	114	270	
								2880	

The LHD's location mentioned at table (1) Shows that 11 dam sites were located at Middle Ayeyarwady region and 5 dams sites were located lower Ayeyarwady region and 5 dams sites were located lower Ayeyarwady.

Fig – 7

The river width which are planned to implement 16 LHD's are 630 meters to 1750 meter and dam height are roughly 8 meter to 10 meter height.

There are Three gorges at middle Ayeyarwady which we called Ayeyarwady river Defile, between Myitkyina to Mandalay.

About 65 kilometers (40 miles) downstream from Myintkyina is the first defile, length 36.5 miles.

Below Bhamo the river makes sharp westward swing, leaving Bhamo alluvial basin to cut through the limestone nocks of the second defile. This defile is about go meters (300ft) wide and narrowest and is flanket by vestical cliffs about 60 to go meters (200-300 ft) high. This Second defile or narrow gorge of the Ayeyarwady is full with lovely scinery and much tourist attraction. Second defile length is 14 miles long.

Fig – 8

Fig - 9

Fig – 10

Fig - 11

Fig - 12

About 100 kilometres (62 miles) north of Mandalay, at thabeitkyin, The river entered third defile length 29 miles between Katha and Mandalay the course of river is remarkably Straight, flowing almost the south, except near Kabwet, where a sheet of lava has coursed river to bend sharply westward.

After rough reconnaissance study shows that from Myitkyina to Hantharda, the river length 1323 kilometer and river water level difference between them is 126.43 meter, at figure (9), Shows the location and difference of water level of each site.

Fig – 13


Beauty of Myanmar: Second defile or narrow gorge of the Irrawaddy River (Julie Bawk)
juliebawk (53) in #travel • 6 years ago

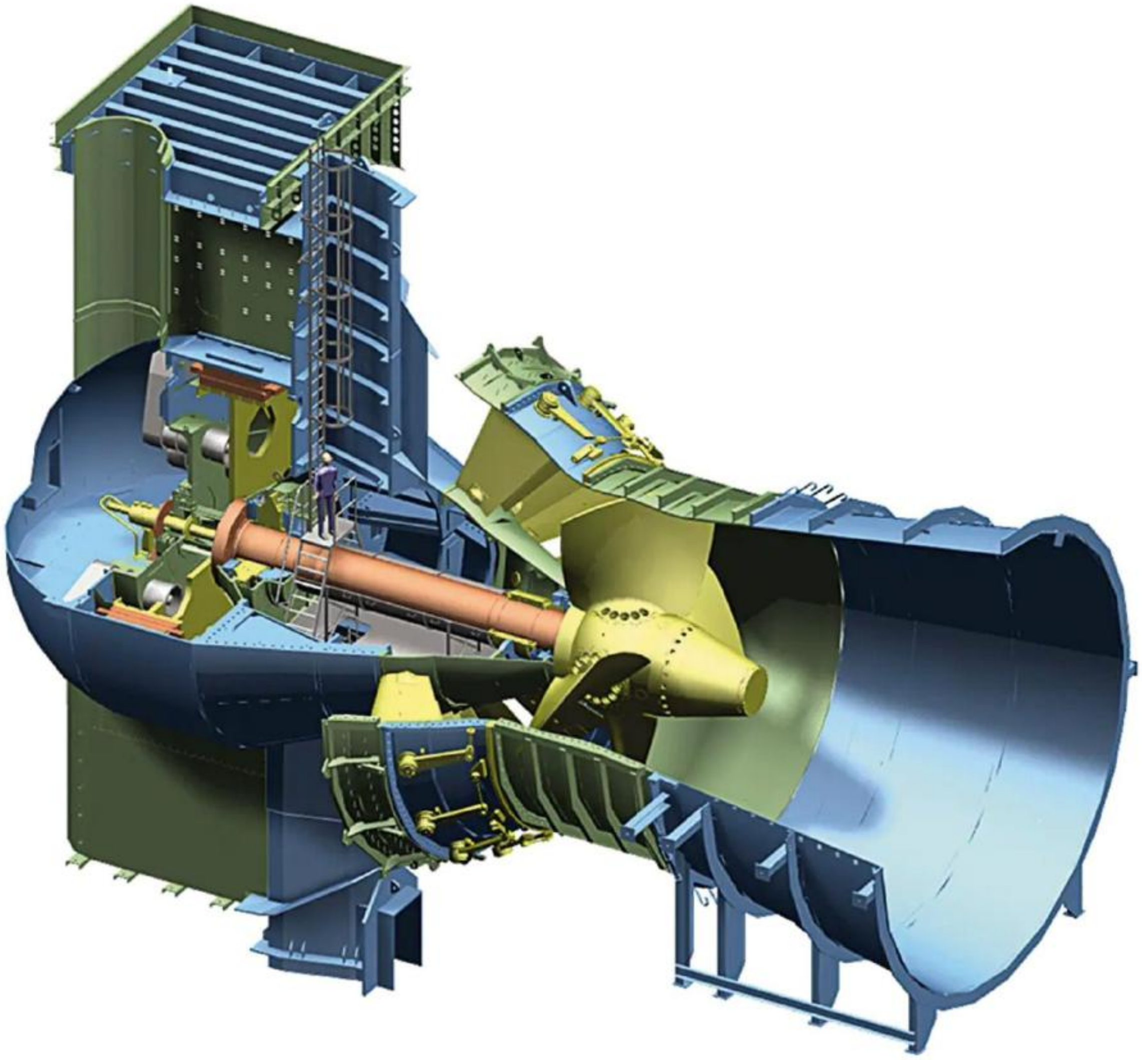
Fig - 14

Bulb Turbines Technology - Fit for the Future

When Austrian professor Viktor Kaplan (1876 –1934) filed his essential patents for the eponymous turbine in 1912 and 1913, he opened the way for a new technology able to use low hydrostatic heads for power generation in an economically feasible way - especially at run-of-river plants.

Bulb turbine runner during installation process at HPP Iffezheim, Germany

Fig - 15



Schematic 3D-drawing of Bulb turbine for HPP Iffezheim, Germany

Fig - 16

Discussion and Conclusion;

11 LHD sites located at middle Ayeyarwady region, between Myintkyina and Mandalay, are good location and this less environmental impact. Chindwin a major tributary of lower Ayeyarwady was Likely worst environmental damage due to gold mine and other activities.

5 LHD's dam site below Chindwin Ayeyarwady conference were worse sediment content, Ayeyarwady river width became larger and larger more and more sediment occurred. Since it is go down toward Yangon, economic city of Myanmar, Navigability is more important than Middle Ayeyarwady. Navigability If we implement in this lower Ayeyarwady, flooding to populated and industrial area, agricultural area and impact to cultural heritage impact may be possible.

We also have to investigate Geotechnical Conditions and natural hazards.

Bulb type turbine is most suited type of all 16 LHD's with largest swigce capacity up to 76 MW is have to consider.

Also for economical feasibility we have to consider project cost of each project and cost benefit ratio.

This low head dams sites have done just reconnaissance study only we have to make more detail investigation and finally choose best two to three low head dam sites and planed for implementation.

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BUILDING BLUE ECONOMY CLUSTERS TOWARDS SUSTAINABLE DEVELOPMENT IN SOUTHEAST ASIA: ECOSYSTEM/S APPROACH WITH SECTORAL SYNERGIES, PATHWAYS, AND CHALLENGES

Nerissa B. Gatdula[1,5], Michael L.S. Abundo[1,2,3,4,5], Mario Jr. Buhali[1,2], and Lloyd Bautista[1,4,5]

[1]OceanPixel Philippines Inc., [2]Nanyang Technological University-Singapore, [3]Center for Research in Energy Systems and Technologies (CREST), University of San Carlos, [4]Ateneo School of Government, [5]OceanPixel Pte Ltd

neri@oceanpixel.org

Abstract

Building blue economy clusters in various scales in many regions in Southeast Asia (SEA) has the potential to generate significant economic and social benefits. However, there are also challenges that need to be addressed to ensure the sustainability of the blue economy. Rather than look at multiple sectors (energy, food (aquaculture), water, transport, environment, tourism) individually, in terms of projects, programs, and portfolios, this paper discusses an ecosystem/s approach where sectoral synergies may be a more progressive manner by which sustainable and inclusive growth pathways can be achieved. It also highlights the role of technology and innovation, public-private partnerships, and capacity building in promoting the blue economy. The paper provides examples and case studies of the blue economy that key players and stakeholders can utilize and learn from, grouped as: (1) marine renewable energy, aquaculture (seaweed farming), electrification of boats, and desalination; (2) digitalization, eco-tourism, blue carbon, electric boats, and clean energy; and (3) green hydrogen, floating fish farms, hybrid-electric boats, and cold storage. The paper also discusses the sustainability efforts of the Brunei Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area (BIMP-EAGA). With a wealth of marine resources, a growing population, and a strong commitment to sustainable development, the right policies, strategies, and investments, SEA has tremendous potential to be a global hub for multiple sustainable blue economy clusters.

***Keywords**: blue economy, ecosystem approach, Southeast Asia, sustainability, marine resources*

1. Introduction

The concept of blue economy is a recent field of study that revolves around economic activities that are reliant on the sea. This concept is often linked with various other sectors such as tourism, maritime transportation, energy production, and fishing (Martínez-Vázquez et al., 2021). According to World Bank (2017), the blue economy is characterized as the sustainable utilization of oceanic resources for economic development, enhancement of livelihoods and job creation, and maintaining the health of ocean ecosystems.

This broad concept of the blue economy includes a variety of sectors. It covers renewable energy production and offshore electrification, fisheries and aquaculture, maritime transportation, and tourism. Additionally, it addresses issues related to climate change, waste management, water supply, and sanitation. The blue economy aims to balance economic growth with ecological sustainability, ensuring a prosperous future for all.

Blue economy promotes economic growth, social inclusion, and improved livelihoods while ensuring the environmental sustainability of oceans and seas (UNDP, 2019). It has gained significant interest in recent years as it covers a range of economic sectors and related policies that collectively ensure the sustainable utilization of marine resources. Ecosystem approach to the blue economy, where sectoral synergies across multiple sectors such as energy, food (aquaculture), water, transport, environment, and tourism are considered for achieving sustainable and inclusive growth pathways (CBD, 2007; Arico, n.d.).

In Southeast Asia (SEA), building blue economy clusters has the potential to generate significant economic and social benefits. However, there are also challenges that need to be addressed to ensure its sustainability. This paper provides examples and case studies of the blue economy that key players and stakeholders can utilize and learn from, grouped as: (1) marine renewable energy, aquaculture (seaweed farming), electrification of boats, and desalination; (2) digitalization, eco-tourism, blue carbon, electric boats, and clean energy; and (3) green hydrogen, floating fish farms, hybrid-electric boats, and cold storage.

This paper also reviewed the sustainability efforts of the Brunei Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area (BIMP-EAGA). The key areas of discussion included the pollution control, sustainable coastal marine development, ocean and climate finance, and ecosystem and natural resource management.

2. Review of Related Literature

The blue economy encompasses many activities such as renewable energy, tourism, climate changes, fisheries, waste management, and maritime transportation. These segments have a high value on the economic side. The worldwide ocean economy is valued at around US 1.5 trillion per year (Fernando, 2022). In SEA, the blue economy holds potential for economic growth, employment, innovation, and promotes economic growth and improvement of livelihoods (United Nations, 2022).

In SEA countries like Indonesia, the blue economy has tremendous potential from tourism, marine products such as fisheries, mining to coral reef conservation for environmental sustainability (Fernando, 2022). The ASEAN Leaders' Declaration on the blue economy recognizes that oceans and seas are key drivers of economic growth and innovation (Brunei Darussalam, 2021).

The Philippines' maritime territories, including its Exclusive Economic Zone (EEZ), span an impressive 2.2 million square kilometers, accounting for 88% of the country's natural territory. A significant 78% of the provinces are located along the coast, home to approximately 62% of the population (PSA, 2016). Mindanao, the archipelago's second-largest island group, boasts a land area of 104,630 square kilometers and is inhabited by over 27 million people as per the 2021 census. In recent years, Mindanao has emerged as the Philippines' second most robust economy after Luzon, registering the highest growth rate of 6.1% between 2020 and 2021. The island's economy, valued at $53.6 billion, contributed a substantial 17.2% to the national GDP (PSA, 2022). Mindanao, see Figure 1, is rich in marine resources, providing livelihoods for millions through fisheries and aquaculture. It is bordered by four seas: the Bohol Sea to the north, the Philippine Sea to the east, the Sulu Sea to the west, and the Celebes Sea to the south. These waters have historically played a significant role in the country's economy, serving as sources of food, transportation and commercial trade routes, tourism attractions, and more. However, despite their potential, these maritime resources remain underutilized.

The ecosystem approach has been advocated by several international bodies. The Convention on Biological Diversity outlines 12 principles for an ecosystem approach: (1) societal choices and ecosystem management; (2) decentralization of management; (3) consideration of effects on other ecosystems; (4) economic context of ecosystem management; (5) conservation of ecosystem structure and functioning; (6) management within ecosystem limits; (7) appropriate spatial and temporal scale for ecosystem approach; (8) establishment of long-term objectives; (9) acceptance of change; (10) strive a balance between the conservation and utilization of biological diversity; (11) all relevant information (e.g. scientific data, indigenous and local knowledge, innovations, and practices) considered in the ecosystems approach; and (12) engagement of all relevant sectors of society and scientific disciplines. Similarly, the United Nations Educational, Scientific and Cultural Organization emphasizes putting humans and their uses of space and resources at the heart of the decision-making process (CBD, 2007).

CBD's 12 principles provide a comprehensive framework for the sustainable management of ecosystem. The management of land, water, and living resources is largely influenced by societal choices. These choices are often dictated by the different ways in which various sectors of society perceive ecosystems, based on their unique economic, cultural, and societal needs. It is important to recognize the rights and interests of indigenous peoples and other local communities living on the land. Both cultural and biological diversity are integral to the ecosystem approach and should be considered in management. Ecosystems should be managed for their inherent values and for the tangible or intangible benefits they provide to humans, in a manner that is fair and equitable. Management should be decentralized to the lowest appropriate level. This approach often leads to increased efficiency, effectiveness, and equity. All stakeholders should be involved in management, balancing local interests with broader public interest. The closer the management is to the ecosystem, the greater the responsibility, ownership, accountability, participation, and use of local knowledge. Ecosystem managers should consider the actual or potential effects of their activities on adjacent and other ecosystems. Management interventions often have unforeseen or unpredictable effects on other ecosystems; therefore, potential impacts need careful consideration and analysis. To recognize potential benefits from ecosystem's management, it is usually necessary to comprehend and manage the ecosystem within an economic framework. This involves mitigating market distortions that adversely affect biodiversity, aligning incentives to encourage biodiversity conservation and sustainable use, and incorporating costs and benefits associated with the ecosystem as much as possible. The conservation of ecosystem structure and functioning should be a priority target of the ecosystem approach to maintain ecosystem services. Ecosystems must be managed within the limits of their functioning. Attention should be given to environmental conditions that limit natural productivity, ecosystem structure, functioning, and diversity. Finally, the ecosystem approach should be undertaken at the appropriate spatial and temporal scales (CBD, 2007).

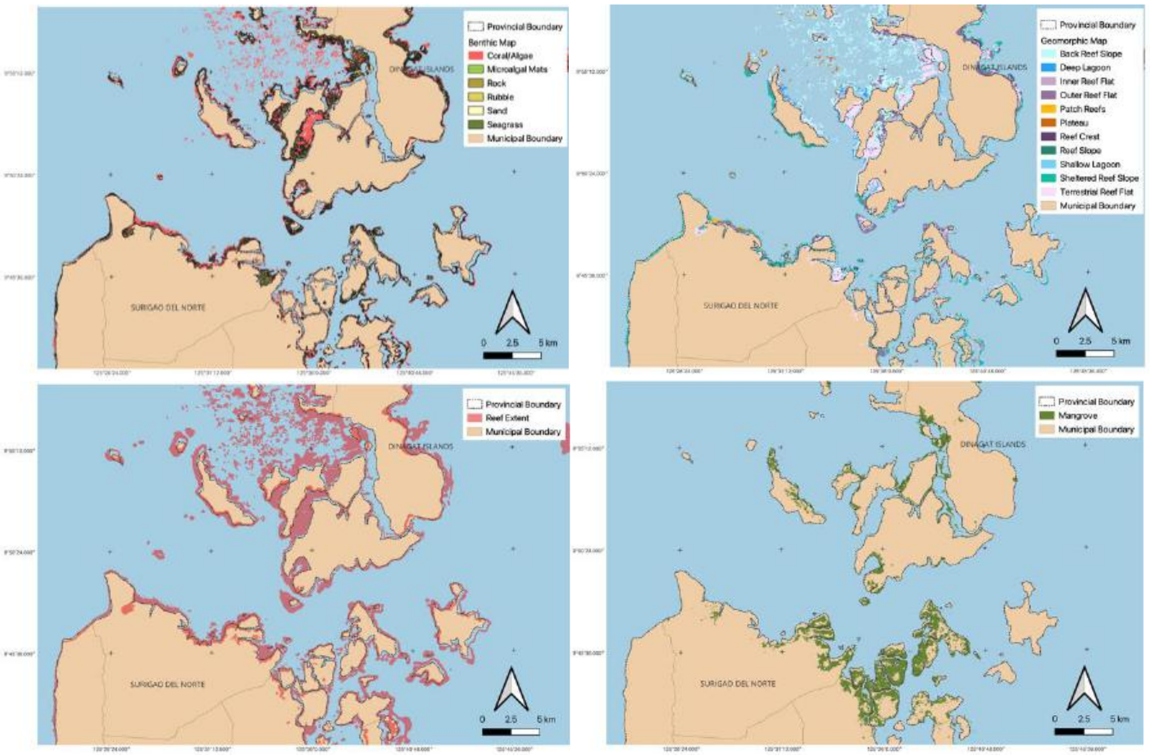

Figure 1. Maps of geomorphic features, benthic habitats, mangrove forests, and coral reefs in selected areas of Mindanao, specifically Dinagat and Surigao del Norte

Sources of data:

Benthic, reef extent, geomorphic layers - Allen Coral Atlas. (2020). Imagery, maps and monitoring of the world's tropical coral reefs. doi.org/10.5281/zenodo.3833242

Mangrove layers - Baloloy, A. B., Blanco, A. C., Ana, R. R. C. S., & Nadaoka, K. (2020). Development and application of a new mangrove vegetation index (MVI) for rapid and accurate mangrove mapping. *Isprs Journal of Photogrammetry and Remote Sensing, 166*, 95–117. https://doi.org/10.1016/j.isprsjprs.2020.06.001

The blue economy supports the sustainable growth of the maritime and marine sectors as the oceans and seas are engines of the global economy and have great potential for growth and innovation. This paper provides examples and case studies of the blue economy that key players and stakeholders can utilize and learn from (Martínez-Vázquez et al., 2021).

Marine Renewable Energy, Aquaculture, Electrification of Boats, and Desalination

Marine energy, also referred to as marine renewable energy or marine hydrokinetic energy, is a form of renewable power derived from the natural movement of water. This includes the motion of waves, tides, and river and ocean currents (EERE, n.d.). The European Science Foundation (2010) characterizes marine renewable energy as the production of renewable energy using marine resources or spaces. This includes offshore wind energy, floating solar power, and marine biomass obtained from micro- and macro-algae.

A specific category within marine renewable energy is ocean renewable energy. This involves harnessing power from ocean currents, tidal currents (also known as in-stream energy), tidal ranges, and wave energy. Additionally, it includes energy produced from salinity or osmotic gradients and thermal gradients.

Seaweed farming is seen as the pinnacle of sustainable aquaculture, requiring no feed other than sunlight and marine nutrients (Waters, 2021). The electrification of boats is gaining momentum with various businesses and manufacturers recognizing the importance of electric boating. They are contributing to this movement by constructing boats that are entirely electric or hybrid models that combine gas and electric power systems (Kong, 2019). Desalination is the process of removing salts and other minerals from water, making it suitable for human consumption, irrigation, or industrial uses (EERE, n.d.).

Digitalization, Eco-tourism, Blue Carbon, Electric Boats, and Clean Energy

Digitalization in the blue economy has been gaining traction with many sectors incorporating digital tools to boost their operations (Cap Digital, 2021). Eco-tourism in the blue economy has been recognized as a significant driver for sustainable growth (Brumbaugh & Patil, 2019). Blue carbon refers to carbon dioxide that is absorbed from the atmosphere and stored in the ocean (NOAA, 2023). Electric boats are becoming increasingly popular as they offer a clean and quiet alternative to traditional boats. Clean energy sources are being explored in various sectors of the blue economy to reduce carbon emissions (XShore, 2023).

Review of Sustainability Efforts of BIMP-EAGA

Thailand: Thailand has been actively implementing measures to control pollution and promote sustainable coastal marine development. The National Solid Waste Management Master Plan (2016-2020) and the EU SWITCH Asia Programme are among the initiatives aimed at protecting ocean health and supporting blue economy development (PEMSEA, 2019). The country's Pollution Management Plan (2017-2021) and Wastewater Management Law are also noteworthy efforts in this direction (Gandimathi et al., n.d.; PEMSEA, 2019).

In terms of sustainable coastal marine development, Thailand has adopted the Driver-Pressure-State-Impact-Response Framework (DPSIR) framework for enhancing the resilience of corals, mangroves, and seagrasses (PEMSEA, 2019). The UNESCO GeoPark and Thai Riviera Project are part of the Second National Tourism Development Plan (2017 - 2021) (Gandimathi et al., n.d.). The Port Authority of Thailand (PAT) is committed to building Green Ports, and the proposed Songkhla energy hub includes investments in renewable energy (Gandimathi et al., n.d.; PEMSEA, 2019).

Efforts towards ecosystem and natural resource management include reef restoration, seagrass cultivation, and the implementation of the 2015 Marine Fisheries Management Plan. The Fisheries Act (2015), Royal Ordinance for Fisheries (2015), and Fisheries Management Plan all include provisions for habitat restoration. Sustainable aquaculture is also being promoted as part of blue economy initiatives (Gandimathi et al., n.d.; PEMSEA, 2019).

While efforts to secure ocean and climate finance are ongoing, coastal, and marine ecosystem conservation and disaster resilience have been listed as priorities of APEC Ocean-Related Ministers (Xiamen Declaration). The National Oceanic and Atmospheric Administration (NOAA) Coral Reef Conservation Programme (CRCP) is also working towards resilience-based marine resource management in Malaysia (GEF, 2023; Gandimathi et al., n.d.; PEMSEA, 2019).

Indonesia: Indonesia is actively pursuing initiatives in pollution control, sustainable coastal marine development, ocean and climate finance, and ecosystem and natural resource management. In terms of pollution control, the focus is on marine debris and single-use plastics, with the Government of Indonesia (GoI) launching a National Action Plan on Marine Debris in June 2017. This area has been identified as a priority and a challenge (World Bank, 2021; BAPPENAS & OECD, 2021).

Sustainable coastal marine development is being supported by the Indonesia Oceans Multi-Donor Trust Fund, established in 2017 with backing from Norway and Denmark. The fund aids in implementing ocean policy, reducing marine debris, and strengthening coastal resilience (World Bank, 2021). The government is also working on improving marine and coastal management systems, with Integrated Tourism Master Plans (ITMPs) proposed as a policy recommendation (Alim, 2022; BAPPENAS & OECD, 2021). Ocean energy is being explored as an emerging sector, although feed-in tariffs are not yet applicable. This area is listed among the proposed priorities for developing a blue economy (World Bank, 2021; BAPPENAS & OECD, 2021).

In the realm of ocean and climate finance, integrated policy recommendations have been proposed for a blue economy. Financing is considered a long-term priority, with targets and indicators established by the United Nations (World Bank, 2021; ERIA, 2023; BAPPENAS & OECD, 2021). Ecosystem and natural resource management initiatives include the restoration of blue resources such as mangroves, which is listed among the government's strategies. Fisheries Management Areas (*Wilayah Pengelolaan Perikanan* (WPP)) have been established, with fishing limits set as part of the government's strategies. Compliance with spatial plans and aquaculture are also included in policy recommendations (World Bank, 2021; BAPPENAS & OECD, 2021; Alim, 2022).

Malaysia: Malaysia has embarked on a journey towards environmental sustainability, with a specific focus on pollution control and sustainable coastal marine development. The country has outlined a roadmap to eliminate single-use plastics by 2030 (Yashiro, 2021; Phang et al., 2023), and has proposed recommendations for a marine litter policy (Ridzuan, 2022). The implementation of a circular economy is being considered as a solution to tackle plastic pollution (Yashiro, 2021; Phang et al., 2023).

In terms of sustainable coastal marine development, Malaysia has drawn inspiration from the Maldives' reef resilience case and proposed the establishment of the National Ocean Policy and the National Institute of Oceanography for effective coastal management. The country is also actively promoting green ports and shipping, and marine renewable energy is being considered as a potential focus area (Yashiro, 2021; Phang et al., 2023; Ridzuan, 2022).

The concept of blue bond markets has been introduced as an approach to blue financing, emphasizing the importance of rich biodiversity and habitat integrity for coastal resilience (Yashiro, 2021; Phang et al., 2023). Ecosystem management and habitat protection are listed among the recommendations for the National Policy, with the Fisheries Act of 1985 playing a crucial role in natural resource management. These initiatives highlight Malaysia's commitment to environmental sustainability and natural resource management (Phang et al., 2023; Kaur, 2020).

Brunei: Brunei Darussalam is actively implementing strategies to address environmental concerns and promote sustainable development. The National Climate Change Policy (BNCCP) includes waste management and climate resilience as key strategies. The country has also adopted the ASEAN Framework on Circular Economy, promoting circular material flows and green growth initiatives as part of its sustainable environment aspiration (PMO, 2021; MOFE, 2021).

Efforts to reduce pollution include the Plastic Bottle Free Initiative and the Green Protocol, coordinated by the Department of Environment, Parks, and Recreation (JASTRe) and the National Council on Climate Change. In terms of sustainable coastal marine development, industries are encouraged to shift to green/eco-friendly activities. Renewable energy is also being promoted as part of the country's green growth initiatives. The government is exploring blended financing to mobilize resources. However, specific activities related to ocean and climate finance are still being identified (PMO, 2021; MOFE, 2021).

Ecosystem and natural resource management are integral parts of Brunei's environmental policy. The government has expressed commitment to the growth of the fisheries sector and has signed a protocol on inspection, quarantine, and veterinary sanitary requirements for farmed aquatic products exported to China. The aspiration for a sustainable environment places significant emphasis on the preservation of marine ecosystem and responsible use of natural resources (PMO, 2021; MOFE, 2021).

Philippines: The Philippines has been actively implementing measures to control pollution and promote sustainable coastal marine development. The Ecological Solid Waste Management Act of 2000 and the Philippine Clean Water Act of 2004 are aimed at preventing solid waste from entering aquatic environments and preserving the quality of marine and freshwater bodies, respectively (Mapa, 2022; Azanza et al., 2022; Azanza et al., 2017; Zafra, 2021; DENR & PEMSEA, 2019). The country is also exploring the concept of a circular economy as part of its blue economy initiatives, which is agreed upon by the Secretary of the Department of Environment and Natural Resources (DENR) (DENR & PEMSEA, 2019).

In terms of sustainable coastal marine development, the National Climate Change Action Plan (NCCAP) 2011-2018 aims to increase the resilience of vulnerable sectors and natural ecosystems. The Coral Triangle Initiative promotes sustainable marine and coastal tourism, and there are policies supporting green ports. The Renewable Energy Act of 2008 and the National Renewable Energy Program 2011-2030 aim to develop the first ocean energy facility (DENR & PEMSEA, 2019).

For ocean and climate finance, the Department of Budget and Management (DBM) has a Budget of Expenditures and Sources Financing (BESF) for coastal construction. Innovative and blue financing schemes are recommended as a way forward (Bersales at al, 2016;Mapa, 2022; Mendoza & Valenzuela, 2021; Azanza et al., 2022; Azanza et al., 2017; Zafra, 2021; DENR & PEMSEA, 2019).

In terms of ecosystem and natural resource management, the DENR has a Coastal and Marine Ecosystem Management Program (CMEMP), and habitat restoration is part of the Philippine Biodiversity Strategic Action Plan 2015-2028 (DENR & PEMSEA, 2019).

3. Results and Discussion

While the blue economy holds potential benefits, several challenges must be overcome to achieve sustainability. These include the unsustainable extraction of marine resources, exemplified by illegal, unreported, and unregulated fishing practices that lead to overfishing. Additionally, the physical alteration and destruction of marine and coastal habitats due to coastal development, deforestation, and mining are also significant challenges (Next IAS, 2021).

Moreover, the emerging needs of a circular economy present challenges in both new and established treatment methods and materials. The circular economy is perceived as an economic model aimed at eliminating waste production, optimizing resource use, and promoting recycling and recovery processes (Martínez-Vázquez et al., 2021).

In this ecosystem approach, technology and innovation play a crucial role. They have the potential to increase productivity, generate wealth and economic well-being, and facilitate the structural transformation of economies. For instance, NOAA advocates the concept of a new blue economy. This concept is based on the improved collection, analysis, and dissemination of ocean and coastal-derived data and information to support economic growth while protecting the health of our oceans (Spinrad, 2023).

Public-private partnerships are another key element in promoting the blue economy. They can help scale up efforts towards sustainable development by uniting individual efforts of different countries into a global network directed towards shared goals. For instance, Goldman Sachs, Bloomberg, and the Asian Development Bank created a new Climate Innovation Fund to deploy capital to energy transition projects across developing markets (McCormick & Nasr, 2023).

Capacity building is also essential in promoting the blue economy. It involves developing specialized skills to foster expansion of new tourism and fisheries products, improving access to education at a local level, strengthening cooperation among Small Island Developing States (SIDS), ensuring inclusion of Least Developed Countries (LDCs) and SIDS as essential actors of the global market (El-Haddad, 2020). For example, the Vanga Blue Forests Initiative in Kenya aims to restore and protect seagrasses with the sale of carbon credits in local communities (ACES & CFA, 2019).

The case studies presented in this paper demonstrate the diverse applications of blue economy principles across different sectors. These sectors range from marine renewable energy to desalination, and the examples provided underscore innovative strategies for sustainably utilizing ocean resources. The integration of digitalization within these sectors has further boosted their efficiency and sustainability. Moreover, eco-tourism offers a means to advocate for conservation while simultaneously driving economic growth. The concept of blue carbon emphasizes the ocean’s vital role in mitigating climate change. Finally, the emergence of electric boats indicates a shift towards more environmentally friendly transportation methods in maritime activities.

SEA has a wealth of marine resources, a growing population, and a strong commitment to sustainable development, the right policies, strategies, and investments. These sustainability efforts have tremendous potential to be a global hub for multiple sustainable blue economy clusters.

4. Conclusions and Recommendations

It is crucial to address the challenges to ensure the sustainability of the blue economy in SEA. This involves creating alliances between sectors that compose blue growth with the incorporation of the circular economy. A stronger, more inclusive, and equitable governance is needed to pursue sustainable development. It is important that in future research, exploring more innovative ways to incorporate circular economy principles into blue economy sectors must be included, and policy recommendations should strengthen governance structures to ensure sustainable development within the blue economy. An ecosystem approach that integrates multiple sectors and leverages technology and innovation, public-private partnerships, and capacity building can effectively promote sustainable and inclusive growth in the blue economy.

The blue economy presents immense opportunities for sustainable growth. However, realizing its full potential requires concerted efforts from all stakeholders. Policymakers should foster an enabling environment for innovation and investment in blue economy sectors. Businesses should adopt sustainable practices that align with blue economy principles. Research institutions should continue exploring new technologies and approaches to enhance sustainability in these sectors. Lastly, consumers can contribute by supporting businesses that adhere to blue economy principles. The blue economy offers a promising pathway towards sustainable development. By learning from existing examples and case studies, stakeholders can gain insights into effective strategies for harnessing ocean resources sustainably. As we move forward, it is crucial to continue exploring innovative solutions that align economic growth with environmental sustainability.

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ESTABLISHING REGIONAL REGULATION TO ENHANCE THE UTILIZATION OF PALM-OIL BASED SUSTAINABLE AVIATION FUEL (SAF) IN ASEAN AVIATION INDUSTRY

Prayitno, Dimas Ramadhan, Abdillah Fikri

Strategic Planning, PT Kilang Pertamina Internasional, Jakarta 10110, Indonesia.
prayitno.prayogo@pertamina.com
dimas.ramadhan@pertamina.com

Abstract

International Civil Aviation Organization (ICAO) construct the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) to minimize CO_2 emissions in aviation industry with several policies including the utilisation of Sustainable Aviation Fuel (SAF). According to CORSIA, an eligible SAF is a drop-in fuel with characteristics similar to conventional Jet-A1 but has 10% lower life cycle carbon emissions that can be achieved by using alternative feedstock such as vegetable oil, waste oil, animal fat, etc. Indonesia and Malaysia are two largest palm oil producers in the world, totalling at 69.8 tonnes in 2022 which comprise 90% of global production. Crude Palm Oil (CPO) can be processed to SAF through Hydroprocessed Esters and Fatty Acid (HEFA) process and is listed as Eligible Feedstock in CORSIA's documentation as long as the palm oil plant has methane capture unit. However, European Union (EU) through its Renewable Energy Directives II (RED II) limits the usage of palm oil derrivatives for fuels, including SAF which makes uncertainties among countries and airlines. To fulfill for even 2% of its 196 million barrels jet fuel demand, ASEAN countries shall endorse through regional regulation for SAF production from their most abundant resources: CPO.

Keywords: Aviation, CORSIA, CPO, SAF.

1. Introduction

The aviation industry serves as a cornerstone of global connectivity, enabling rapid transport of goods and passengers across vast distances. However, its environmental footprint is a growing cause for concern, particularly with regard to greenhouse gas emissions. Accounting for approximately 3.5% of global CO_2 emissions and forecasted to increase to between 7 and 12% by 2050 [1], the sector finds itself at a crossroads where the demand for increased mobility clashes with the imperative need for sustainability. As air travel is projected to grow in the coming decades, understanding and mitigating its emissions has become a critical area of focus. This condition drives the International Civil Aviation Organization (ICAO) to release its Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) as a standardized methodology that can be refered by countries to reduce the emissions from Aviation Industry. As January 2023, 115 states had announced their intention to participate in CORSIA. Therefore, CORSIA's policy is deemed to be the most influential regulatory framework adopted by aviation industry in the world.

Differ with land transportation which has imposed the success of electrification, aeroplane is considered to be much more difficult to be electrified, especially for the medium to long haul flights. Hence, the implementation of drop-in liquid low carbon fuel, hereafter labeled with term Sustainable Aviation Fuel (SAF), has shown major adoption in the industry since no modification is required from the current aeroplane design to utilize this fuel.

There have been a lot of technological advancements on the production of SAF, started by Hydroprocessed Esters and Fatty Acids (HEFA), Fischer-Tropsch (FT), Direct Sugars to Hydrocarbons (DSHC), Hydrotretated Depolymerized Cellulosic Jet (HDCJ), Alcohol to Jet (ATJ), and Aqueous Phase Reforming (APR) [2]. Although other technologies are currently undergoing leap advancement, HEFA remains as the most efficient and affordable pathway to produce SAF to date, given the simplicity of its process and the abundance of the feedstocks for this technology. As the name suggests, HEFA process fatty acids from various sources with hydrogen to remove its carbonyl group, hydroxyl group, as well as its double bonds. The sources can be vegetable oil such as rapeseed, palm, or even used cooking oil (UCO), to animal fats. ASEAN, as the largest source of vegetable oils, has a potential to be the epicentrum of SAF production.

To ensure the achievements of CORSIA's target, a criterion of emissions reduction has been stated as CORSIA's eligible fuel. The SAF shall reduce at least 10% of emissions from conventional jet A-1 fuel which is calculated as 89 gCO_{2e}/MJ. This criterion makes waste feedstock such as UCO and Palm Fatty Acid Distillate (PFAD) become prefered feedstock as they reduce more than half of the jet A-1 emissions, while Crude Palm Oil (CPO) can only be use as SAF feedstock if at least 85% of the biogas released from the Palm Oil Mill Effluent (POME) treated in anaerobic ponds is captured and oxidized [3].

However, European Union (EU) with its Renewable Energy Directives II (RED II) Annex IX omits all vegetable oils which are related with food industry as eligible feedstock for renewable fuel, including palm oil and its derivative. This created different eligibility standards with CORSIA, thus sparking uncertainty for airlines to adopt palm-oil based SAF. ICAO lays CORSIA as basic framework for global effort in emissions reduction, while allowing countries to postulate region-specific regulation as long as the minimum criteria are met. Hence, ASEAN can also create regulations derived from ICAO's CORSIA for SAF implementation within the region.

2. Methodology

Demand Forecasting. Consultant forecast data of jet fuel demand in ASEAN. The consultant uses historical real trading data on country-by-country and sector-by-sector basis worldwide and the assumed demand growth is calculated with certain percentage which considers various demand growth factors including population growth, geopolitical situation, relevant legislation (e.g. RED II proposals), GDP growth, etc.

Supply Forecasting. Indonesian and Malaysian CPO production figures are collected from reports by Gabungan Pengusaha Kelapa Sawit Indonesia (GAPKI) [4] and Malaysian Palm Oil Board (MPOB)[5]. SAF production capacity from external consultant data.

Case Simulation. Using the demand and supply forecasting as defined previously, several simulation cases are constructed to see the gap between the supply and demand, thus initiating analysis on how to strategize better scenarios to fulfil the demand.

3. Results and Discussion

ASEAN SAF Supply-Demand Case Simulation.

Based on recent news and consultant data, there are projections of SAF supply from Indonesia, Malaysia, and Singapore due to planned establishment of several SAF producing plant including Green Refinery Cilacap (Indonesia), ENI-Euglena-Petronas Biojet Plant (Malaysia), and expansion of Neste's plant (Singapore) as shown in **Table *1***. It is known that Malaysia's and Singapore's SAF supply will be exported to Europe's market, where the demand for SAF may reach ~6,000 kL per year by 2030 while only produce ~5,000 kL at the same year. This condition leaves only small portions of SAF that can be utilized by ASEAN countries if they start to mandate the usage of SAF. If ASEAN countries are committed to CORSIA's resolution on using SAF by 2024 onwards and assuming that 5% blend of SAF shall be utilized, the current projection of supply, if all product is used within ASEAN and no export to EU, can only fulfill the demand until 2028, thus needed additional production capacity as tabulated in **Table 2**. This suggests that ASEAN countries shall have a solid strategy to fulfil the projected demand, including the security of feedstock's supply.

Table 1 ASEAN SAF Supply based on Consultant Data (in kL per year)

	2023	2024	2025	2026	2027	2028	2029	2030
Total ASEAN	908	1,844	2,037	2,152	2,152	2,152	2,152	2,152
Indonesia	8	356	356	356	356	356	356	356
Malaysia	0	0	51	166	166	166	166	166
Singapore	892	1,274	1,274	1,274	1,274	1,274	1,274	1,274

Table 2 ASEAN SAF Demand based on Percentage of Total Jet Fuel Demand (in kL per year)

	2023	2024	2025	2026	2027	2028	2029	2030
Jet Fuel Total	29,873	36,012	37,710	39,498	41,262	42,954	44,560	46,087
SAF by Percent								
2%	0	720	754	790	825	859	891	922
3%	0	1,080	1,131	1,185	1,238	1,289	1,337	1,383
5%	0	1,801	1,885	1,975	2,063	2,148	2,228	2,304

If we look at the feedstock availability shown in

Table *3* we can calculate theoretical SAF product that can be produced with those feedstock with assumed yield of 71.7% shown in **Table 4**. If ASEAN countries only produce SAF from UCO, the feedstock will not fulfil even the production capacity (e.g. in 2030 projected production capacity is 2,152 kL/year from **Table 1**, while based on the feedstock availability, only 1,017 kL/year of SAF can be produced solely from UCO as shown in **Table 4**). In the other hand, CPO shows tremendous availability for SAF production with ~60,000 kL/year potential production in 2030. It suggests that ASEAN countries shall consider CPO as one of the potential feedstock for SAF production to fulfil the forecasted demand risen by the commitment of CORSIA's participating states.

Table 3 ASEAN SAF Feedstock Availability based on Consultant Data (in kL per year)

	2023	2024	2025	2026	2027	2028	2029	2030
UCO	1,006	1,096	1,195	1,254	1,317	1,350	1,384	1,418
CPO	79,995	80,012	80,011	80,868	81,735	82,611	83,498	84,361

Table 4 Theoretical ASEAN SAF Production from Available Feedstock (in kL per year)

	2023	2024	2025	2026	2027	2028	2029	2030
SAF from UCO	721	786	856	899	944	968	992	1,017
SAF from CPO	57,330	57,342	57,341	57,956	58,576	59,205	59,840	60,459

Concern Identification and Future Optimization.

Even though it had been shown before that CPO is a potential feedstock for SAF production if we only consider by its volume, CPO possesses concerning issue that may hinders it to become potential SAF feedstock: the Indirect Land Use Change / ILUC. As regulated by CORSIA, the eligible fuel shall reduce at least 10% of fossil-based jet fuel. A CPO-based SAF may fulfil this requirement only if at least 85% of the biogas released from the Palm Oil Mill Effluent (POME) treated in anaerobic ponds is captured and oxidized as shown in **Table 5**. CPO without the biogas capture even has more emissions than the base fossil jet fuel. If we look deeper into the values, CPO's ILUC LCA Value contribute more than half of its total LCA value (for CPO with biogas capture, or nearly half as much of the core LCA value for CPO without biogas capture), which indicates that this value shall be the main concern if ASEAN countries are planning to utilize CPO as SAF feedstock. This ILUC value could be re-assessed and proposed to CORSIA if we can prove our effort to minimize the land use change for palm oil plantation.

Table 5 Default Life Cycle Emissions Values for CORSIA Eligible Fuels [3]

Feedstock	Core LCA Value (gCO_{2e}/MJ)	ILUC LCA Value (gCO_{2e}/MJ)	Total LCA (gCO_{2e}/MJ)	% Reduction
Jet Fuel (fossil)			89.0	base
CPO (with biogas capture in POME pond)	37.4	39.1	76.5	14.0
CPO (without biogas capture in POME pond)	60.0	39.1	99.1	-11.3
UCO	13.9	0.0	13.9	84.4

As written by Wicke, et. al. [6], ILUC can occur either:

- when a direct displacement of pastureland, cropland, or crop use results in livestock or crops being produced elsewhere to continue meet demand; or
- when the diversion of the crop to other uses triggers higher crop prices, which results in more land being taken into agricultural production elsewhere.

Thus, the main strategies for controlling the extent of ILUC are to:

- increase efficiencies in agricultural crop production, e.g., by utilizing fertilizer, better weed and pest management, switching varieties grown, investment in agricultural R&D and multiple rotations;
- integrate food, feed, and fuel production to increase total biomass production per hectare;
- improve efficiencies of agricultural, forestry, and bioenergy supply chains, this will also increase the per-hectare productivity, e.g., by reducing losses in storage and transportation and increasing conversion and processing efficiencies (e.g., using better catalyst in HEFA process)
- minimize degradation and abandonment of agricultural land;
- apply other forms of highly efficient land use, e.g., algae production on waste land, despite of its low economic feasibility;
- develop and implement sustainable land use planning and monitoring, this only possible if sufficient data on land use and land cover are available with acceptable accuracy and a proper resolution, collected at regular time intervals;
- exclude high-carbon stock and important biodiversity areas by land use policies all around the world;
- promote the use of marginal land, degraded lands, or abandoned agricultural land for bioenergy production.

Mitigation strategies mentioned above are mainly heavy in regulation implementation and efficiency improvements by R&D. These are achievable if join efforts can be done by ASEAN countries, especially those that produce CPO. If the mitigation strategy can be implemented, countries should construct a specialized task force consists of governmental body, CPO plantation company, SAF producer, researcher, and ICAO / IATA delegation for the country to re-assess the ILUC of CPO production after the mitigation effort. A non-profit organization such as IPEF can also join this task force to support the effort financially.

If the ILUC reduction effort could be done, it is important to also establish a regulation to be implemented in ASEAN so that the member countries can refer the regulation as the derivative of CORSIA's document. As stated by CORSIA's representative in Bangkok on May 2023, CORSIA lays the baseline framework for emissions reduction. Participating countries or regions can establish derivative documents to better implementation for their specific conditions. The regulation can be discussed in ASEAN Air Transport Working Group annual meeting with recommendations from the result of ILUC reduction effort report.

4. Conclusion and Recommendations

Conclusion: SAF has been the most viable path to reduce carbon emissions in aviation industry, and the current most-matured technology to produce SAF is the HEFA process. ASEAN, with its growing population and economic strength, is projected to be one of the largest SAF user with the demand of more than 2.3 million liters on 2030 if 5% blend of SAF is mandated by ASEAN. UCO, the most prominent feedstock used for biofuels production for EU market, is a promising feedstock for SAF production. However, due to its scattered point of origins, the collection of UCO is the biggest hindrance to meet the demand of SAF, which had been shown above as low supply forecast that struggles to even meet the production capacity. In the other hand, CPO is the most abundance bio-feedstock in ASEAN, where the two of largest CPO producting countries are member of ASEAN. CPO is a highly potential bio-feedstock for SAF if only its ILUC can be decreased. As shown above, ILUC from CPO can be half of its total LCA Value which makes CPO less attractive as SAF feedstock.

Recommendations: ASEAN countries shall form a joint effort to improve the ILUC by creating task force that includes the governmental body, CPO plantation companies, SAF producers, researchers, and ICAO / IATA delegates. The resulting improvement of ILUC from CPO shall be the basis to propose a regulation for SAF implementation in ASEAN region as derivation of CORSIA’s document. The document shall be submitted to ASEAN Air Transport Working Group as a recommendation for ASEAN countries to maximize its potential, utilizing their abundance of feedstock supply to create better future with lower emission from aviation industries. Therefore, ASEAN could fulfil its future SAF demand as planned in CORSIA’s commitment on carbon emissions reduction by itself, independently from RED II which are adopted in EU.

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EMISSION REDUCTION OF TRANSPORTATION SECTOR IN DKI JAKARTA

Dicky Arisikam[1)], Shafira Nur Fadhillah[2)]
[1)]Infrastructure Directorate, PT. Kereta Api Indonesia (Persero), Bandung
2)Faculty of Civil Engineering, Widyatama University, Bandung
E-mail: dicky.arisikam@kai.id[1)], shafira.fadhillah@widyatama.ac.id[2)]

Abstract

The transportation sector has become one of the largest contributors to emissions in the world. Data shows that from 1990 to 2020, the transportation sector contributed to 19% of emissions [7]. In Indonesia, in the year 2020, the transportation sector was the second-largest contributor to emissions after the electricity sector, accounting for 27% [3]. The growth in the population in major cities like DKI Jakarta will be a driver for an increase in the number of motor vehicles. This situation is exacerbated by traffic congestion in DKI Jakarta, making it the primary contributor to emissions in the transportation sector. Based on data on the population of DKI Jakarta and the growth in the number of motor vehicles from 2017 to 2021, a linear regression model was developed to predict the growth in the number of motor vehicles in DKI Jakarta, which is represented as $Y = 0.116X - 2.93$, where Y represents the population. From this prediction of the number of motor vehicles, we can calculate the emissions that will be generated. In 2022, the emissions from motor vehicles amounted to 3,248,640 grams of CO2 per kilometer. If the number of vehicles is converted into mass transit (KRL), it is equivalent to 264 KRL journeys in a year, resulting in 10,839 grams of CO2 per kilometer or approximately 0.0003% of motor vehicle emissions. Therefore, to address emissions from the transportation sector, it is necessary to develop mass public transportation and limit the number of vehicles in DKI Jakarta.

Keywords: Emissions, Transportation, Population, Motor Vehicles, KRL (Commuter Line)

1. Introduction

The fog that has been covering the city of Jakarta and other big cities recently is not anatural process of condensation. Because the 'fog' that occurs is actually emissions that are formed from burning carbon, one of which comes from motorized vehicles.

Air pollution has become one of the global environmental challenges that is urgent to be overcome. Motor vehicle emissions, especially in urban areas such as Jakarta, have become a major contributor to increased air pollution. The rapid growth of mobility has encouraged an increase in the number of motorized vehicles on the road, which in turn produces emissions of various atmospheric pollutants.

Emissions from motor vehicles include a large number of pollutants including fine particulate matter (PM2.5), nitrogen dioxide (NO2), carbon monoxide (CO), hydrocarbons (HC), and tropospheric ozone (O3). The impact of vehicle emissions not only affects air quality, but also has serious consequences for human health, the environment and the global climate.

Science recommends limiting global temperature increases to 1.5 to 2.0 Celsius to avoid catastrophic consequences from climate change. These temperature levels require ambitious emissions reduction efforts from both developed and developing countries. To achieve this, developed countries need to reduce their GHG emissions by 25 to 40% by 2020, compared to 1990 levels, while developing countries need to reduce their GHG emissions by 15 to 30% by 2020, compared to current conditions. business as usual [1]. More radical reductions in GHG emissions, around 50 to 80%, will be required by 2050 for both developed and developing countries [4]. These emissions reductions have not yet been formally agreed upon but serve as a guide to the scale of emissions reductions

Mitigation measures are required. The transportation sector has an important contribution to the 2020 and 2050 emission reduction goals. Due to the long lifespan of infrastructure, transformational changes must begin to be made now in the transportation sector so that countries are not stuck with current emissions trends.

1.1. Characteristics of Transportation in Developing Countries

Transport systems between countries vary greatly, with a special distinction to be made between transport systems in less developed countries and transport systems in developing countries. Transport systems in less developed countries tend to be characterized by high NMT (walking and cycling) mode shares, low per capita private car ownership, and low formal public transport mode shares. Informal passenger transportation (paratransit) tends to have a large modal share. Paratransit operations are an important mode of transportation in these countries. They are usually operated by the private sector and are less subject to regulation. Vehicles used in paratransit are often assembled locally in the informal sector and do not always meet emissions or road safety standards. This situation is not conducive to high levels is a symptom of inadequate institutional structures and legal frameworks. efficiency, passenger comfort or convenience and can undermine public transport services, with their poor environmental track record. This tends to be a symptom of inadequate institutional structures and legal frameworks. Developing countries tend to reflect many of the trends experienced during development in countries now considered developed. Car ownership (and motorbike ownership, particularly in Asian countries) is increasing rapidly in urban areas due to widespread income growth, availability of financing schemes, and private vehicle ownership status. Another driving factor of motorization is the inability of public transport services to accommodate the ever-increasing demand for transport, and the often inconvenient, uncomfortable and unsafe nature of public transport.

Increasing travel by private vehicles is more desirable with rapid economic growth having a negative impact related to high vehicle ownership. Environmental management planning is generally unable to keep up with the rapid pace of motorization and as a consequence these cities often have high levels of noise congestion and air pollution.

1.2. Greenhouse Gas (GHG) Emissions from Transportation

The transportation sector is currently responsible for 13% of GHG emissions [3] and 23% of CO2 emissions from global energy consumption [6]. Provided current trends are maintained, transportation energy use and CO2 emissions are projected to increase by around 80% by 2050. Although current per capita GHG emissions are much higher in Organization for Economic Co-operation and Development (OECD) countries, nearly 90% of emissions growth in the future it is estimated that it will come from non-OECD countries [6]. The amount of GHG emissions from transportation is directly related to the distance traveled, vehicle occupancy load and vehicle carbon efficiency. The projected growth in emissions in non-OECD countries is caused by increased passenger and goods transportation activities. The growth of goods transportation activities in non-OECD countries is expected to dominate the growth of world transportation activities in the future (See Figure 1).

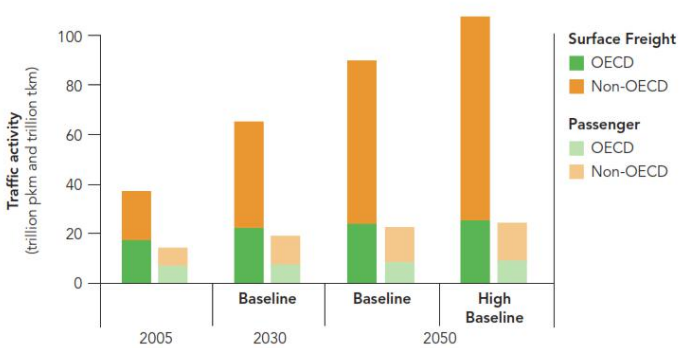

Figure 1 Mobility Split by type of transport, OECD and non-OECD
Source : IEA (2009) Transport, Energy and CO, Moving towands sustainability [5

The results of the International scenario planning by the International Energy Agency [6] underscore the need for full participation of the transport sector at the global level to realize the climate stabilization target of 2° Celsius by 2050. This 2° Celsius target is the limit of global temperature warming which must not be exceeded to prevent climate change. permanent and irreversible can be avoided [3] The same IEA study shows a reduction in CO2 emissions of more than 50% in 2050 compared to 2005 for all regions of the world with the greatest potential for emission reductions being in OECD countries. This is because even though the largest emissions growth occurred in non-OECD countries, the technology and knowledge needed to achieve a 50% reduction in emissions in OECD countries already exists. The potential for land transportation emissions reductions has also been documented in other planning studies. For example, the World Bank (2009) estimates a possible 19% reduction in emissions by 2032 compared to dynamic baseline data in selected countries in East Asia.

Based on the data from 2022, it is shown that the number of vehicles in Jakarta, which was 3.76 million vehicles (Source: Central Statistics Agency), while the number of passengers on the Commuter Line (KRL) was 215,049,396 people in 2022 (Source: KAI Commuter). According to the results of previous research analysis, the emissions generated by vehicles in Jakarta in 2022 were 192 grams, while the emissions from trains (KA) were 41 grams. This data indicates that the emissions contributed by transportation have a significant impact on the environment. Research on air pollution due to vehicle emissions has significant relevance in efforts to maintain good air quality and reduce negative impacts on society and the environment. By understanding the sources, composition, distribution, and effects of vehicle emissions, we can develop more effective policies to reduce air pollution and mitigate its consequences.

The aim of this research is to analyze the impact of air pollution caused by motor vehicle emissions. In this research, we will analyze vehicle emissions in DKI Jakarta and compare them with the use of Electric Rail Trains (KRL) so that we can see the comparison of the emissions produced. In addition, we will also discuss potential solutions and steps that can be taken to reduce vehicle emissions and mitigate their negative impacts.

By highlighting the importance of this research, we hope that the results of this research will make a valuable contribution to the development of sustainable environmental policies and efforts to prevent air pollution due to vehicle emissions in the future.

2. Research Method

This research was carried out by calculating a comparative analysis of population, number of vehicles and annual emissions. The vehicle emissions data was obtained through field measurements using gas emission sensor equipment. Calibrated gas emission sensors are used to measure concentrations of nitrogen dioxide (NO2), carbon monoxide (CO), and hydrocarbons (HC) in ppm (parts per million).

There are two ways that can be done to determine the reduction in emissions that has been achieved. First, by looking for the difference between the baseline GHG emissions in Business as Usual (BaU) conditions and the results of the emissions inventory in actual conditions. This difference is considered a reduction in emissions and can be calculated historically. Second, by calculating the reduction in emissions from each mitigation action that has been carried out.

To determine the reduction in emissions using the first method, a complete and accurate inventory of emissions data is needed so that the reduction can be measured clearly. Complete emissions data is obtained by regularly taking inventory of all data needed to calculate emissions. Accurate emissions data is obtained through the use of appropriate methodology in accordance with international guidelines.

Traffic data is obtained from the city's traffic authority, which includes information on vehicle type, traffic flow rate, and average speed at the same location as the emissions measurements. Data on vehicle characteristics such as fuel type, year of manufacture and Euro emission class were also collected through field surveys and motor vehicle authority databases. Gas emission data and traffic data are analyzed to identify emission patterns and the factors that influence them.

To determine the comparison of vehicle emissions from data samples to the theoretical frequency distribution that is estimated to describe or represent.

To predict the population, the number of vehicles is carried out using a regression test

The following is a simple regression test equation to predict the dependent variable (Y) if the independent variable (X) is known. Simple regression can be analyzed because it is based on a functional or causal relationship between the independent variable (X) and the dependent variable (Y).

The simple regression test equation is formulated: [6]

$$\hat{Y} = a + Bx$$

the values a and b can be calculated using the formula (1)

$$b = \frac{n\sum XY - \sum X \sum Y}{n\sum X^2 - (\sum X)^2} \quad \text{dan} \quad a = \overline{Y} - b\overline{X}$$

Ŷ = (read; Y hat), projected dependent variable subject.
X = Independent variable that has a certain value to be predicted.
a = constant value of price Y if X = 0
b = direction value as a determinant of forecast (prediction) which shows the value of increase (+) or value of decrease (-) of variable Y

3. Calculation Analysis

The process of analyzing and retrieving data was conducted through library research. The process of analyzing the population and the number of vehicles is conducted by collecting data sourced from the Central Statistics Agency. The obtained data is processed using a regression test to generate predictions of unknown quantities. Microsoft Excel was used as the software.

3.1. Analysis using Regression Test Method

The analysis process is carried out using the regression test method. Data on population growth and the number of vehicles in DKI Jakarta were obtained through the Central Statistics Agency. From the data collection results, the population growth over 12 years, from 2010 to 2022, and the development of vehicles over 5 years, from 2017 to 2021, were obtained. Microsoft Excel was used with the regression test method to obtain a comparison of emissions from the use of cars and commuter trains (KRL). From the conducted analysis, it is evident that the use of commuter trains (KRL) has a significant impact on reducing CO2 emissions in DKI Jakarta.

The data below is population and vehicle quantity data obtained from the Central Statistics Agency.

No	Years	Total Population [Million]	Total of Cars [Million Unit]
1	2010	9.6	
2	2011	9.89	
3	2012	9.99	
4	2013	9.97	
5	2014	10.08	
6	2015	10.18	
7	2016	10.28	
8	2017	10.37	3.1
9	2018	10.47	3.08
10	2019	10.56	3.31
11	2020	10.56	3.36
12	2021	10.64	3.54
13	2022	10.68	3.76

Table 1 Total Pupulations and Total of cars/ Years
Source : Badan Pusat Statistik

From the data above, a regression test method was conducted to obtain predictions for the population and the number of cars from 2023 to 2045. The results yielded the population and car development figures.

This test method involved the following steps:

A. Linear regression to determine the population count up to 2045.

a. Creating an auxiliary table to calculate statistical figures

No	x_i	y_i	$x_i * y_i$	x_i^2
1	2010	9.6	19296	4040100
2	2011	9.89	19888.79	4044121
3	2012	9.99	20099.88	4048144
4	2013	9.97	20069.61	4052169
5	2014	10.08	20301.12	4056196
6	2015	10.18	20512.7	4060225
7	2016	10.28	20724.48	4064256
8	2017	10.37	20916.29	4068289
9	2018	10.47	21128.46	4072324
10	2019	10.56	21320.64	4076361
11	2020	10.56	21331.2	4080400
12	2021	10.64	21503.44	4084441
13	2022	10.68	21594.96	4088484
∑	26208	133.27	268687.57	52835510

Table 2 calculations using auxiliary tables

b. Calculate the statistical figures and formulate the regression equation:

i. Using the regression test method formula (1), the value of b is obtained as 0.0838

ii. Using the regression test method formula (1), the value of a is obtained as 133.27-0.0838 x 26208

c. Creating the regression equation line:
The average value of X varies for each data point obtained by subtracting the last year from the year in question.
The average value of Y is 10.15
The diagram obtained is as follows:

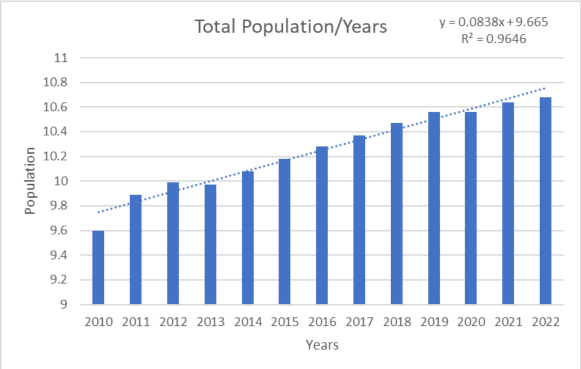

Figure 2 Chart of Total Pupulations / Years

B. Linear regression to determine the number of vehicles up to 2045.

a. Creating an auxiliary table to calculate statistical figures.

No	x_i	y_i	$x_i * y_i$	x_i^2
1	2017	3.10	6252.7	4068289
2	2018	3.08	6215.44	4072324
3	2019	3.31	6682.89	4076361
4	2020	3.36	6787.2	4080400
5	2021	3.54	7154.34	4084441
6	2022	3.76	7602.72	4088484
∑	10095	16.39	33092.57	20381815

Table 3 calculations using auxiliary tables

b. Calculate statistical figures and create the regression equation:

i. i. Using the regression test method formula (1), the value of b is obtained as 0.116

ii. Using the regression test method formula (1), the value of a is obtained as Y=0.116x + 2.93

Creating the regression equation line:

The average value of X varies for each data point obtained by subtracting the last year from the year in question.
The average value of Y is 2.731
The diagram obtained is as follows:

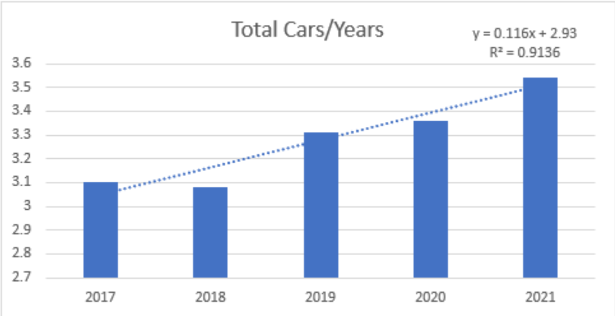

Figure 3 Chart of Total Pupulations / Years

From the calculations above, data is obtained using the regression test method.

No	Years	Total Population [Million]	Total of Cars [Million Unit]
1	2010	9.6	
2	2011	9.89	
3	2012	9.99	
4	2013	9.97	
5	2014	10.08	
6	2015	10.18	
7	2016	10.28	
8	2017	10.37	3.1
9	2018	10.47	3.08
10	2019	10.56	3.31
11	2020	10.56	3.36
12	2021	10.64	3.54
13	2022	10.68	3.76
14	2023	10.75	4.46
15	2024	10.84	4.57
16	2025	10.92	4.69
17	2026	11.01	4.80
18	2027	11.09	4.92
19	2028	11.17	5.04
20	2029	11.26	5.15
21	2030	11.34	5.27
22	2031	11.42	5.38
23	2032	11.51	5.50
24	2033	11.59	5.62
25	2034	11.68	5.73
26	2035	11.76	5.85
27	2036	11.84	5.96
28	2037	11.93	6.08
29	2038	12.01	6.20
30	2039	12.09	6.31
31	2040	12.18	6.43
32	2041	12.26	6.54
33	2042	12.35	6.66
34	2043	12.43	6.78
35	2044	12.51	6.89
36	2045	12.60	7.01

Table 4 The regression test results of the population and the number of cars.

3.2. Comparative Analysis of Emissions

The analysis process is conducted assuming calculations obtained from previous regression tests and from other research data sources.

The CO2 Equivalent Emissions per kilometer (CO2/km) is known from a study conducted by the Department for Business, Energy, and Industrial Strategy of the United Kingdom through Our World in Data.

Vehicles	Unit
Cars	41 gr/km
Commuter Line / Rail	192 gr/km

Table 5 Equivalent emissions

As of September 2021, the emission standards for motor vehicles in Indonesia are based on the Minister of Environment and Forestry Regulation (Permen LH) No. 20 of 2019 Concerning the Exhaust Emission Standards for Motor Vehicles. This regulation adopts Euro 4 emission standards for gasoline-fueled motor vehicles and Euro 3 emission standards for diesel-fueled motor vehicles. These emission standards apply to new vehicles produced or imported into Indonesia.

According to this regulation, Euro 4 emission standards are set as follows in the table below:

Standart of Emission	Type	Total	Unit
Gasoline emission limits	Co	1	g/km
	HC	0.1	g/km
	Nox	0.08	g/km
Diesel emission limits	Co	0.5	g/km
	HC+ Nox	0.3	g/km
	Nox	0.25	g/km

Table 6 emission standards

From the data that has been tested using regression analysis, the assumed calculations are as follows:

Assuming that 1 car is occupied by 2 people, and the number of cars on the road per day is 45% of the total annual number of vehicles. In addition, in 1 commuter train (KRL), there are 8 carriages, each carrying 200 passengers with an occupancy rate of 80%, totaling 1280 passengers.

As a result, the data is obtained in the form of calculation results in a table:

No	Years	Total Population [Million]	Total of vehicles [Million/Day]	Total of cars [Million/Day]	Total of active residents [Million/ Day]	Vehicle emissions [Co2/gr/km]	Commuter Line [unit]	Commuter Line [Co2/gr/km]	Persent [%]
	(a)	(b)	(c)	(d) = ...% x (c)	(e) = (d) xTotal Passenger (2)	(f) = (d) x Standard of Emissions (192 gr/km)	(g) = (c) / Total Passenger (1280)	(h) = (g) x Standard of Emissions (41 gr/km)	(i) = (h) / (f)
1	2017	10.37	3.10	1.40	2.79	267840000	218	8937	0.0033%
2	2018	10.47	3.08	1.39	2.77	266112000	217	8879	0.0033%
3	2019	10.56	3.31	1.49	2.98	285984000	233	9542	0.0033%
4	2020	10.56	3.36	1.51	3.02	290304000	236	9686	0.0033%
5	2021	10.64	3.54	1.59	3.19	305856000	249	10205	0.0033%
6	2022	10.68	3.76	1.69	3.38	324864000	264	10839	0.0033%
7	2023	10.75	4.46	2.01	4.01	385084800	313	12849	0.0033%
8	2024	10.84	4.57	2.06	4.12	395107200	322	13183	0.0033%
9	2025	10.92	4.69	2.11	4.22	405129600	330	13518	0.0033%
10	2026	11.01	4.80	2.16	4.32	415152000	338	13852	0.0033%
11	2027	11.09	4.92	2.21	4.43	425174400	346	14186	0.0033%
12	2028	11.17	5.04	2.27	4.53	435196800	354	14521	0.0033%
13	2029	11.26	5.15	2.32	4.64	445219200	362	14855	0.0033%
14	2030	11.34	5.27	2.37	4.74	455241600	370	15190	0.0033%
15	2031	11.42	5.38	2.42	4.85	465264000	379	15524	0.0033%
16	2032	11.51	5.50	2.48	4.95	475286400	387	15858	0.0033%
17	2033	11.59	5.62	2.53	5.06	485308800	395	16193	0.0033%
18	2034	11.68	5.73	2.58	5.16	495331200	403	16527	0.0033%
19	2035	11.76	5.85	2.63	5.26	505353600	411	16862	0.0033%
20	2036	11.84	5.96	2.68	5.37	515376000	419	17196	0.0033%
21	2037	11.93	6.08	2.74	5.47	525398400	428	17530	0.0033%
22	2038	12.01	6.20	2.79	5.58	535420800	436	17865	0.0033%
23	2039	12.09	6.31	2.84	5.68	545443200	444	18199	0.0033%
24	2040	12.18	6.43	2.89	5.79	555465600	452	18534	0.0033%
25	2041	12.26	6.54	2.95	5.89	565488000	460	18868	0.0033%
26	2042	12.35	6.66	3.00	5.99	575510400	468	19202	0.0033%
27	2043	12.43	6.78	3.05	6.10	585532800	477	19537	0.0033%
28	2044	12.51	6.89	3.10	6.20	595555200	485	19871	0.0033%
29	2045	12.60	7.01	3.15	6.31	605577600	493	20206	0.0033%

Table 7 emission standards

3.3. Conclusion

Based on the analysis results, it can be concluded from the calculations using multiple regression analysis that the use of Commuter Line (KRL) has a significant impact on reducing CO2 emissions in Jakarta. The analysis calculations show that the emissions generated by KRL have a very significant effect on reducing emissions in Jakarta. As for the recommendations for addressing this issue, it involves reducing private car usage and switching to public transportation such as KRL, using fuels that meet Euro 4 requirements such as Pertamax Turbo or equivalent.

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Building a Greener Future: Kuala Lumpur's Smart City Initiatives and Carbon Emission Reduction

Rusnida Talib[1], Rahayu Muhammad Taib[2]

[1]Civil Engineering and Drainage Department, Kuala Lumpur City Hall, Menara DBKL 1,
50350 Jalan Raja Laut, Kuala Lumpur, MALAYSIA
[2]Urban Transportation Department, Kuala Lumpur City Hall, Menara DBKL 1,
50350 Jalan Raja Laut, Kuala Lumpur, MALAYSIA

E-mail: rusnida@dbkl.gov.my , rahayutaib@dbkl.gov.my

Abstract

In the face of rapid urbanization, cities are grappling with issues of congestion and pollution. However, the integration of technology presents an unprecedented opportunity to reshape urban planning, design, financing, development, and governance. Addressing these challenges requires societal commitment towards future needs, fostering social cohesion, inclusivity, and sustainable development. Urban concentration strains resources like land, water, housing, transport, and employment, posing multifaceted challenges. Kuala Lumpur's approach to Smart City development prioritizes its people, utilizing information and communication technology to enhance liveability, workability, and sustainability. With a vision to reduce carbon emissions by 70% by 2030, the city emphasizes sectors such as economy, transport, energy efficiency, and lifestyle. The transformation includes transitioning to electric buses to combat the 23% contribution of the transport sector to carbon emissions. By replacing existing diesel-powered units with electric buses, Kuala Lumpur takes a significant step towards a cleaner and healthier urban environment.

***Keywords**: Urbanization, Technology Integration, Sustainable Development, Smart City, Carbon Emissions*

1. Introduction

The significant urbanization that has occurred over recent decades has given rise to a range of urban challenges, including issues such as traffic congestion and pollution. With the integration of technology, there is now an opportunity to redefine how cities are conceived, planned, funded, developed, and governed. Society bears a substantial responsibility in addressing future needs, progressing towards greater social unity, bridging societal divisions, advocating for participatory and all-inclusive local governance, and promoting sustainable development.

The swift urbanization process has had far-reaching effects on population distribution and has placed immense demands on resources like land, water, housing, transportation, and job opportunities. These concentrated and rapidly growing population centers pose dual challenges in terms of quantity and quality, necessitating solutions for ensuring an adequate housing supply, alleviating urban congestion, and safeguarding the environment, both at the local and national policy levels.

In response to these urbanization challenges, the city of Kuala Lumpur, Malaysia, has embarked on its inaugural endeavor to tackle these issues head-on. On the national scale of Malaysia, the National Smart City Framework serves as the benchmark, guiding Kuala Lumpur City Hall (KLCH) in taking progressive measures to enhance connectivity, infrastructure, and communication effectiveness with its residents, businesses, and communities. This, in turn, enhances the overall quality of life for the people of Kuala Lumpur. Zooming in on a more granular level, we find the masterplan for the capital city, Kuala Lumpur itself. The Kuala Lumpur Smart City Master Plan 2021-2025 represents a significant leap forward in the city's transformation, aiming to position KL as a prominent and exemplary urban center of the future. KLSCMP2025 shares its Smart City aspirations with both the Pelan Strategik DBKL 2021-2030 and Pelan Struktur Kuala Lumpur 2040 (PSKL 2040) to effectively address the rapid urbanization challenges faced by the capital.

1.1 Smart City Framework

In Kuala Lumpur, a Smart City is defined as a holistic urban management approach that prioritizes its citizens, utilizing various technologies to augment and enhance their daily lives.

The diverse range of interpretations surrounding the concept of a Smart City has led to comprehensive definitions that do not specifically hone in on particular technologies or sectors. Kuala Lumpur, however, has adopted a people-centric approach to Smart City development. Kuala Lumpur is committed to leveraging information and communication technology to enhance the quality of life, work environment, and sustainability of the city.

The importance of the Smart City concept in Malaysia is illustrated in Figure 1, with particular emphasis on the following key aspects:

1. Addressing urban challenges stemming from rapid urbanization.
2. Aligning with national and global agendas.
3. Adapting to emerging global development trends.
4. Fostering the growth of the digital economy.
5. Elevating Kuala Lumpur's status to be on par with other global cities.

Figure 1 : Significance of smart city development for Kuala Lumpur, Malaysia

The Kuala Lumpur Smart City Master Plan 2021-2025 serves as a cornerstone for advancing Kuala Lumpur's reputation as one of the world's most vibrant, livable, and sustainable cities. It provides a platform for enhancing the city's distinctive features and environment, nurturing its innovation ecosystem, celebrating its rich cultural diversity, and strengthening the sense of community and belonging. The master plan aspires to align with top global Smart City benchmarks, as depicted in Figure 2, reflecting the increasing global demand for urban metrics, city performance evaluations, and international comparisons.

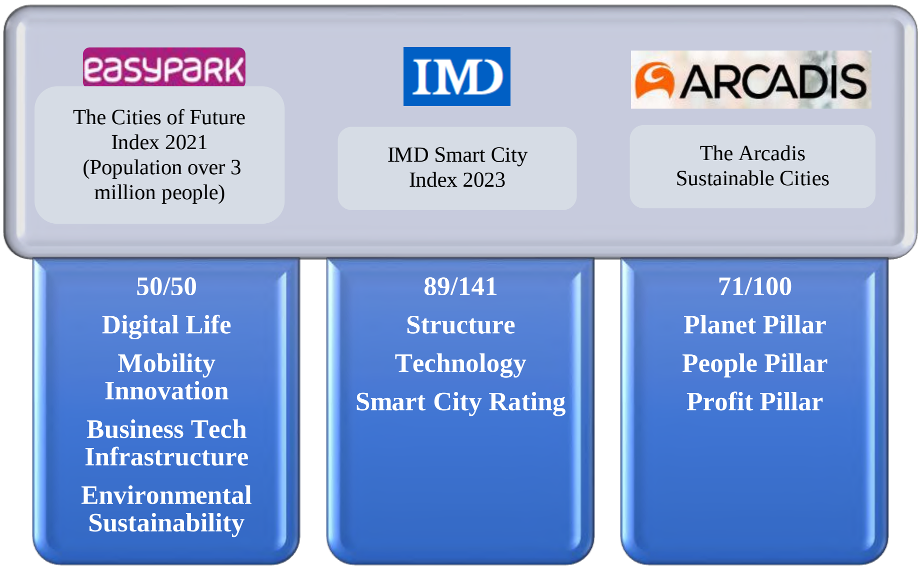

Figure 2 : Kuala Lumpur City in the Multiple Global Ranking

This Master Plan materialized through the application of a three-phase Gap Analysis approach, with a strong emphasis on co-creation, aligning with the people-centric definition of Kuala Lumpur Smart City. There are three main approaches taken in the development of the master plan, as illustrated here:

1. Analysis of the current state.
2. Exploration of future state scenarios.
3. Formulation of strategic recommendations.

As a result of this master plan, Kuala Lumpur has identified, developed, or initiated over 350 projects before or during its development. The initiatives outlined below aim to further bolster Kuala Lumpur's vision of becoming an inclusive city for all. KLSCMP2025 includes a list of 28 proposed initiatives, with one of the primary initiatives explored in this paper focusing on Smart Mobility, particularly the transition to electric buses to address the transport sector's 23% contribution to carbon emissions.

1.2 Smart Mobility - Transportation Sector

Kuala Lumpur is dedicated to reducing carbon emissions by up to 70% by 2030, recognizing that key sectors, including the economy, transportation, development, energy efficiency, and lifestyle, play a crucial role in carbon measurement within the city.

Our vision is rooted in the belief that:

- A fully occupied bus can replace 40 cars on the road, and the shift from private cars to public transport can contribute to a 65% reduction in carbon emissions during peak hours.
- An electric bus (EV) can reduce carbon emissions by 18%-24% per charging cycle.

Figure 3 : Introduction of Electric Vehicle Bus (EV Bus) by Kuala Lumpur City Hall (KLCH)

With reference based on Kuala Lumpur Low Carbon Society Blueprint 2030, Kuala Lumpur looking at potential for reducing over 48,000 ktCO_2eq by 2030. Transportation sector currently contributes around 23% of carbon emissions and from the blueprint, Kuala Lumpur targeting a reduction up to 14.2% or equivalent up to 7000 ktCO_2eq.

Kuala Lumpur City Hall (DBKL) is actively committed to advancing the transportation sector by embracing state-of-the-art technologies. One crucial initiative currently under examination revolves around the incorporation of environmentally friendly and sustainable transportation systems. Additionally, DBKL aims to encourage a voluntary shift from motorized vehicles to walking and cycling for shorter to mid-range journeys. The utilization of diesel fuel, known for emitting harmful fine particulates, presents potential hazards to respiratory well-being and the ecological landscape.

To tackle this concern, the GoKL Free Bus Service (illustrated in Figure 3) is in the process of transforming into battery electric vehicles (BEVs), recognized as a more environmentally conscious and health-friendly choice. The GoKL service is gradually making the shift to electric buses, with plans to introduce additional units into its fleet in the upcoming year. The ultimate deployment strategy aims to replace all current diesel-powered vehicles with electric buses by early 2023. This aligns with a directive outlined in the blueprint to encourage the adoption of eco-friendly vehicles. Under this directive, four programs have been proposed to achieve this goal:

GM 19: Implementation of viable low-carbon vehicles by Kuala Lumpur City Hall.
GM 20: Collaboration with EV car-sharing companies.
GM 21: Tax incentives for the purchase of green vehicles.
GM 22: A phased-out approach for conventional diesel engine buses.

1.3 Bus Specifications

Remarkably, aside from the drivetrain and electrical components (which are imported), these buses are entirely manufactured locally, a source of pride for the company. Each bus can accommodate 56 passengers at once and has a top speed of 70 km/h, performing optimally at speeds between 55-60 km/h. The energy storage capacity totals 299 kWh, provided by eight lithium-ion traction battery packs located at the rear of the bus. With a full charge, the bus can travel up to 250 km. The full charging period is approximately 1.5 hours depending on the charging type.

Currently, the existing charging stations are located at the Pulau Meranti bus depot in Puchong. The coach builder has added a charging station in Sentul, making a total of 4 charging stations for EV buses.

Fast Charging will be used if the bus requires a shorter charging time, where 2 charging units will be used simultaneously to expedite the charging period, which is 20 minutes to complete, and the bus can continue its journey as usual. It is estimated that a single full charge of an EV bus can meet the number of daily trips, which is estimated to be 6-8 rounds per day.

To attract more members of the public to use public tran sportation, especially the free GoKL bus, this bus is equipped with the following amenities for its passengers as shown in Figure 4:

- Free Wi-Fi service.
- Equipped with 5 closed-circuit television (CCTV) cameras.
- Monitoring system for the bus and GPS.
- LED destination boards and public address systems.
- Accessibility for persons with disabilities (OKU).
- Cashless electronic ticketing system.
- Passenger counting system (PHC).

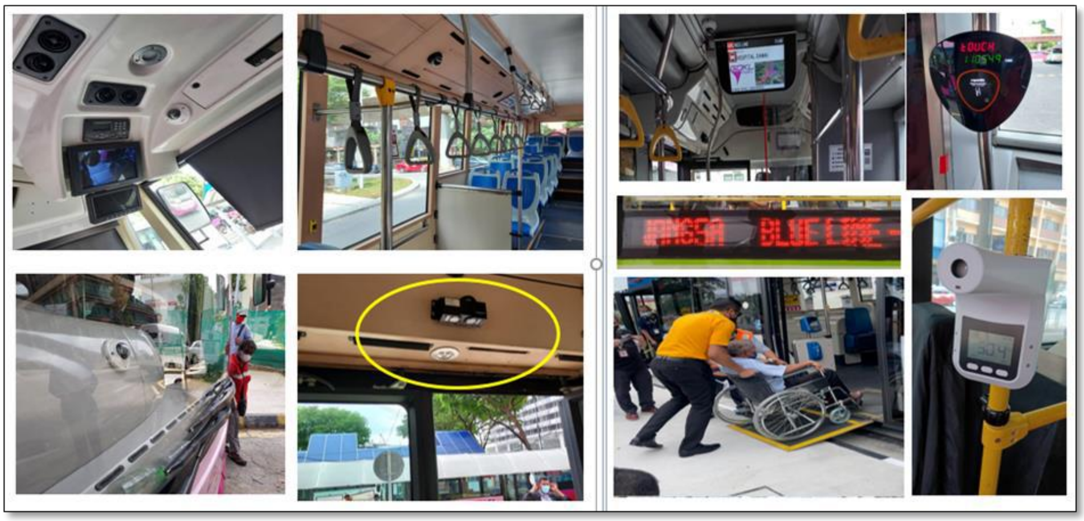

Figure 4 : Amenities provided in the GoKL Bus

Furthermore, the GoKL electric bus service is complemented by a mobile application, GoKL (Figure 5), which provides users with valuable information including:

- Bus route listings.
- Estimated bus arrival times.
- Bus stop locations.
- Service feedback options.

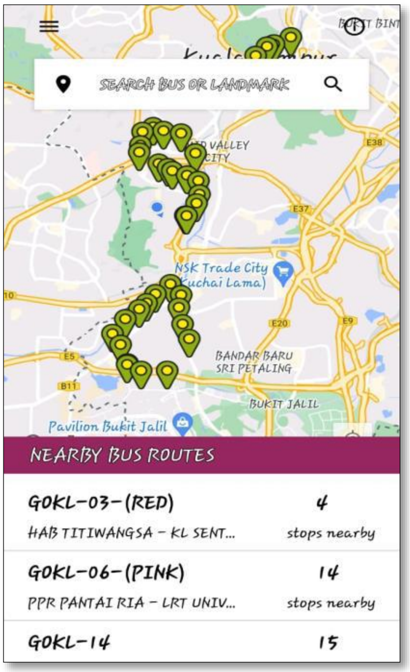

Figure 5 : Mobile Apps GOKL

2. Discussion

The EV Bus is environmentally friendly as it does not emit smoke that can cause air pollution, as it is powered by electricity. Reducing environmental pollution, electric buses also do not produce loud noises compared to regular diesel engine buses. Low carbon emissions rate (carbon is still used for air conditioning/charging stations).

It is also quieter and less vibration compared to conventional buses. Passengers will feel more comfortable because there is no engine noise disturbance and no vibration when the bus is moving. Furthermore, there will be no harmful smoke and particles are emitted and it will definitely contribute to cost-effective in terms of fuel.

In addition to that, should the target of 70% use of public transportation, that will definitely reduce the volume of traffic congestion as shown in Figure 6.

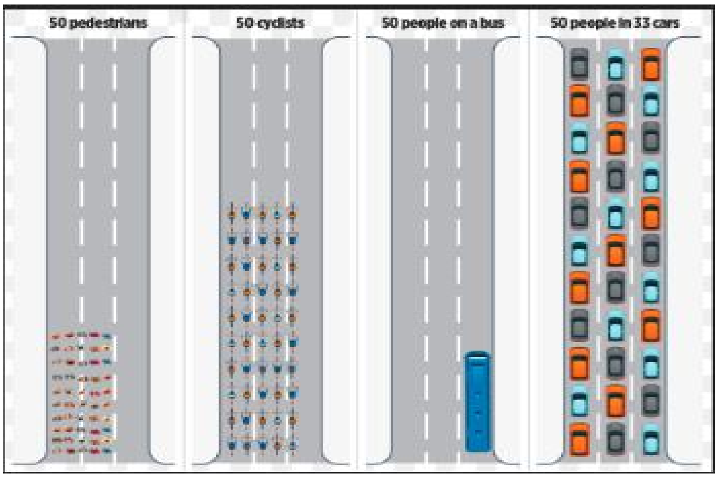

Figure 6 : Comparison of different road users and vehicles *(Source : phillytalksclimate.com)*

2.1 Impact on Society

The following among the impact to society in implanting the EV Bus.

1. **Environmental Sustainability**: The transition to electric buses and the promotion of public transport contribute significantly to reducing carbon emissions and combatting climate change. Cleaner air and a healthier environment are immediate benefits that have a lasting impact on the well-being of society.

2. **Improved Public Health**: By reducing emissions from diesel-powered vehicles and enhancing air quality, these initiatives directly address respiratory health issues. Fewer fine particulates in the air mean fewer respiratory problems, lower healthcare costs, and an overall healthier population.

3. **Enhanced Mobility and Accessibility**: The introduction of electric buses and smart technologies makes public transportation more convenient, user-friendly, and accessible to all residents. This fosters inclusivity, ensuring that transportation services cater to a broader demographic.

4. **Traffic Congestion Relief**: Less reliance on private cars and improved public transport options can lead to reduced traffic congestion. This translates to less time spent in traffic, lower stress levels among commuters, and ultimately, an improved quality of life.

5. **Economic Savings**: While the upfront investment in electric buses is substantial, these vehicles often have lower operational costs. This can potentially lead to savings in the city's transportation budget, which can be reinvested in public services or used to reduce fares, benefitting the public directly.

6. **Technological Advancements**: The integration of smart technologies, such as GPS and passenger counting systems, not only improves the commuting experience but also sets the stage for further technological advancements, potentially creating new opportunities and services for residents.

Kuala Lumpur's Smart City Framework and its commitment to sustainable transportation are transforming the city in ways that significantly benefit society. The impact extends beyond reducing carbon emissions and traffic congestion; it encompasses public health improvements, economic savings, enhanced accessibility, and a brighter, more sustainable future for all residents. By placing people at the centre of its initiatives and leveraging technology to improve lives, Kuala Lumpur exemplifies how Smart Cities can make a real difference in the world today.

Furthermore, implementing Electric Buses (EV buses) can effectively reduce carbon emissions through several key mechanisms:

1. **Zero Tailpipe Emissions**: Electric buses produce zero tailpipe emissions. Unlike traditional diesel or gasoline-powered buses, which emit harmful pollutants such as carbon dioxide (CO2), nitrogen oxides (NOx), particulate matter, and volatile organic compounds (VOCs), electric buses produce no such pollutants during their operation. This eliminates the direct contribution of these harmful emissions to air pollution and greenhouse gas accumulation.

2. **Energy Efficiency**: Electric buses are generally more energy-efficient than their internal combustion engine (ICE) counterparts. Electric motors convert a higher percentage of the energy from the power source into kinetic energy, while ICE vehicles experience energy losses through heat and friction. This increased energy efficiency means that electric buses can travel longer distances using the same amount of energy, ultimately reducing the overall energy consumption and associated carbon emissions.

3. **Clean Energy Sources**: When electric buses are charged with electricity generated from renewable and clean energy sources such as wind, solar, or hydroelectric power, their carbon footprint is significantly reduced. In regions where the electricity grid relies heavily on fossil fuels, there may still be emissions associated with electricity generation. However, the shift toward cleaner energy sources over time further reduces these emissions.

4. **Regenerative Braking**: Many electric buses incorporate regenerative braking systems. These systems capture and convert energy during braking or descending slopes, which is then returned to the vehicle's battery for reuse. This regenerative process not only improves energy efficiency but also reduces wear and tear on the braking system, resulting in longer vehicle lifespan and less maintenance.

5. **Reduced Noise Pollution**: Electric buses are quieter than traditional buses powered by internal combustion engines. Reduced noise levels not only contribute to a more pleasant urban environment but also promote the use of public transportation, further reducing the number of private vehicles on the road and associated emissions.

6. **Lifecycle Emissions**: While the manufacturing of electric buses and their batteries does have an initial carbon footprint, it is generally offset by the emissions savings over the vehicle's operational lifespan. As battery technology improves and becomes more sustainable, the lifecycle emissions associated with electric buses continue to decrease.

7. **Local Air Quality Improvement**: The absence of tailpipe emissions from electric buses directly improves local air quality. Reduced emissions of NOx and particulate matter have a positive impact on respiratory health and well-being for residents in urban areas.

3. Limitation and Future Works

Until August 2023, there have been 78 buses operating on the roads. However, many studies are still needed to gather more data regarding the amount of carbon that can be reduced. Lack of information related to technical data hinders the ability to calculate carbon emissions to facilitate load balancing, regulate frequency and voltage, reduce peak loads, and increase the use of renewable energy.

Further studies should also include a life cycle assessment, encompassing capital costs, labour costs, operational costs, and social costs related to carbon. Key performance metrics involve calculating the energy demand of EBs, investigating the impact of EBs on the power grid during charging, determining life cycle costs, and computing life cycle greenhouse gas emissions. Therefore, an optimization method should be developed to determine the optimal size of photovoltaic-grid-BEB charging components.

4. Conclusion

In conclusion, Kuala Lumpur's commitment to building a greener future through its Smart City initiatives is both commendable and promising. By embarking on a journey to reduce carbon emissions, the city is not only addressing pressing environmental concerns but also embracing a vision of sustainability and improved quality of life for its residents. Through initiatives such as transitioning to electric buses, promoting eco-friendly transportation methods, and implementing tax incentives for green vehicles, Kuala Lumpur is actively contributing to a more environmentally responsible and health-conscious urban landscape.

The city's efforts serve as an inspiring example for other metropolises worldwide, demonstrating that innovative technology, strategic planning, and the collective will to reduce carbon emissions can pave the way for a brighter, cleaner, and more sustainable future. As we witness Kuala Lumpur's transformation into a greener and smarter city, it reinforces the notion that sustainable urban development is not just a necessity but a beacon of hope for a better tomorrow.

Acknowledgement

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ASSESSMENT OF HORIZONTAL AXIS WIND MICROTURBINE WITH POWER OF 5 KW

Naing Htoo Hlaing[1]
Lecturer, Workshop and Mechanical Department, Yangon Technological University,
Yangon, Myanmar
E mail: nhtoo328@gmail.com

Abstract

The world is running out of conventional energy sources and there is a pressing need to utilize non-traditional energy sources to endure the ever-escalating energy needs. The health and the very survival of humanity are dependent on the health of the planet, which is deteriorating rapidly due to the burning of fossil fuels. Renewable energy is of paramount importance to humanity for this reason. Wind energy is one of the most ancient forms of energy. Wind turbines are an environmentally friendly power generation option for the sustainable future of our planet and of humanity. This provides an alternative way of generating energy from the power of wind. Under the circumstances of the total energetic recourses deficit in the Republic of the Union of Myanmar appears the problem of non-traditional sources utilization recovered by energy. Important sources of renewable energy are wind, solar, and hydraulic energies. Concurrently with the emergence of new energy sources (fossil fuels, atomic energy, etc.) this form of energy yielded up the priority and changed itself into an alternative one, which at present, begins to regain its positions not only from the ecological but also from the economical point of view. Under the circumstances of the present energy crisis (even at the worldwide level), wind energy conversion systems could have a significant weight in the production of (mechanical, electrical, etc.) energy. This paper deals with the elaboration and fabrication of the industrial prototypes of horizontal axis wind microturbines with a power of 5kW.

Keywords: blade, energy sources, horizontal axis, wind turbine

1. Introduction

Among renewable energy resources, wind energy is one of clean and inexhaustible energies. A wind turbine is a device that converts the kinetic energy of the wind into electrical energy that can be harnessed for use. Wind turbines can help us reduce the use of conventional resources. There are various designs of wind turbines all over the world. Types of wind turbines are horizontal and vertical axis wind turbines. They both have their advantages and disadvantages. The advantage of a horizontal wind turbine is able to produce more electricity from a given amount of wind.

For the horizontal axis wind turbine system, the efficiency of the system transformation is related to the blade shape. Therefore, it is critical to design the most efficient blade shape possible. Blade element momentum theory is widely used when designing horizontal-axis wind turbine blade design.

In general, three blades are used for the wind turbine system to keep the dynamic balance. The blades are the key to the operation of the wind turbine. The rotor blade among the components of the wind turbine system transforms wind power into mechanical power.

2. Data Calculation of Horizontal Axis Wind Turbine Blade

Data Specification;

Average wind speed, Vavg = 5 m/s

Cut-in speed, Vcut-in = 0.7 Vavg = 3.5 m/s

Rated speed, Vrated = 2 Vavg = 10 m/s

Cut-out speed, V-cut-out =3 Vavg = 15 m/s

Power coefficient, Cp = 47.41%

Mechanical efficiency, ηmech = 96%

Generator efficiency, ηgen = 70%

Number of blades, B = 3

Air density, $\rho = 1.2396 kg/m3$

Dynamic viscosity, $\mu = 1.7865\times10^{-5}$ Ns/m^2

For the calculation of rotor radius for three turbine blades, the intended designed power is 5kw and the data can be put into this electrical power equation [1].

$$Power = 1/2 \times \rho \times A \times (V_{rated})^3 \times C_p \times \eta_{mech} \times \eta_{gen} \quad (1)$$

$A = 25.32\ m^2$

$D = 5.6779\ m$

Three blades were chosen for this wind turbine. The solidity, S, must be less than 5% for three-bladed wind rotors. So it is set to be 4.5%. The average chord length C can be from the solidity equation.

$$S = \frac{BC}{\pi D} \quad (2)$$

$C = 0.2676\ m$

Reynold's number of airfoils can be calculated as follows.

$$Re = \frac{\rho\, VavgC}{\mu} \quad (3)$$

$Re = 92839$

In NACA 44, the airfoil value with the maximum lift-to-drag ratio is calculated by using COMSOL MULTI-PHYSICS for the most common airfoil shapes NACA 4412,4414 and 4415.

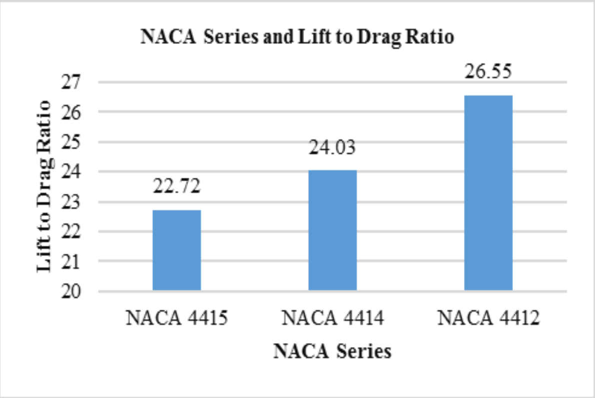


Figure 1. Compares the Lift Drag Ratio Between NACA 4412, NACA 4414, and NACA 4415

As a result, NACA 4412 is found that it has the maximum lift-to-drag ratio and it is selected for this design.

From Table 1. results, to drag ratio is maximum at an angle of attack of 6º. The lift coefficient is 1.02. The drag coefficient is 0.0384.

Table 1. Numerical Results of Lift and Drag Ratios Respect to Angle of Attack for NACA 4412 (By COMSOL Multi-physics)

Angle of attack (degree)	Lift coefficient	Drag coefficient	Lift to drag ratio
-1	0.2882	0.0246	11.72
0	0.3953	0.0251	15.76
1	0.5023	0.0262	19.20
2	0.6121	0.0276	22.18
3	0.7225	0.0296	24.41
4	0.8269	0.0320	25.82
5	0.9242	0.0350	26.36
6	1.0200	0.0384	26.57
7	1.1190	0.0431	25.96
8	1.2050	0.0539	24.98
9	1.2520	0.0539	23.22
10	1.3050	0.0617	21.16

The blade is divided into 10 equal sections as shown in Figure 2. The length of 0.1190 m at the root of the blade is to attach the blade and hub. dr is the length of each divided section. The radius of the rotor axis to each section is denoted by ri, and the subscript i refers to the section number.

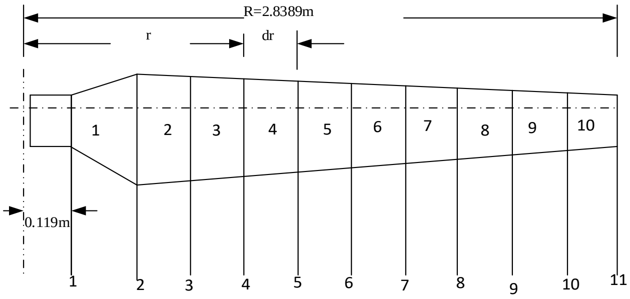


Figure 2. Elements of the blade section

$$dr = \frac{R-0.119}{\text{number of section}} \quad (4)$$

dr = 0.272 m

For sections 2 to 11,

$$r_i = r_{i-1} + dr \quad (5)$$

The following formula is used to calculate the speed ratio at each section and tip speed ratio λ for power coefficient (0.4741) and the three-blade rotor is 6 from Appendix (Figure. A).

$$\lambda_r = \lambda \text{ x } \frac{r}{R} \quad (6)$$

Table 2. Calculated Results of Speed Ratio for Rotor Blade at Each Section

Cross section number	Tip speed ratio λ	Radius,r (m)	Speed ratio λ_r
1	6	0.119	0.2515
2	6	0.391	0.8264
3	6	0.663	1.4012
4	6	0.935	1.9761
5	6	1.207	2.5510
6	6	1.479	3.1174
7	6	1.751	3.7007
8	6	2.023	4.2756
9	6	2.295	4.8505
10	6	2.567	5.4253
11	6	2.837	6.0000

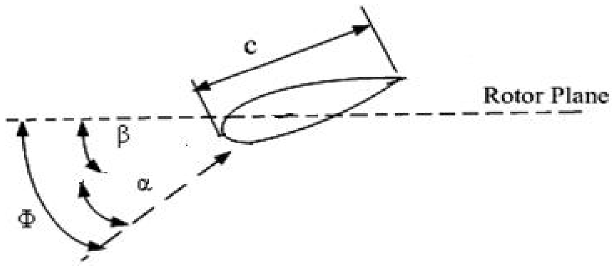


Figure 3. Blade Setting Angles

The shape parameters for each speed ratio λr1 to λr11, from Appendix (Figure. B) are 3.2, 3.2, 1.8, 1.2, 0.8, 0.6, 0.45, 0.32, 0.25, 0.19 and 0.17.

Chord length, $c = \frac{rxSP}{C1xB}$ (7)

Twist angle, $\phi = \tan^{-1} [\frac{2}{3} \text{ x } \frac{1}{\lambda 1}]$ (8)

Blade setting angle, $\beta = \phi - \alpha$ (9)

Airfoil maximum thickness,

$t = c \times 0.12$ (10)

Table 3. Calculated Results of Blade Parameters

Cross section number	α (degree)	c (m)	ϕ (degree)	β (degree)	t (m)
1	6	0.1244	69	63	0.0149
2	6	0.4089	39	33	0.0491
3	6	0.3900	25	19	0.0468
4	6	0.3667	19	13	0.0440
5	6	0.3156	15	9	0.0379
6	6	0.2892	12	6	0.0347
7	6	0.2575	10	4	0.0309
8	6	0.2116	9	3	0.0254
9	6	0.1875	8	2	0.0225
10	6	0.1597	7	1	0.0192
11	6	0.1577	6	0	0.0190

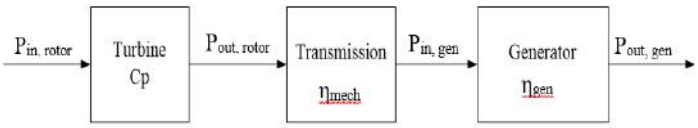


Figure 4. Power transmission Diagram from Rotor Input Power to Generator Output Power

$P_{in,rotor} = 1/2x\ \rho\ A\ (V_{rated})^3 = 15.6939$ kw

$P_{out,rotor} = P_{in,rotor}\ xC_P = 7{,}4405$ kw

$P_{in,gen} = P_{out,rotor}\ x\ \eta_{mech} = 7.1429$ kw

$Po_{ut,gen} = P_{in}\ x\ \eta_{gen} = 5$ kw

3. Stress On The Blade

To make the stress analysis, the loading conditions must be known so it is essential to know how the aerodynamic and centrifugal forces are acting on the blade. In the simulation test, the thrust and moment forces which are the components of lift and drag forces are implied on each blade section. The values of aerodynamic forces acting on each blade are described in Table 4. The following relation for centrifugal force can be used for centrifugal force.

$F_c = mr\omega^2$ (11)

Where F_c is centrifugal force (N), m is the mass of an element (kg), ω is the angular velocity (27.0522rad/sec) and r is the distance between the rotor center and blade C.G(m).

Stress analysis can be performed by using failure theories. Von Mises's failure theory will be used to check the strength of the blade. Von Mises stress, also known as Huber stress, is a measure that accounts for all six stress components of a general 3-D state of stress. The Von Mises equivalent stress is computed as:

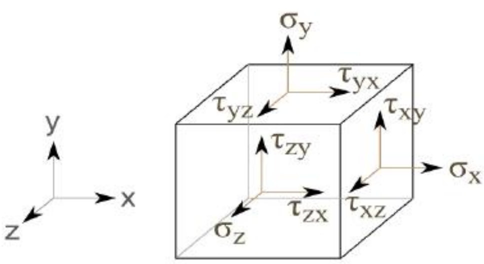


Figure 5. 3D state of stress

$$\sigma_{VM}=[0.5(\sigma_x-\sigma_y)^2+(\sigma_y-\sigma_z)^2+(\sigma_z-\sigma_x)^2+3(\tau_{xy}^2+\tau_{yz}^2+\tau_{zx}^2]^{1/2} \quad (12)$$

Where, σ_x= direct stress in the x-direction

σ_y= direct stress in the y-direction

σ_z = direct stress in the z-direction

τ_{xy} = shear stress on the xy-plane

τ_{yz} = shear stress on the yz-plane

τ_{zx} = shear stress on the zx-plane

$$\sigma_x=\frac{Ex}{h}[1-(v_{yz})^2\frac{E_z}{E_y}](\varepsilon_x-\alpha_x\Delta T)+\frac{E_y}{h}(v_{xy})+v_{xz}v_{yz}\frac{E_z}{E_y}(\varepsilon_y-\alpha_y\Delta T)+\frac{E_z}{h}(v_{xz}+v_{yz}v_{xy})(\varepsilon_z-\alpha_z\Delta T) \quad (13)$$

Where

The value of h can be determined from the following equation.

$$h=1-(v_{xy})^2\frac{E_y}{E_x}-(v_{yz})^2\frac{E_z}{E_y}-(v_{xz})^2\frac{E_z}{E_x}-2v_{xy}v_{yz}v_{xz}\frac{E_z}{E_x} \quad (14)$$

The shear stress equation can be described as follows:

$$\sigma_{xy}=G_{xy}\varepsilon_{xy} \quad (15)$$

Where ε_{xy}= shear strain in the x-y plane

G_{xy}= shear modulus

Then according to von Mises's failure criterion, the material under multi-axial loading will yield when the von Mises stress is equal to or greater than the critical value for the material.

$$\sigma_{VM}\geq\sigma_v \quad (16)$$

Table 4. Mechanical Properties of Material

Type	Pine(Pinus strobes)	Red Oak	Teak wood (Tectona Grands)
Elastic modulus(MN/m^2)	11500	8100	9400
Poisson's ratio	0.328	0.154	0.341
Mass density (kg/m^3)	470	560	630
Yield strength (MN/ m^2	11500	47	10830

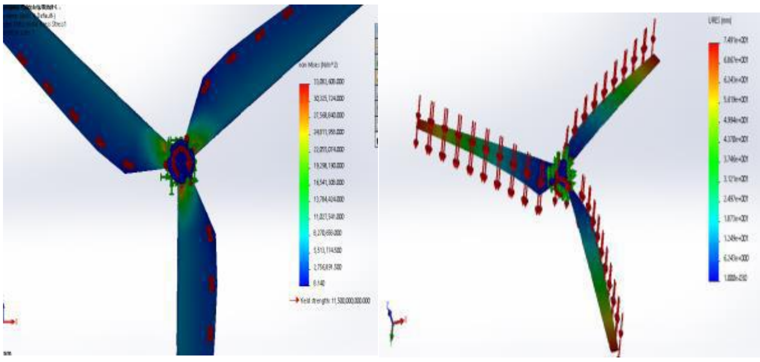


Figure 6. Stress and Deflection Induced in the Blade (Pine)

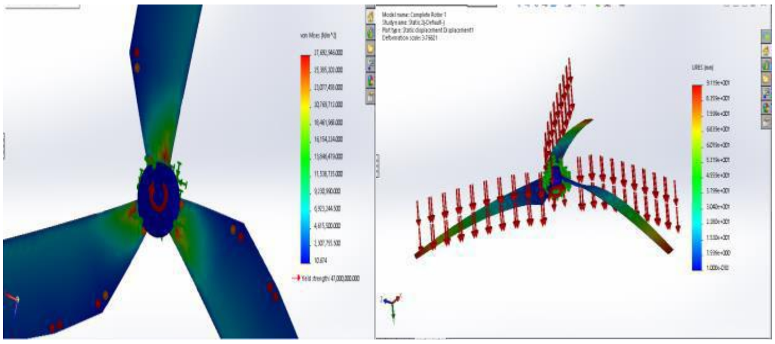


Figure 7. Stress and Deflection Induced in the Blade (Red Oak)

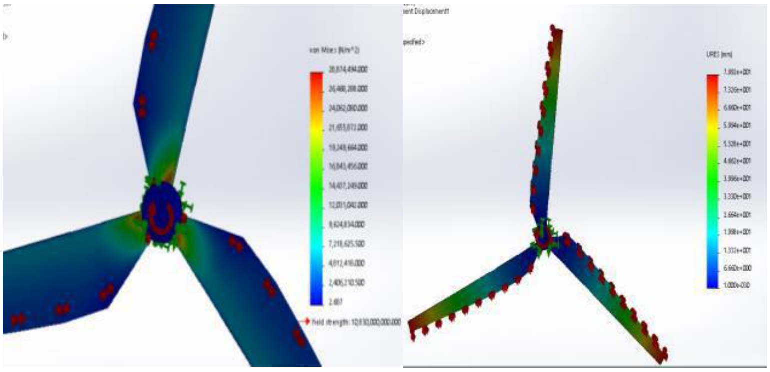
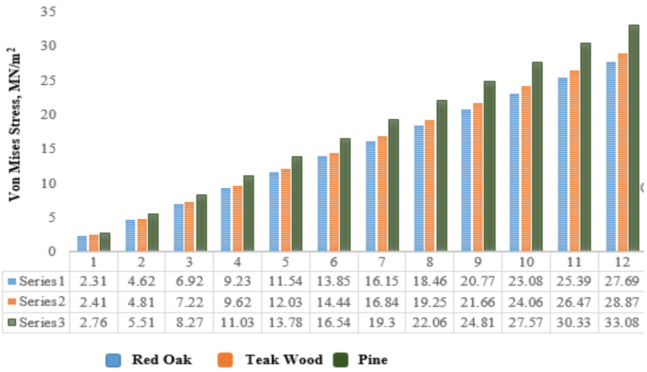


Figure 8. Stress and Deflection Induced in the Blade (Teak wood)

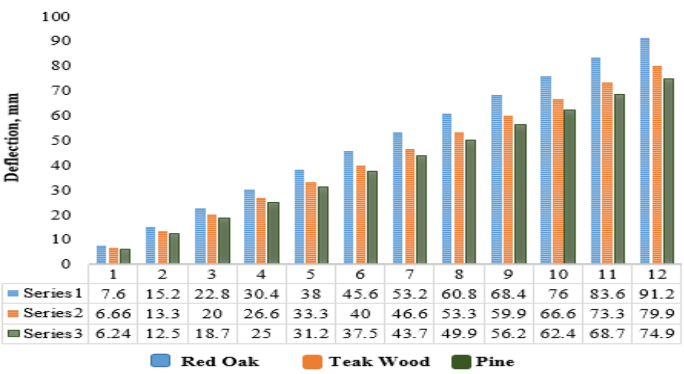
4. Results and Discussion

After making a stress simulation, the Von-Mises stress at the blade for three different materials is compared with their respective yield strength. In Red Oak, Teak wood, and Pine, the maximum Von-Mises stresses occur at the blade root and the maximum deflections occurring at the blade tip are very small.



	1	2	3	4	5	6	7	8	9	10	11	12
Series1	2.31	4.62	6.92	9.23	11.54	13.85	16.15	18.46	20.77	23.08	25.39	27.69
Series2	2.41	4.81	7.22	9.62	12.03	14.44	16.84	19.25	21.66	24.06	26.47	28.87
Series3	2.76	5.51	8.27	11.03	13.78	16.54	19.3	22.06	24.81	27.57	30.33	33.08

Figure 9. Results of Von Mises Stress of Pine, Red Oak, and Teak Wood



	1	2	3	4	5	6	7	8	9	10	11	12
Series1	7.6	15.2	22.8	30.4	38	45.6	53.2	60.8	68.4	76	83.6	91.2
Series2	6.66	13.3	20	26.6	33.3	40	46.6	53.3	59.9	66.6	73.3	79.9
Series3	6.24	12.5	18.7	25	31.2	37.5	43.7	49.9	56.2	62.4	68.7	74.9

Figure 10. Results of deflection of Pine, Red Oak, and Teak Wood

Table 5. Comparison with Simulation Results of Pine, Red Oak, and Teak Wood

Materials	Maximum Von Mises Stress (MN/m^2)	Maximum Deflection (mm)
Pine	33.08	74.91
Red Oak	27.69	91.2
Teak wood	28.87	79.92

The Von-Mises stresses of three different materials are less than their respective yield strength. So, the designed blade is safe.

According to the simulation result, Von Mises stress and deflection that occur at the blade (Teak wood) is more than the other two materials. So, Teak wood is a suitable material for this design.

5. Conclusion

In this paper, the blade is divided into 10 equal sections, and chord length, twist angle, blade setting angle, airfoil thickness, tip speed ratio, velocity components, lift force, drag force, thrust force, moment force, and power acting on each blade section was calculated. The power input to the rotor is 15.6939kW and the power output from the rotor is 7.4405kW. Power input to the generator is 7.1429kW and the power output from the generator is 5kW.

In this paper, Pine, Red Oak, and Teak wood are simulated for Von-Mises stress. The Von-Mises stress at the blade for three different materials is compared with their respective yield strength. The Von-Mises stresses of three different materials are less than their respective yield strength. So, the designed blade is safe. According to the simulation result, Von Mises stress and deflection that occur at the blade (Teak wood) is more than the other two materials. So, Teak wood is a suitable material for this design.

Appendix

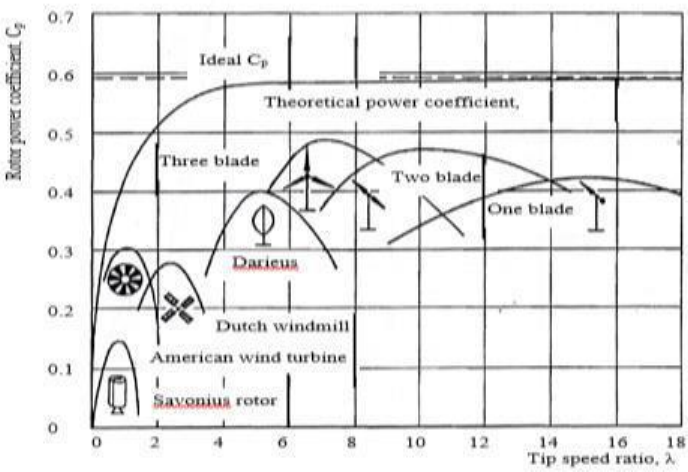


Figure A. Tip speed ratio Vs performance coefficient [2]

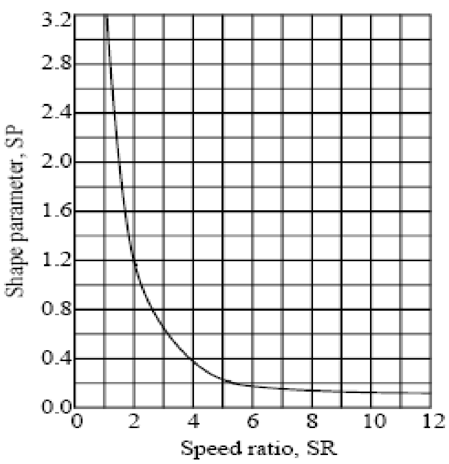


Figure B. Tip Speed Ratio Vs Shape Parameter

Acknowledgment

The author would like to express his teachers who taught him everything from childhood now. The author would like to acknowledge his sincere thanks and gratitude to all those who have offered their useful advice, criticism, and help during the preparation of this research.

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BALANCING ENERGY CONSUMPTION, ECONOMIC GROWTH, AND EMISSION REDUCTION IN ASEAN NATIONS: INSIGHTS INTO THE GREEN ENERGY TRANSITION

King Harold A. Recto, Romano Q. Neyra and Rex Paolo C. Gamara

1. Department of Electronics, Computer and Communications Engineering, Faculty, Ateneo de Manila University, Loyola Heights, Quezon City, 1108, Philippines
2. College of Engineering, Senior Director for Engineering, FEU Institute of Technology, P. Paredes Street, Manila, 1015, Philippines
3. Electronics Engineering Department, Faculty, FEU Institute of Technology, P. Paredes Street, Manila, 1015, Philippines

E-mail: krecto@ateneo.edu, rqneyra@feutech.edu.ph,rcgamara@feutech.edu.ph

Abstract

As the global pandemic recedes, economic activities around the world are resuming. However, this action has also impacted various facets of the society, particularly energy use, economic expansion, and pollution control. While numerous studies have investigated this issue, they have predominantly focused on the global level, with an emphasis on industrialized nations. Naturally, this backdrop is much different from Southeast Asia. In this study, the mathematical relationships between energy consumption, economic growth, and emission reduction were determined using regression modelling of the World Energy Council (WEC) trilemma scores of the Association of Southeast Asian Nations (ASEAN) members, as well as its implications for sustainable energy policy in the ASEAN. The analysis discovered that the best fit model to utilize for this purpose is Gaussian Process Regression - Exponential GPR. In light of the results, measures that would help ASEAN take the Green Energy Transition were proposed:

(1) Promoting investments in clean and renewable energy sources to support long-term economic growth and at the same time lower carbon emissions.
(2) Encouraging governmental organizations and businesses to adopt and incorporate cleaner energy technology and practices in order to support the goals of global sustainability.
(3) Implementing efficient strategies to reduce carbon dioxide emissions resulting from energy use to ensure a trajectory towards greater environmental awareness.
(4) Examining variations in energy use and efficiency between the ASEAN region to allow energy policies to be tailored to meet particular demands and difficulties.
(5) Motivating people, organizations, and communities to adopt energy-saving practices and technologies in order to collectively reduce energy demand and aid in environmental preservation.

Keywords: Economic Growth, Energy, Energy Trilemma, Environment, Sustainability

1. Introduction

This paper is an extension of work originally presented in conference name at the International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management 2023. [1]

The economies of countries like the Philippines are anticipated to revive with the lifting of lockdowns and the return to the workplace of many people who used to work remotely. For instance, the research by Wang et al. [2] shows that China's overall demand for power in all sectors has returned to pre-pandemic levels. Other countries, like India and the European Union, have also seen a rise in energy usage as a result of the softening policies. [3]

Therefore, as stated by Acheampong [4], effects on economic development and carbon emissions are to be anticipated. Although he discovered that economic development has no impact on energy use, he also discovered that energy use "uni-directionally" promotes economic growth. Aside from that, he also discovered that increased energy use and carbon emissions are inversely correlated.

Speakers at the United Nations conference on sustainable development now concur that energy is essential to resolving almost all other significant social issues, including the elimination of poverty, food security, employment, health, and education. [5]. However, over 60% of all global greenhouse gas emissions are related to the energy sector. [6]

This paper aims to provide insights into potential policy directions in light of the global recovery from the pandemic by understanding the interaction between energy consumption, economic growth, and emission reduction in the ASEAN region.

2. Literature Review

A straightforward instrument to help with energy policies was supplied by Gasser's recent comparative analysis of the energy security indices of numerous countries, including Thailand and Singapore. [7] It cannot, however, address other energy-related problems, including environmental sustainability and energy equity

The Cherp and Jewell research [8] provided a more comprehensive analysis of energy since it went beyond the four A's—availability, affordability, accessibility, and acceptability—to concentrate on energy security. However, its treatment of environmental sustainability is within the limits of accessibility. As it is, the study made note of the fact that each stakeholder defines what is environmental differently. The research by Axon and Darton [9], which incorporates sustainability and risk into its analysis of energy security, is another more thorough study. In fact, the report discovered overlaps between energy security and sustainability and suggested ways to enhance energy security assessments to support policymakers. However, the strategy lacks a specific emphasis on Southeast Asia since it is generalist in its approach. Furthermore, a more thorough examination of the relationship between the economy and energy appeared to be beyond the purview of their article.

In his study [10], Radovanovic developed a novel method for measuring energy security that is sustainable in that it already takes into account social and environmental factors. Even though these were considered, the economic effect was a clear component of the final method for assessing energy security. The economics are covered in Liu et al.'s [11] study. It was also able to address environmental sustainability, energy security, and equity by employing the energy trilemma concept. Finally, the Lu et al. [12] article is more detailed since it explores the tension between economic development and emission reduction. However, the research was only conducted on the top 10 performing countries according to the World Energy Council's energy trilemma ranking. Moreover, it seems that the study's coverage of energy use is limited.

3. Research Questions and Methodology

This paper answers the question, "What are the impacts of environmental sustainability, energy security, and energy equity to energy consumption, economic development, and emission reduction in the Association of Southeast Asian Nations (ASEAN). It specifically tries to respond to the following questions: (1) What mathematical model would connect the energy trilemma—that is, energy justice, security, and sustainability—with ASEAN's energy consumption? (2) What mathematical model would link ASEAN economic expansion to the energy trilemma? (3) What mathematical model would link ASEAN carbon reduction to the energy trilemma? (4) What ramifications do the created models have for an ASEAN sustainable energy policy?

Data were processed and gathered from reliable online sources to address these questions. This comprises the most current World Energy Trilemma indices for ASEAN from the World Energy Council for environmental sustainability, energy security, and energy equity. These countries' energy consumption, economic expansion, and emission reductions were also gleaned from other data sources such World Data Info and Statistica. The process shown in Figure 1 is then followed by the relevant regression models. [13]

Fig. 1. Training Regression Model

In this study, a number of regression models were taken into account, including the squared exponential kernel, exponential kernel, matern 3/2, matern 5/2, rational quadratic kernel, ARD squared exponential kernel, exponential kernel, matern 5/2, and rational quadratic kernel. [14] The answers to the first three research questions are then obtained by comparing the root mean squared error (RMSE), R-squared coefficient of determination, mean squared error (MSE), and mean absolute error (MAE) of each regression model. [15] The training time in seconds (sec) and prediction time in observations per second (obs/sec) are additional metrics that are mentioned. Policy implications were generated based on the models used.

4. Results and Discussion

Mathematical Model Relating Energy Trilemma with Energy Consumption. The World Energy Council (WEC) Trilemma Scores for ASEAN nations are shown in Table 1 in terms of energy equity, environmental sustainability, and security of supply [16].

Table 1. World Energy Council Trilemma Scores

Country	Table Column Head		
	Energy Security	*Environmental Sustainability*	*Energy Equity*
Brunei	52.1	60.4	95.4
Cambodia	50	56.7	36.1
Burma (Myanmar)	58.4	58.3	27.7
Singapore	38.2	67.7	95.7
Philippines	58.4	62.5	46.1
Malaysia	64.1	64.4	91.5
Vietnam	58.6	55.9	67.5
Thailand	55.5	63.7	70.5
Indonesia	64.4	63.9	57

The trilemma ratings place Indonesia and Malaysia at the top for energy security, receiving 64.6 and 64.1 points, respectively. The top two countries in terms of environmental sustainability were Malaysia and Singapore, with ratings of 64.4 and 67.7, respectively. In terms of energy equity, Singapore and Brunei are at the top with scores of 95.7 and 95.4, respectively.

Table 2. Energy Consumption of ASEAN Countries

Country	Energy Consumption (Billion kWh)
Brunei	3.77
Cambodia	5.86
Burma (Myanmar)	14.93
Singapore	47.69
Philippines	78.3
Malaysia	136.9
Vietnam	143.2
Thailand	187.7
Indonesia	213.4

Table 2 shows the comparable energy usage for the ASEAN nations in billions of kWh units. [17] Thailand and Indonesia are rated 213.4 and 187.7, respectively, making them the top two nations. With respective energy consumption of 3.77 and 5.86, Brunei and Cambodia are the least energy-intensive countries.

Based on regression modeling of the data in Tables 1 and 2, the Gaussian Process Regression-Exponential GPR model produced the best results, with a prediction time of 4100 obs/sec and training time of 0.10137 sec, and the lowest RMSE value of 0.0096449, R-squared coefficient of 1.00, MSE of 9.3025e-05, MAE of 0.008936. The best-fitting regression model is shown in Figure 2 on the response plot of each input record to the output of energy consumption.

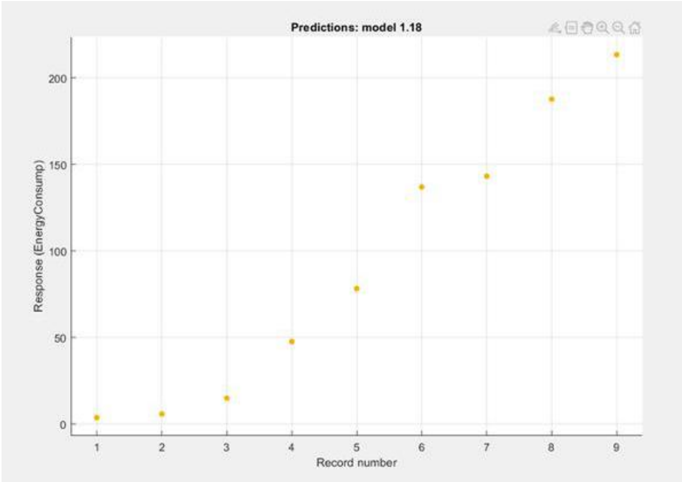

Fig. 2. Trilemma Score vs. Energy Consumption Response Plot (Best Fit)

The second-best-fitting SVM-Fine Gaussian Model is shown in Fig. 3. It includes the following statistics: prediction time is 3900 obs/sec, training time is 0.084929 sec, RMSE is 11.168, R2 is 0.98, MSE is 124.73, and MAE is 11.057.

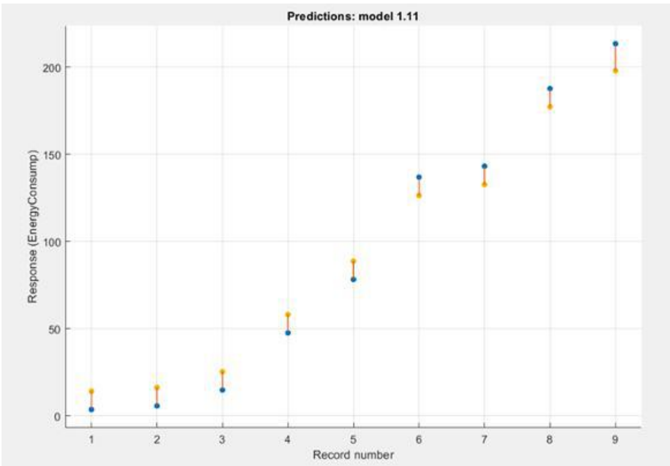

Fig. 3. Trilemma Score vs. Energy Consumption Response Plot (2nd Best Fit)

Mathematical Model Relating Energy Trilemma with Economic Growth. Table 3 presently shows the GDP of the ASEAN member states together with the economic development of each nation. [19] Thailand and Indonesia are ranked first and second, with 1,059.90 and 500.29 points, respectively. However, with 25,19 and 12, respectively, Cambodia and Brunei are the lowest.

The Gaussian Process Regression-Exponential GPR model has the lowest RMSE value of 0.037405, the highest R-squared coefficient of 1.00, the lowest MSE of 0.0013991, and the lowest MAE of 0.025956 when regression modeling is applied to the data shown in Tables 1 and 3. It has a prediction rate of around 3800 obs/sec and a training rate of 0.0928224 seconds. Fig. 4 presents the response plot of each input record to the GDP output along with the best-fitting regression model.

Table 3. Economic Growth (GDP) of ASEAN Countries

Country	GDP (Billion USD)
Brunei	12
Cambodia	25.19
Burma (Myanmar)	81.26

Singapore	345.29
Philippines	361.49
Malaysia	337.28
Vietnam	342.94
Thailand	500.29
Indonesia	1,059.90

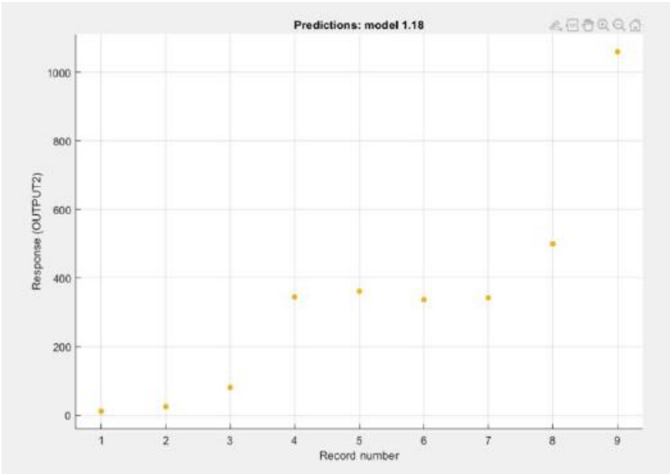

Fig. 4. Trilemma Score vs. Economic Growth (GDP) Response Plot (Best Fit)

Contrarily, Fig. 5 depicts the Gaussian Process Regression (Matern 5/2 GPR Model), the second-best fitting model. Its RMSE was 82.024, its R-squared was 0.93, its MSE was 6727.9, and its MAE was 58.053. Its training time was 0.0749201 seconds, and its prediction time was 3600 obs/sec.

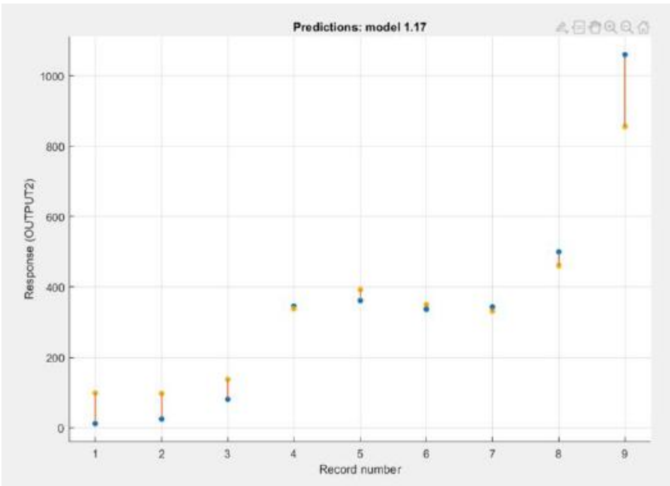

Fig. 5. Trilemma Score vs. Economic Growth (GDP) Response Plot (2^{nd} Best Fit)

Mathematical Model Relating Energy Trilemma with Emission Reduction. The ASEAN nations' reductions in carbon dioxide (CO_2) emissions are shown in Table 5. [18] Only Singapore and Thailand truly saw a decrease in CO2 according to the statistics, as seen by the positive readings of 0.258 and 0.098, respectively. All other countries have negative carbon dioxide emissions, with Cambodia and Myanmar having the worst levels at -0.76 and -0.64, respectively.

Table 4. Emission Reduction of ASEAN Countries

Country	CO_2 Reduction Percentage (Billion kWh)
Brunei	-0.428571429
Cambodia	-0.764705882
Burma (Myanmar)	-0.636363636
Singapore	0.258064516
Philippines	-0.214285714
Malaysia	-0.176724138
Vietnam	-0.316062176
Thailand	0.097902098
Indonesia	-0.06884058

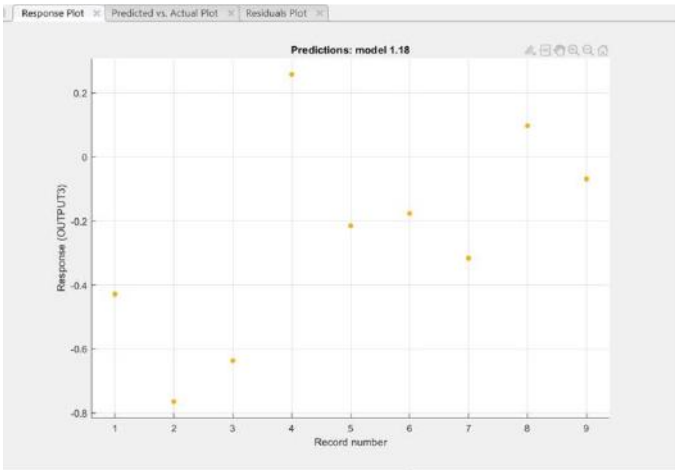

Fig. 6. Trilemma Score vs. CO_2 Emission Reduction Response Plot (Best Fit)

The Gaussian Process Regression-Exponential GPR model produced the lowest RMSE value of 3.8646e-05, R-squared coefficient of 1.00, MSE of 1.4935e-09, and MAE of 3.2929e-05 based on the regression modelling of the data shown in Tables 1 and 4. Its training time is 0.0663644 seconds, and its prediction time is around 3500 obs/sec. The best-fitting regression model is shown in Fig. 6, which shows the response plot of each input record to the CO2 emission reduction output.

The Gaussian Process Regression-Matern 5/2 GPR Model, the second-best-fitting model, is seen in Figure 7. Its R-squared coefficient is 1.00, its RMSE is 4.5631e-05, its MSE is 2.0822e-09, and its MAE is 3.9652e-05. Additionally, it has a training time of 0.0679793 seconds and a prediction time of around 5400 obs/sec.

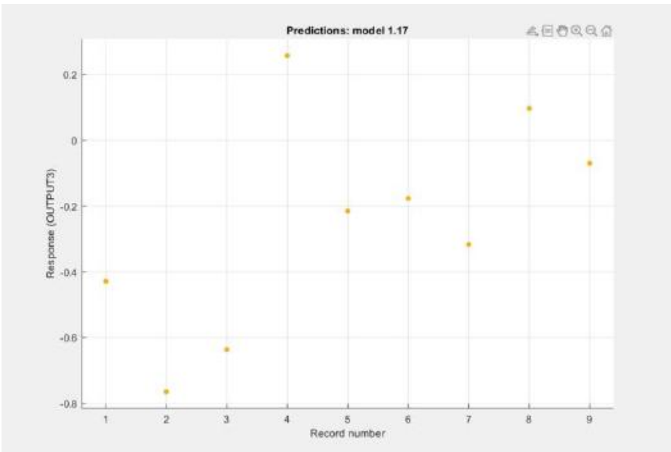

Fig. 7. Trilemma Score vs. CO_2 Emission Reduction Response Plot (2nd Best Fit)

Implications to Sustainable Energy Policy in the ASEAN. The models created seem to concur with Acheampong's results [3] about the link between energy use and economic expansion. Since a model was discovered to connect the energy trilemma scores to carbon dioxide reduction, an indication of environmental quality, they also supported Liu et al.'s [10] assertion about the link between energy consumption and environmental quality. Additionally, by taking into account the situation in the ASEAN area, it reinforced the research of Fu et al. [12] on the dynamic effect of the energy trilemma index on economic development and emission reduction. In other words, boosting the nation's performance in the environmental sustainability, energy security, and energy equity indices would have favorable effects given that it was discovered that energy consumption, economic growth, and emission reduction were associated with the WEC trilemma scores. This effectively makes the development of green energy transition the goal of policy directives since the transition to sustainable energy has been shown to have favorable long-term effects on both economic growth and environmental quality, as indicated by Liu et al. [11] and corroborated by this research.
To that purpose, the following proposals for policy towards the Green Energy transition, set in the context of the ASEAN, are made:

- *Promoting investments in clean and renewable energy sources to support long-term economic growth and at the same time lower carbon emissions.* Implementing measures like tax incentives for businesses joining the industry, which produce short-term investment boosts, is one way to encourage investment in sustainable energy. These regulations foster an infusion of money and encourage innovation, growth, and job development in the renewable energy sector. Beyond the short-term benefits, such investments benefit ASEAN nations long-term by helping them perform better in the WEC Energy Trilemma, which balances energy security, equity, and sustainability.

  By embracing cutting-edge technology for sustainable energy, diversifying the energy mix via increasing investment can also increase energy security. Furthermore, by increasing accessibility of renewable energy to a wider range of demographics, these investments also improve energy equity. In addition, moving away from fossil fuels supports sustainability objectives by reducing negative environmental effects including pollution and emissions.

  A key component of this approach is investing strategy in Energy Storage, as emphasized by Andoni et al. [20]. Energy storage options are adaptable when it comes to managing sporadic renewable energy, lowering curtailment, and boosting system resilience. Energy storage sets the door for more renewable energy source adoption by increasing the capacity of renewable energy sources at certain sites. Encouragement of strategic energy storage and investments in sustainable energy work together to address short-term economic goals and long-term trilemma problems, supporting a sustainable energy landscape.

- *Encouraging governmental organizations and businesses to adopt and incorporate cleaner energy technology and practices in order to support the goals of global sustainability*. According to Li [21], the increasing demand for both industrial and household energy justifies the necessity of a coordinated drive towards a sustainable energy transition. To effectively handle this growing demand, effective monitoring becomes essential. The overall goal is to streamline this transition process through a calculated shift towards electrification. Industries and people must move away from polluting energy sources and pave the way for a more sustainable energy environment by adopting electrification based on clean energy.

  Moreover, it is also crucial to address air pollution caused by industrial energy sources. This calls for a gradual transition to cleaner fuels. Finally, it should be noted that the effective implementation of the transition is just as important as creating strategies and goals for the adoption of clean energy throughout ASEAN nations. It is important to remember that a poorly planned shift might possibly impede economic progress. Therefore, it is essential to have a well-thought-out transition strategy to prevent negative economic effects while seeking greener energy sources.

- *Implementing efficient strategies to reduce carbon dioxide emissions resulting from energy use to ensure a trajectory towards greater environmental awareness*. For ASEAN nations, reducing energy-related CO2 emissions must be a top priority, necessitating the implementation of focused policies to reduce the share of fossil fuels in the energy mix. A workable strategy combines strict restrictions on the use of petroleum with powerful incentives to promote the use of eco-friendly substitutes like electric vehicles. ASEAN countries can significantly reduce carbon emissions by carefully reducing the use of fossil fuels and promoting cleaner alternatives. Other nations in the area might copy these procedures in order to achieve equivalent reductions in their CO2 emissions by taking inspiration from the effective carbon reduction programmes of Singapore and Thailand.

Zhao and Li [22] provide an illustration of an inventive effort addressing emissions reduction. In their proposal, an innovative idea known as an offshore hybrid renewable energy sources (OHRES) system is introduced. This system aims to achieve zero CO2 emissions from offshore platforms and so help to mitigate climate change. In order to balance out the inherent fluctuation of wind energy in the OHRES system, this innovative technology integrates Battery Energy Storage Systems (BESS) with Hydrogen Energy Storage Systems (HESS). By enhancing the reliability of renewable energy sources and thereby lowering the carbon footprint associated with energy production, this strategy emphasizes the potential of energy storage systems.

- *Examining variations in energy use and efficiency between the ASEAN region to allow energy policies to be tailored to meet particular demands and difficulties*. The key to identifying neglected people and launching policy reforms for their benefit is studying the differences in energy usage and efficiency among diverse groups within ASEAN nations. An in-depth understanding of energy access and consumption patterns is made possible by research initiatives centered on this issue, which in turn enables governments to develop policies that are specifically tailored to the requirements of marginalized people. The ASEAN nations can improve energy equity and guarantee that all facets of society have equitable and affordable access to energy resources by identifying and addressing these gaps. Additionally, examining successful models from nations like Malaysia and Singapore might offer important insights that can help other ASEAN countries develop successful policies to improve energy equity.

  The examples of Malaysia and Singapore provide powerful illustrations of successful policies to promote energy equity. Other ASEAN nations may learn a lot from their best practices when developing their own policies to guarantee universal access to electricity. The implementation of tested strategies that have produced fruitful results is made possible by this information sharing which results to further quickening of the march towards just energy allocation. A collaborative approach to energy equity is fostered by such cross-country learning, which also empowers the area to make more informed and significant policy choices.

  The study carried out by Kluabwang et al. [23] serves as an example of a research in this field that the different nations may want to embark on. This research provides as an example of attempts to understand energy consumption differences between various populations. Such study not only clarifies discrepancies but also prepares the road for decision-making based on facts. ASEAN nations may make significant progress towards closing the energy access gap, creating social inclusion, and advancing sustainable development by examining energy usage trends, identifying vulnerable populations, and suggesting targeted policy reforms.

- *Motivating people, organizations, and communities to adopt energy-saving practices and technologies in order to collectively reduce energy demand and aid in environmental preservation.* One practical way of doing this in the households is following the recommendations of Liang et al. [24]. By installing rooftop photovoltaics (PV) systems together with energy storage devices, a building can be converted to zero net energy (ZNE). In their study, smart meter data collected from 5000 buildings at 30-minute resolution in 2016 are used as the baseline energy consumption. To create “ZNE ready” load profiles, water heater and air conditioning loads are first separated from the total building energy consumption and are replaced by energy efficient water heaters and air conditioner load profiles.

  It should be noted that for sustainable development in ASEAN nations, energy conservation and improved energy source efficiency go hand in hand. While pursuing energy sources that are more efficient like the energy efficient water heaters and air conditioners is vital, focusing on energy savings offers a quick and affordable option to reduce energy usage. Adopting daylight saving time (DST) is one possible method for doing this. However, because to potential negative effects on residents' health, the introduction of DST needs to be carefully considered. To achieve a balanced approach, governments should perform in-depth investigations before enacting such regulations.

5. Conclusion

This study provided important new understandings of how environmental sustainability, energy security, and energy equity interact in ASEAN nations. It highlights the significant influence of these variables on key energy-related measures, including energy consumption, economic growth, and emission reduction. The complex nature of these linkages is shown by the choice of the Gaussian Process Regression (exponential GPR) model as the best method for connecting the energy trilemma with energy consumption, economic growth, and emission reduction. This finding provides a solid foundation for understanding and forecasting the effects of sustainable energy policies on ASEAN's energy system.

The evident implication of this research is that the sustainable energy plan of the region must prioritize a green energy transition. The integration of renewable energy sources, strengthening energy security, and providing fair access to energy become the three main foundations. With a united strategy that improves their position on the energy trilemma ratings, ASEAN nations may make significant progress in balancing environmental sustainability, energy security, and fair energy distribution by embracing these elements.

In essence, the findings of this research shed light on the role of energy equity, security, and environmental sustainability in determining ASEAN's energy landscape. The ASEAN countries can use these insights to plow the road for a comprehensive green energy transition that harmonizes the goals for a resilient and sustainable future by including sustainable energy policies into their trilemma solutions.

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ERGONOMIC DESIGN AND DEVELOPMENT OF FOOD CART WITH SOLAR PHOTOVOLTAIC SYSTEM

Willie C. Buclatin[1], Aivar M. Lopez[2], Celso S. Lobos[3], Catherine T. Mendrez[3], Mariel E. Peji[3], Dianne V. Salandanan [3]
[1]Department of Industrial Engineering and Technology, Cavite State University, Indang, Cavite, 4122, Philippines
willie.ceit@cvsu.edu.ph

Abstract

The focus of the study was to develop an ergonomic food cart with solar photovoltaic system. The assessment of the condition of workers, as well as preparation of solutions for improvement were presented through the application of DMADV methodology. The researchers determined the needs of users in relation to the usability of the product. Such issues include insufficiency of space and appropriate security measure, as well as difficulty in control and maneuverability for user-performance view; aesthetics and appearance on user-oriented view; and musculoskeletal disorder risks and manual machine use for product-oriented view of the user. MSD risks on upper, central and lower body caused by static positions, repetitive motions and poor posture were also analyzed. In order to aid in the application of ergonomics for the proposed design, comparative analysis between anthropometric measurements of the users and current cart dimensions were performed.

For the proposed invention, the use of electric food cart was recommended. Renewable energy in the form of solar energy was used as the main source of power for the electric food cart with the installation of standalone solar PV system.

Keywords: Keywords: ergonomics, solar photovoltaic, DMADV

1. Introduction

Food cart business has grown considerably in recent years, with its rapid expansion being attributed to customers' desire for quality, value, speed and preference for small and sustainable establishments. Often found in large cities throughout the world, food carts offer food of just about any variety. In the Philippines, even the most unexpected kind of foods have also started to be sold in small and colorful carts that can easily be spotted anywhere - from MRT and LRT stations to malls, sidewalks and schools; even the churches have now become the tiny hubs where these small and sometimes moveable kiosks have flourished (Polistico, 2010).

Despite of its continuous progression, studies and improvements regarding food cart businesses remain to be an unexplored area. Mobile food vendors, as stated by Bumol et al. (2013), have generally been neglected in academic researches while literatures focusing on the carts' usability, safety and quality are inadequate. Only few published studies have attempted to assess any aspects of the business, and have generally done so with limited scope on a limited scale. With these definitions, the main focus of the study is to provide a comprehensive analysis of cotton candy business through innovation and development on present machine and cart design.

2. Methodology

Research Method. To meet the objectives of the developmental study, the research method used is the DMADV approach which stands for Define, Measure, Analyze, Design and Verify. The application of DMADV was primarily for the improvement and adjustment of the product currently in use.

Define Phase. The needs and requirements of users in relation to the final output of the study were identified during this phase. The problems associated with the current product were also defined.

Measure Phase. In this phase, specifications describing customer requirements and risks associated with the use of the existing machine were measured and assessed. Issues related with work were determined in order to assess the extent of musculoskeletal disorders among working population. Moreover, risk factor index was analyzed to define the risk capacity for improvement.

Analyze Phase. The frequency, severity and interference of musculoskeletal symptoms were evaluated together with the musculoskeletal risk initially measured. The analysis of body measurement and MSDs were conducted for the design to be developed. Lastly, financial difference of installation of solar panel and frequent purchase of denatured alcohol was discussed.

Percentile for anthropometric data was used to serve as a reference in assigning dimensions on the design to be developed. The formula for percentile value is:

$$p = m + ks \tag{1}$$

where:

p = percentile value
m = mean
k = factor value
s = standard deviation

Table 1. Action level for REBA scores

ACTION LEVEL	REBA SCORE	RISK LEVEL	ACTION
0	1	Negligible	Not necessary
1	2-3	Low	May be necessary
2	4-7	Medium	Necessary
3	8-10	High	Necessary soon
4	11-15	Very High	Necessary now

For the REBA data, results were calculated separately according to the operations indicated on the form. Mode of the answers was then used as the REBA scores for each type of cart. Scores gathered using this assessment tool were compared to the CMDQ scores and enabled the researchers to identify ergonomic problems and aided in formulating appropriate solutions. REBA scores were interpreted using the description indicated on Table 1.

The correlations between age, as factor of the demographic profile, and frequency of musculoskeletal disorder risks across various body parts were calculated. Correlation is a statistical technique that can show whether and how strongly the pairs of variables are related. Positive and negative correlations were obtained and expressed with interpretation shown on Table 2.

Table 2. Descriptive level of correlation

RANGE	STRENGTH OF ASSOCIATION	QUALITATIVE DESCRIPTION
0	None	No association found between two variables
0 - ±0.25	Negligible	Negligible association is present between the two variables
±0.25 - ±0.50	Weak	Weak association is present between the two variables
±0.50 - ±0.75	Moderate	Moderate association is present between the two variables
±0.75 - ±1.00	Very strong	Very strong association is present between the two variables
±1.00	Perfect	Perfect association is found between two variables

Design Phase. This phase presented the design of the project with consideration of ergonomics. Design of the machine, solar panel and cart were scrutinized and developed to provide solutions on the problems primarily identified.

Verify Phase. The last phase in the DMADV method, concentrated on confirming whether the design suited the requirements of the users. The effectiveness of the project, illustration of modifications and difference on risk factors were assessed through the application of indicators.

As for the evaluation phase, responses on different indicators must be tabulated and analyzed. A five-point Likert type scale was used to interpret the mean obtained. Participants were required to rate each item depending on how they perceived the final product made, with five being the highest score and one as the lowest score, as shown on Table 3.

Table 3. Descriptive level of mean

MEAN	VERBAL INTERPRETATION	QUALITATIVE DESCRIPTION
1.00 – 1.79	Poor	Poor level of design is made and partially meets the expectation of the participant
1.80 – 2.59	Fair	Fair level design is made and somehow meets the expectation of the participant
2.60 – 3.39	Good	Good design is made and meets the expectation of the participant
3.40 – 4.19	Very Good	Very good design is made and meets the expectation of the participant
4.20 – 5.00	Excellent	Excellent design is made and exceeds the expectation of the participant

3. Results and Discussion

Problems Associated with the Current Machine and Cart Design

Three different approaches of product usability include user-performance view, user-oriented view, and product-oriented view. User-performance view stated that usability can be measured by examining how the vendor interacts with the product while user-oriented view defined usability by measuring mental effort and attitude of the user toward the product. Product-oriented view, the last approach of product usability, can be measured in terms of ergonomic attributes of the product.

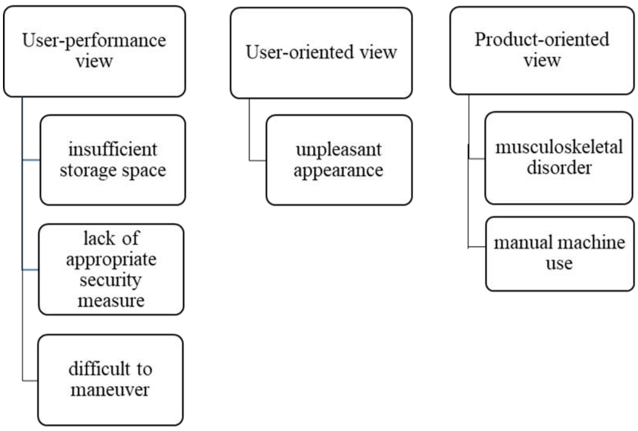

Figure 1. Affinity diagram

Musculoskeletal Risks

Scores that exceeded the mid-range on five-point scale, which is equals to three, and on three-point scale, which is equals to two, were given a remarks of High indicating the prevalence of MSDs. On the other hand, scores which did not exceeded the mid-range were given a remarks of Low indicating the low level of MSDs. High level of MSDs were found on neck, right shoulder and right upper arm for upper body; on right forearm and right wrist for central body and lastly, on right thigh, right knee, lower right leg and right foot for lower body.

Table 4. Presence of MSDs across various body parts.

BODY PARTS	FREQUENCY	SEVERITY	INTERFERENCE	REMARKS
Neck	4.00	2.29	2.21	High
Shoulder (right)	4.57	2.36	2.64	High
Shoulder (left)	1.79	1.10	1.10	Low
Upper Back	2.86	1.00	1.57	Low
Upper Arm (right)	3.79	2.14	2.14	High
Upper Arm (left)	1.36	1.00	1.40	Low

Lower Back	2.57	1.08	1.42	Low
Forearm (right)	4.00	2.57	2.43	High
Forearm (left)	1.36	1.00	1.00	Low
Wrist (right)	4.14	2.57	2.43	High
Wrist (left)	1.50	1.00	1.00	Low
Hip/Buttocks	2.50	1.67	1.78	Low
Thigh (right)	5.00	2.71	2.36	High
Thigh (left)	2.00	1.00	1.50	Low
Knee (right)	4.79	2.57	2.29	High
Knee (left)	2.14	1.00	1.43	Low
Lower Leg (right)	4.79	2.43	2.29	High
Lower Leg (left)	1.93	1.20	1.60	Low
Foot (right)	4.50	2.21	2.29	High
Foot (left)	2.71	1.33	1.67	Low

Understanding the Problems Identified

The problems initially identified and presented using Affinity Diagram were evaluated with Tree Diagram. It was found how poor cart design resulted to insufficient storage space, lack of appropriate security measures and difficulty in maneuvering. It is also the cause of unpleasant design, as well as the presence of MSD. Similarly, MSDs were associated with poor cart design and laborious use of the machine. Vendors were utilizing manual machine because of unavailability of other alternatives for powering the equipment.

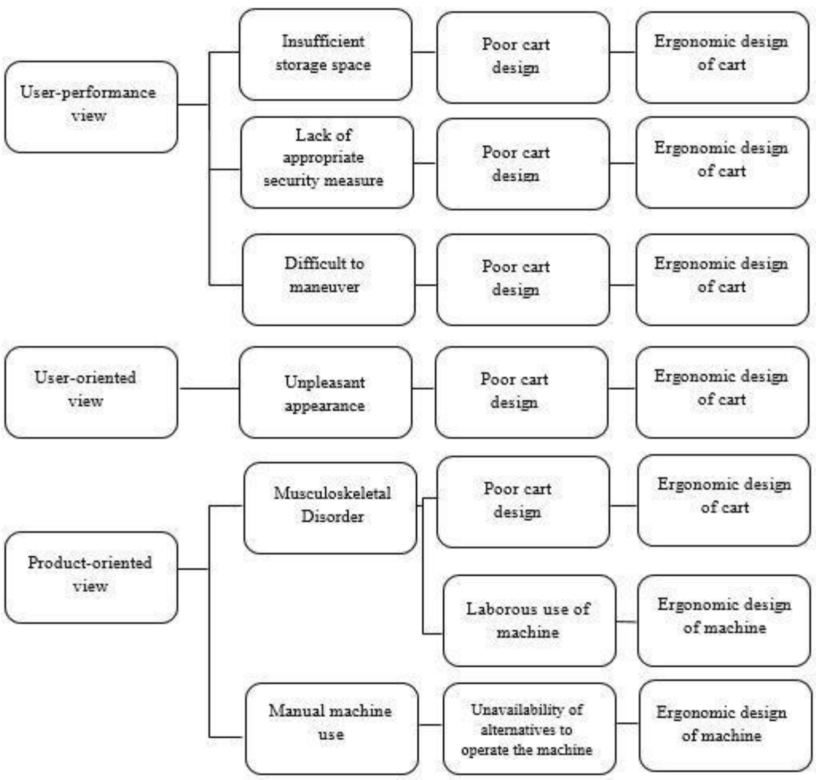

Figure 2. Tree Diagram

Relationship of Participants' Age and Musculoskeletal Disorder Risks

The correlation between the age of the participants and the frequency of musculoskeletal disorder risks across body parts was analyzed. Age of the participants ranges from 28 years old to 58 years old, with a mean of 42.86 and a standard deviation of 11.13. In terms of frequency, risks were found to be highest at neck, right shoulder, upper right arm, right forearm, right wrist, right thigh, right knee, lower right leg, and right foot of participants.

Associations between the two variables was computed using the Pearson's correlation. No correlation was found between age and thigh which was represented by zero value. Positive negligible correlations were calculated on upper back, upper right arm and right forearm with values of 0.09, 0.25, and 0.16. Negative negligible correlation were calculated on upper left arm, right wrist and left foot with values of 0.18, 0.03 and 0.04, respectively.

Furthermore, positive weak correlations on age and left shoulder, lower back, left wrist, right knee, lower right leg and right foot were computed with scores of 0.34, 0.39, 0.29, 0.45, 0.45 and 0.29, respectively. Negative weak correlations were present on neck right shoulder, left forearm and left knee with scores of 0.38, 0.33, 0.31 and 0.35.

Negative moderate correlations were obtained on left thigh with value of 0.54, and lower left leg with value of 0.73. Out of the 20 body parts included in the study, only hip/buttocks of the participants were calculated to have a very strong correlation with age, having a positive value of 0.79.

Table 5. Relationship between age and frequency of MSD of the participants

BODY PART	COEFFICIENT OF CORRELATION	VERBAL INTERPRETATION
Neck	-0.38	Weak
Shoulder (right)	-0.33	Weak
Shoulder (left)	0.34	Weak
Upper back	0.09	Negligible
Upper arm (right)	0.25	Negligible
Upper arm (left)	-0.18	Negligible
Lower back	0.39	Weak
Forearm (right)	0.16	Negligible
Forearm (left)	-0.31	Weak
Wrist (right)	-0.03	Negligible
Wrist (left)	0.29	Weak
Hip/Buttocks	0.79	Very strong
Thigh (right)	0.00	None
Thigh (left)	-0.54	Moderate
Knee (right)	0.45	Weak
Knee (left)	-0.35	Weak
Lower Leg (right)	0.45	Weak
Lower Leg (left)	-0.73	Moderate
Foot (right)	0.29	Weak
Foot (left)	-0.04	Negligible

Cost of Denatured Alcohol and Solar PV System

The evaluation of results revealed that an average vendor consumes 2.86 bottles in a day. Cost of such alcohol varies from locality to locality, with prices ranging from P30 to P45. Majority of the vendors purchase denatured alcohol daily while the remaining vendors purchase on weekly and monthly basis. In total, a vendor who needs two bottles a day would consume 432 bottles annually and spend around P17,280.00. Similarly, a vendor who needs three bottles a day would consume 648 bottles annually while that who needs four bottles a day would consume 846 bottles while spending around P25,920.00 and P34,560.00, respectively.

Solar panels provide inexhaustible energy supply for years. Using a solar-powered machine requires sufficient fund for the materials and labor. Parts required to utilize solar power includes inverter, charge controller, stranded wire, solar panel, breaker, eye terminal and battery. In total, one would need P17,381.00 to install the solar PV system, however, the values may vary depending on the location from which the materials would be purchased and varying fee depending on the rate of the professionals.

Solar Panel Installation

Various materials were used in the installation of solar PV system, with ratings based on the capacity of the machine to be used. The solar panel installed is made of monocrystalline silicon, rated at 200 Watts with dimension of 32 in by 62 in. Monocrystalline solar panels have the highest efficiency rates since they are made out of the highest-grade silicon. It is also space-efficient, long in lifespan and high in heat tolerance. The inverter used is a pure sine wave power inverter, rated 1000 Watts. Pure sine wave power inverters are recommended for appliances with AC motor, which was used on the prototype.

Moreover, the charge controller and battery are 60 Ampere and 100 Ampere, respectively. Valve regulated lead-acid battery, also known as sealed battery and maintenance-free battery, was used in the system. In order to protect the system from damage, a circuit breaker was installed. The 20 Ampere AC circuit breaker acts as safety mechanism that can cut power in the incident of high current flow and makes the system practical to use.

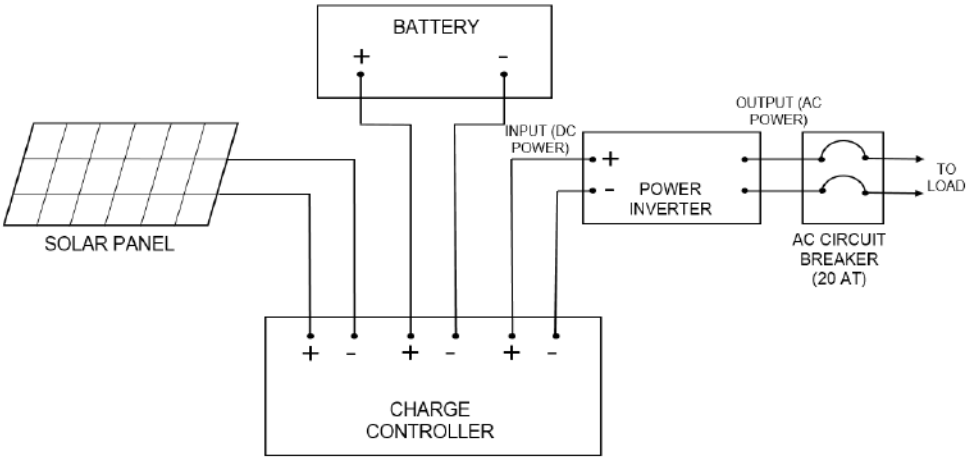

Figure 3. Wiring diagram

The illustration of wiring diagram for the solar PV system, as shown on Figure 3, begins from absorption of energy and generation of direct current (DC) to its consumption. The process will begin upon the absorption of energy from the sun through the solar panel. This will generate DC that will be regulated by the charge controller and transfer it directly store to the battery. This stored energy is to be converted from DC to alternating current (AC) once it passes through the inverter. The process will end when the AC load, such as the cotton candy machine, consumed and used the energy.

Exploded diagram of the pushcart

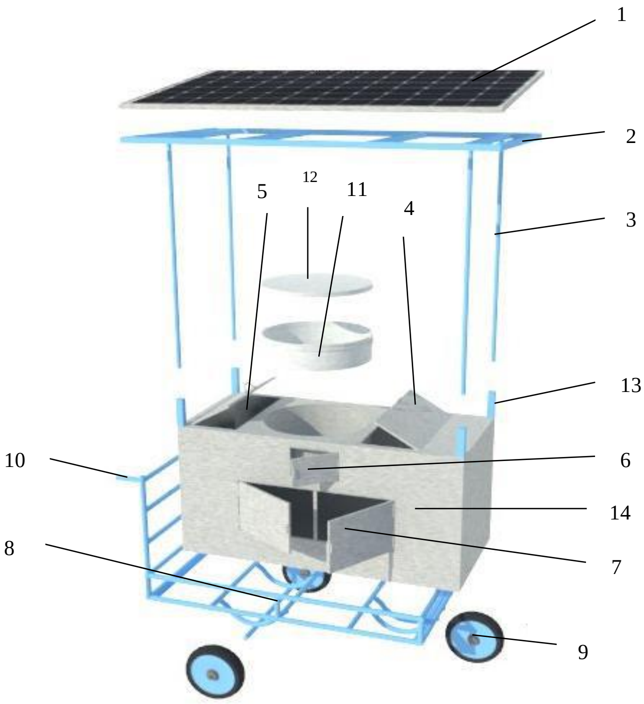

Figure 4. Exploded diagram of the pushcart

Legend:

1- solar panel	8- metal brace body
2- roof frame	9- cart wheels
3- cart pole	10- pushcart handle
4- compartment for solar power components	11- stainless tub
5- compartment for sugar floss	12- stainless tub cover
6- opening for machine inspection and maintenance	13- pole holder
7- compartment for battery	14- cart frame

4. Conclusion

Usability was given focus in identifying present problems associated with the condition of the food cart and machine. The overall survey results for the user-performance view revealed issues on space, security measures and maneuverability. Data for the user-oriented view claimed that a number of participants believed that their current were not aesthetically pleasing, does not motivate them to work, nor was helpful to attract customers. For product-oriented view, the survey found that participants experienced pain and discomfort caused by poor cart design and manual machine. The absence of alternatives, other than the use of denatured alcohol, was also found to be a problem among users of manual machine.

The application of Cornell's Musculoskeletal Disorder revealed the frequency, severity and interference of ache, pain and discomfort as experienced by the workers. High level of musculoskeletal risks were found on neck, right shoulder and upper right arm for upper body; on right forearm and right wrist for central body and on right thigh, right knee, lower right leg and right foot for lower body. The accomplishment of Rapid Entire Body Assessment found how the activity was at medium risk level, requiring further investigation and change soon for motor and bike users. For pushcart users, the activity implied how work is at high risk that requires investigation and implementation of change.

For points which were independent on anthropometric data such as frame width and compartment volume, the average measurements of the existing product were considered. Anthropometric measurements of pushcart users were considered on frame height, cart height, frame length, frame width, and handle diameter and length. For users of both bicycle with cart and motorcycle with cart, anthropometric measurements were linked on pole height and frame length of the cart.

The application of renewable energy in the form of standalone solar PV system was also implemented. Finally, adjustments to present design of food cart were implemented with the use of anthropometry.

Excellence of the product were notable when it comes to meeting design functions and objectives, availability of space and security measures, appeal, impression, safety and ergonomics. The evaluation revealed satisfactory scores on maneuverability of the product, as well as on cost and labor requirement.

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TOWARDS SUSTAINABLE NUCLEAR WASTE MANAGEMENT: A STUDY OF PHILIPPINE GEOLOGICAL DISPOSAL ALTERNATIVES

King Harold A. Recto[1,2] , Alyssa Inocencio[2], Kevin Lester Lobo[2]

1. Ateneo Energy Research Lab, Department of Electronics, Computer and Communications Engineering, Ateneo de Manila University, Loyola Heights, Quezon City, 1108 Philippines
2. Energy Engineering Program, National Graduate School of Engineering, University of the Philippines Diliman, Loyola Heights, Quezon City, 1101 Philippines

Email: krecto@ateneo.edu, adinocencio@up.edu.ph, kblobo@up.edu.ph

Abstract

The study delves into the complex area of nuclear waste disposal in the Philippine setting. It described the probable situations that were under consideration, exploring the fundamental motivating factors leading to these situations. These included the crucial aspects of categorizing radioactive waste, the range of management choices accessible, and the various disposal strategies developed for various waste tiers. Each alternative was considered in light of a variety of factors, including technological, environmental and practical. The also explored the landscape of implementation with emphasis on the inventory of radioactive waste and a roadmap outlining the course of action. In essence, the study integrated the complex web of scientific and socio-political components and came to a conclusion by utilizing stakeholder analysis and the Prince Method. The study concludes that the creation of a geological disposal site under the administration of the Philippine Government was determined to be the best course of action. This solution was deemed to be the most sensible course of action, earning a Prince Score of 76.2%. It is hoped that this study would not only add to the scholarly conversations but also give policymakers a well-rounded viewpoint.

Keywords: geological disposal site, nuclear energy, nuclear waste disposal, Prince Method, stakeholder analysis

1. Introduction

Throughout their lifetimes, both conventional and renewable energy resources produce waste and byproducts. Those in control of nuclear energy in the country are responsible for the appropriate management and disposal of radioactive material. This includes instituting stringent safety measures and investing in advanced storage and disposal technologies. In addition, continuous research and development should be conducted to identify innovative methods for minimizing the environmental impact of nuclear energy production.

The use of nuclear energy for power generation remains highly controversial and is perpetually contested. The radioactive waste it generates during its operation and decommissioning is always cited as a reason for opposition to its use. People residing in the vicinity of nuclear power plants and radioactive waste disposal sites are deemed to be harmed or even killed by these wastes.

Now, the first steps have been taken to include nuclear energy into the overall energy portfolio of the Philippines in accordance with Executive Order No. 164 (also known as "E.O. 164"), which was issued by President Rodrigo Duterte on February 28, 2022. In the Executive Order, the national position for a Nuclear Energy Programme (NEP) is adopted. This position takes into account a variety of economic, political, social, and environmental goals. One of these goals is the utilisation of nuclear power as a "viable component to bridge the gap between rising energy demands and supply. In addition, the President of the Philippines, Ferdinand Marcos Jr., has said that he believes that it is now time for the Philippines to start using nuclear energy. [1] In light of these developments, it is highly likely that nuclear energy will now be a component of the Philippine energy mix, posing a challenge for waste disposal.

Given these, this paper hopes to address the issue of nuclear waste disposal in the Philippines. In particular, it endeavors to develop a road map for the processing, management, storage, and disposal of radioactive wastes under each category of waste for a nuclear power plant (NPP). It shall define the different waste-level criteria for decision-making, present the various processing, handling, storage, and disposal technologies, and describe the feasibility of constructing a disposal facility for nuclear waste in the Philippines using the Prince Method.

2. Literature Review

Radioactive Waste Classification. There are six types of radioactive waste. [2] Exempt waste (EW) meets the criteria for clearance, exemption, or exclusion from regulatory control for radiation protection purposes. Very short-lived waste (VSLW) contains radionuclides with short half-lives of about a hundred days or less and activity concentrations above the clearance levels. VLLW contains radionuclides with half-lives of less than 30 years, longer than VSLW, and has a higher radioactivity content than exempt waste. VLLW is suitable for disposal in near-surface landfill facilities with limited regulatory control. Low-level waste (LLW) is waste that is contaminated with radioactive material or has become radioactive through exposure to neutron radiation. It may contain short-lived radionuclides at higher levels of activity concentration and limited long-lived radionuclides, but only at relatively low levels of activity concentration. LLW composes 90% of the total volume of nuclear waste and represents only 1% of the total radioactivity associated with nuclear waste. Intermediate-level waste (ILW) is more radioactive than LLW and requires a certain degree of shielding when handling, storing, and disposing of it. ILW typically comprises resins, chemical sludges, metal fuel cladding, and contaminated materials from reactor decommissioning. High-level waste (HLW) typically has levels of activity concentrations in the range of 104–106 terra-becquerels per metre (TBq/m), which generate significant quantities of heat by the radioactive decay process. HLW generates more than two kW/m3 of heat. High-level wastes are hazardous because they produce fatal radiation doses during short periods of direct exposure and pose a great threat to public health and the environment if not handled, stored, and disposed of properly. Disposal in deep, stable geological formations is generally recognised as HLW disposal.

The classification and characterization of radioactive waste are conducted to provide information on the properties of the radioactive wastes and verification of the process to facilitate subsequent steps such as determining the necessary arrangements for handling, processing, and storage. [3] Aside from the level of radioactivity, Radioactive wastes are also classified based on their state. Gaseous or airborne radioactive wastes are classified for treatment purposes into waste that arises from the reactor and waste that comes from ventilation areas of the nuclear power plant. Liquid radioactive wastes are characterized for processing purposes based on activity concentration, phase status, chemical properties, and composition. Lastly, solid radioactive wastes are classified for processing and disposal option purposes based on their combustibility, compressibility, viability for melting, and the amount of radionuclide content on its surface for possible decontamination. [4]

Radioactive Waste Management Options and Disposal Approaches. The proper disposal of radioactive waste from NPP facilities is vital to ensure its sustainability and acceptability. Nuclear waste management strategies rely on two options, namely: (1) Dilute and Disperse, and (2) Contain and Confine (Abdel Rahman & Saleh, 2018). The latter option is the primarily employed strategy. The objective in this option is to limit the release of short- and long-lived radionuclides by isolating the radioactive wastes for specific durations depending on the level of radioactivity and allowing them to decay (Abdel Rahman & Saleh, 2018). Effective radioactive waste management involves classification and characterization, processing, handling and transportation, and storage and disposal.

Processing. The processing of radioactive waste involves three steps, namely: pre-treatment, treatment, and conditioning. Pretreatment aims to reduce the number of waste that requires further processing. [4] Such processes can help save time and resources and open up additional space for more waste to proceed in succeeding steps. This process includes the actual collection of radioactive waste, segregation, chemical adjustment, and decontamination. Waste with short-lived radionuclides is separated from those with long-lived radionuclides and is assessed whether it can be recycled, directly discharged, needs decontamination, or would require to spend some time in temporary on-site storage for radioactive decay before disposal.

Treatment of radioactive waste intends to vary the waste's physical characteristics by reducing its size, removing radionuclides, and changing its composition in order to improve safety or economy [5] in disposing of them.

One example of the treatment process for solid radioactive waste is compaction. It aims to reduce the size of the waste by pressing them together. Compactors can range from low-range compaction suitable for transportation and incineration preparations to super-compaction for large drums in preparation for final disposal. Another example is the process of incineration. It burns combustible wastes to achieve the greatest volume reduction while at the same time transitioning the wastes into a more stable form. [4] Segmentation or disassembly can also be performed for bulky and oversized solid radioactive wastes. This is done using cutters with high-temperature flames, various sawing methods, hydraulic shearing, abrasive cutting, and plasma arc cutting. [4]

Liquid radioactive waste treatment includes evaporation, chemical precipitation, ion exchange, filtration, centrifugation, ultrafiltration, thermal treatment, and reverse osmosis. The appropriate method to be used is selected based on the limitations of each process such as corrosion, scaling, foaming, and the risk of fire or explosion in the presence of organic material. The main objective of processing radioactive liquid waste is to make it acceptable to be dispersed in water upon discharge. Liquid wastes containing suspended solids need to undergo a filtration process, acidic and alkaline liquid waste must be neutralized prior to discharge, and liquid waste that is immiscible with water should be completely excluded from discharge. [4]

Radioactive particulates and aerosols in the air can be treated by the filtration process. HEPA filters can remove gaseous effluents while charcoal filters can subtract the iodine in the air and absorption beds charged with activated carbon can delay noble gasses. The use of air scrubbers is another method of treating gaseous chemicals, particulates, and aerosols from off-gasses. Some of the factors that are needed to be considered in treating gaseous radioactive wastes are the amount of gas to be treated, level of radioactivity, particle concentration, chemical composition, humidity, and toxicity. [4]

The conditioning process aims to slow down the release of radionuclides from the waste to the surroundings by encapsulating or solidifying it in special containers [4] and making them suitable for handling, transport, and final disposal.

One example of the conditioning process is cementation. It is used to immobilize radioactive sludges, precipitates or gels, activated materials, and fragmented solids wastes using specially formulated gouts. Another example of the conditioning process is vitrification. This is done to immobilize high-level liquid waste by forming it into insoluble solid waste in borosilicate glass. [6] Reprocessing of spent fuels produces a lot of HLW that are mostly in liquid form. Such wastes are made up of long-lived radionuclides and some transuranic elements. These wastes are dried into a granular powder before being incorporated into the molten glass matrix. The resulting product is then poured into robust steel containers that are welded shut for storage and final disposal. [6] Lastly, synroc is another type of conditioning process that involves a hot isostatic press (HIP) using very high temperatures and pressure to lock in the radionuclides in the wastes. [6] Radioactive liquid wastes are mixed with additives to form a slurry, then it is dried to produce a granular powder. The powder is placed in cans that are sealed before subjecting it to HIP.

Handling and Transportation. Handling and transportation can take place in between each step of the radioactive waste management process. Such movements of radioactive waste materials do not constitute a high-risk scenario as it is done in a controlled environment inside the waste processing facility as long as strict safety protocols, and the use of shielded containers and appropriate personal protective equipment (PPE) are implemented. The critical process happens when transporting radioactive waste from one radioactive waste producing or processing facility such as a nuclear power plant, waste processing plant, storage facility, and final disposal site, going to another.

Radioactive waste can be transported by land using trucks or trains, or by sea using cargo ships. One of the objectives in transporting radioactive waste is to keep the drivers, the public, and the environment safe even in extreme accidents. A specially designed lead-lined cask that is made to withstand high impact, explosions, immersion under water, and exposure to fires are used in order to meet this objective [7]. Purposely design cargo ships used to transport radioactive waste have double hulls to withstand collision damage, enhanced buoyancy to prevent the ship from sinking even in extreme circumstances, a refrigeration plant for cargo cooling, additional firefighting equipment with a hold flooding system, and advanced navigation and communication systems. [8] The amount of radioactivity of the waste material dictates the level of controls that are needed when being transported. Transport of VHLW requires additional security, selection of controlled routes, and proper coordination with national and local officials. [9]

Storage and Disposal. Similar to every other energy system, a power plant would also eventually reach a point where it needs to retire and be demolished due to deteriorating running efficiency as the age and hours of operation pile up. In the case of a nuclear power plant, the decommissioning process involves the clean-up of radioactivity together with the dismantling process to ensure that no radioactive waste will be left on-site and the area could be safely used afterward. The IAEA proposed three decommissioning options for nuclear power plants, namely immediate dismantling, deferred dismantling, and entombment. [10]

The immediate dismantling option removes and decontaminates equipment, structures, and other parts of the nuclear power facility that contain radioactive contaminants a few months after the termination of plant activities and removal from regulatory control. This allows the site of the decommissioned nuclear power plant that has undergone this process to be used again nearly after a decade. [10] However, the level of radioactivity and availability of disposal sites must be carefully considered [11] before choosing this decommissioning option. The deferred dismantling option places the site of the decommissioned nuclear power plant into a safe storage facility and allows for the radioactivity to decay for about 40 to 60 years [10] before dismantling the plant and decontaminating the area. Such extended periods of delay can cause regulatory change which can increase decommissioning costs. Lastly, the entombment option places the remaining radioactive materials and portions of the facility on-site and encases them in concrete and other radiation shielding that are necessary to eliminate the threat of harmful radiation penetrating the environment. [10]

3. Discussion

Disposal Road Map. The roadmap starts with identifying the technical requirements needed for the disposal of the waste followed by selecting a site that suits the technical requirements. After which would be an evaluation of the financial capability to undertake the endeavor. Next would be accomplishing and acquiring the required regulatory permits. Ending with the goal of operational radioactive waste disposal. (See Figure 1)

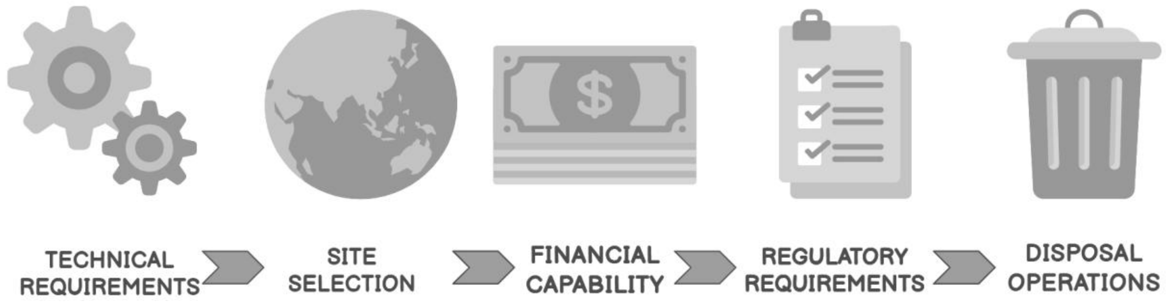

Figure 1. Disposal Road Map

Technical Requirements. In the complex domain of radioactive waste management, a thorough understanding of its technical requirements is essential. Each category of radioactive waste necessitates individualized strategies for treatment and containment. This section examines the essential technical requirements for the secure disposal of various categories of radioactive waste, from exempt waste to high-level waste. It would also explicate the complexities underlying the management of radioactive waste by addressing distinct processing, containment, storage, and disposal considerations.

Exempt Waste. Exempt waste does not require processing, radiation protection, or storage like higher-level radioactive wastes. It can be reduced through compaction, pulverizing, or incineration, disposed of in landfills as conventional waste, or recycled. The disposal and site selection processes are simple. The funding for exempt waste disposal is comparable to conventional waste disposal, contingent on the quantity of waste generated by the NPP. Exempt waste disposal also requires regulatory permits.

Very Short Lived Waste. Extremely short-lived waste, such as exempt waste, must be contained for a few years in order to decompose to levels below regulatory clearance levels. Similar to exempt waste, it can be disposed of as conventional waste in landfills or recycled. Location selection is straightforward, but funding and regulatory permits may be necessary. Similar site selection, funding, and requirements are necessary for the disposal of exempt and conventional waste. Like exempt waste, extremely short-lived waste does not require specific treatment or conditioning to reduce or contain radioactivity. However, it must be contained for a few years until its radioactivity decays to levels below those required for regulatory certification. Similar to exempt waste, it can then be disposed of as conventional waste in landfills or recycled. It is possible to store energy at the same location as its generation, but funding and regulatory permits may be necessary. Similar to exempt and conventional waste, final disposal requires site selection, funding, and compliance with similar regulatory requirements.

Very Low Level Waste. Typically, very low level waste (VLLW) is not processed, but it can be diminished through characterization, segregation, and compression. It can be stored at the site of generation or in a protected central facility. VLLW can be disposed of in conventional landfills or trenches constructed specifically for the purpose near the power plant. It can also be disposed of alongside other waste categories, including LLW and non-hazardous hazardous waste. Storage operations require both funding and regulatory approvals.

Low Level Waste. Drying, incineration, evaporation, high-pressure compaction, melting, and cementing are typical conditioning procedures for low level waste (LLW). Cementing incorporates LLW into a matrix for radiation shielding and packaging, transforming waste into a form that is manageable, transportable, and suitable for disposal. LLW must be isolated and contained for up to a few hundred years, but handling and interim storage do not require significant shielding. LLW is disposed of in covered near-surface repositories with engineered cover systems to prevent water infiltration and erosion following storage. Some nations are considering disposing of low-level radioactive waste in deep geologic repositories or in conjunction with higher-level wastes. Due to the volume of LLW, establishing dedicated storage and disposal sites would present significant financial, regulatory, and logistical challenges.

Intermediate Level Waste. Prior to packaging, intermediate level waste (ILW) processing involves separation, volume reduction, and stabilization. Drying, evaporation, high-pressure compaction, and cementing are typical treatments. After processing, isolation and containment storage for 100 years or more are often required. Long-lived ILW must be disposed of at depths that provide long-term isolation from the biosphere, usually in deep geological repositories. The only licensed disposal facility for long-lived ILW is the waste Isolation Pilot Plant (WIPP) in the United States, which disposes of long-lived, non-heat-generating refuse from defense activities in a geological repository. Some nations intend to dispose of all LLW and ILW in a single multipurpose deep geological facility, thereby eradicating the need to separate waste containing short- and long-lived radionuclides prior to disposal.

High Level Waste. After spent nuclear fuel is removed from a nuclear power reactor, it is stored for decades to minimize decay heat. Options for storage include moist storage in a reservoir of water and dry storage in casks or vaults. Before disposal, high-level waste (HLW) must be stabilized after refrigeration. This is accomplished by heating high-level waste to the point of vaporization, leaving behind a radionuclide-containing residue that has been desiccated. This residue is combined with glass-forming materials, such as borosilicate or phosphate glass, and then heated at a high temperature to create a liquid glass. This liquid is then poured into receptacles made of stainless steel, which are then welded sealed and allowed to settle to form vitrified glass. In shielded cells, the vitrification procedure and container management operations are executed remotely.

Before final disposal, the canisters are deposited in dry storage, most likely in a deep geological repository. Technical specialists believe that isolation in a deep geological repository (DGR) is the preferable method for the long-term safety of depleted fuel and high-level waste (HLW). The expended fuel is encapsulated in a corrosion-resistant, heat-resistant container, typically made of solid copper, and then disposed of in a deep geological repository for thousands of years or longer. Deep borehole systems are several times deeper than typical mined geological deposits and well below the depth limit of pure groundwater resources.

The ONKALO disposal facility in Finland is a deep geological repository for spent nuclear fuel, based on the 'KBS-3' disposal concept devised by the Swedish Nuclear Fuel and Waste Management Company in collaboration with Posiva. The repository's disposal operations are scheduled to commence in 2024.

Financial Capability. The management of radioactive waste in the Philippines is a multifaceted matter that encompasses several factors such as economic stability, fiscal allocation, technical infrastructure, regulatory framework, and international collaboration. The financial viability of a nation is contingent upon its acknowledgment of the significance of proper waste disposal practices and the possible environmental and health hazards that may arise from improper treatment. The allocation of budgetary resources is of utmost importance in ensuring effective employee training, the establishment of appropriate disposal facilities, and the execution of rigorous monitoring protocols. Similarly, the creation and maintenance of technical infrastructure need significant investments in research, development, and the subsequent application of these advancements. A robust regulatory structure is important to ensure the safe management of waste, necessitating enough financial resources for the purposes of training, conducting inspections, and monitoring compliance. International collaboration and partnerships have the potential to facilitate the exchange of information, provision of technical help, and allocation of financial resources towards the establishment of specialized facilities. Balancing these priorities while ensuring safe waste management is a delicate task. To address these challenges, the Philippines should consider financing options such as public-private partnerships, international assistance, and innovative funding mechanisms. Additionally, incorporating waste management costs into nuclear facility operational costs can ensure financial provisions for waste generated. Decision-makers must assess the financial implications, weigh them against the benefits of safe waste management, and plan for the long-term sustainability of these endeavors.

Regulatory Requirements. President Ferdinand Marcos Jr.'s perspective signals a pivotal juncture for the Philippines to reevaluate its stance on nuclear energy utilization. Notably, modern technology has fortified safety measures against potential mishaps, prompting a reconsideration of nuclear energy's viability. During his State of the Nation Address (Sona) on July 25, 2022, Marcos emphasized that, if the country chooses nuclear energy during his term, it will adhere to the guidelines endorsed by the International Atomic Energy Agency (IAEA) [1].

Anticipating a transformation in its energy landscape, the Philippine government is in the process of formulating a comprehensive nuclear energy roadmap, expected to reach its final iteration before the year concludes. The Nuclear Energy Program Interagency Committee (NEP-IAC) is meticulously examining 19 intricate infrastructure aspects pivotal to nuclear power development. These facets encompass nuclear safety, grid infrastructure, connectivity, and the management of spent fuel. Mylene Capongcol, Energy Assistant Secretary, conveyed that the roadmap's completion holds precedence, underscoring its anticipated finalization by the year's end [12].

As the Philippines contemplates incorporating nuclear energy into its energy mix, stringent regulatory standards are necessary to ensure the safety, security, and environmentally responsible deployment of nuclear technology. Licenses and permits, safety and security standards, radiation protection, waste management, international collaboration, public engagement, and emergency preparedness are essential regulatory considerations. A comprehensive licensing framework is required for the construction, operation, and decommissioning of nuclear energy facilities, among other phases of nuclear energy development. To protect employees, the general public, and the environment, these standards should align with international norms. Radiation protection regulations should regulate the prevention of excessive radiation exposure, whereas waste management regulations should ensure the proper management, storing, and disposal of refuse in accordance with international standards. International collaboration with organizations such as the IAEA can provide regulatory measures with expertise, guidelines, and technical assistance. Regular exercises, training, and coordination between relevant authorities are essential components of a robust regulatory framework, as is public participation. The work of the Nuclear Energy Program Interagency Committee would be crucial in all these.

Disposal Operations. The search for disposal options that are both efficient and risk-free is a primary obstacle to effectively managing and safeguarding potentially hazardous nuclear wastes. Currently, a number of potential courses of action are being studied, each of which seeks to strike a delicate equilibrium between technological viability, environmental responsibility, and compliance with regulatory requirements. Using the Prince Method, these options were considered.

Recto and Florano [13] described the Prince Method. This starts by collecting stakeholders who had a similar stance on the subject. It consists of four steps. The first step would be to identify the "actors," which may be a single person or a group of persons who would likely have a direct or indirect influence on the decision. The second step would be to determine each actor's "issue position." The "issue position" is an estimation of whether each actor would support, disagree with, or have no opinion on the choice. Actors were given ratings ranging from -3 to +3, with +3 denoting strong support, -3 denoting strong opposition, and 0 denoting neutrality, depending on how they were regarded. The third step would be to determine each actor's "power" (p), or how important they are in aiding or impeding the choice or its execution. A scale of +1 to +3 is employed in this instance, with +1 denoting weak strength and +3 denoting high power. Once more, power is assessed according to the researcher's opinion. The last factor is "salience" (s), or how crucial the choice is to each actor. On a scale of +1 to +3, where +1 denotes weak salience and +3 denotes great salience, salience was evaluated. The Prince Method reveals which is the preferred alternative given the stakeholders issue position, power, and salience. Below are the results of the Prince Method.

Option 1: Status Quo. The Philippines currently has not establish a nuclear waste disposal facility, electing instead for secure containment and storage. This strategy seeks to uphold safety standards and prevent harm to human health and the environment. To mitigate the impact on human populations, ecosystems, and water sources, secure containers and storage locations are chosen. Nonetheless, this strategy encounters obstacles, such as the long-term viability of storage sites and containers, as the materials within can degrade and deteriorate over time. Technical, financial, regulatory, and societal factors influence the decision not to establish a nuclear waste disposal facility.

Due to the complex interaction of numerous factors, executive, quasi-judicial agencies/offices, government-owned/controlled entities, and national agencies frequently exhibit ambivalence toward the establishment of a dedicated nuclear waste disposal facility. These entities are responsible for the implementation and supervision of policies, regulations, and projects that affect the welfare, security, and environment of the nation. Ambivalence stems from the complex challenges posed by nuclear waste disposal and the need to strike a balance between immediate safety concerns and long-term sustainability. Since the status quo is tied to the absence of a nuclear facility, the legislative may even oppose the ideas since the majority support the President's vision of adding nuclear energy to the Philippine Energy Mix. This combination lead to low Prince Score of 50%.

Table 1. Status Quo Prince Ratings

Stakeholders	**Issue Position** (-3 to +3)	x	**Power** (1 to 3)	x	**Salience** (1 to 3)	=	**Prince Scores**
Legislative	-1	x	2	x	2	=	-4
Local Government Units/ Residents	0	x	1	x	1	=	(1)
Executive	0	x	3	x	1	=	(3)
Quasi-judicial Agencies/Offices	0	x	2	x	1	=	(2)
Government Owned/Controlled Entities	0	x	1	x	1		(1)
National Agencies	0	x	2	x	2	=	(4)
Key Agency: PNRI	-2	x	1	x	3	=	-6
Calculation 1: A + 0.5 C (Sum of all the positive scores plus ½ neutral scores)							5+5.5
Calculation 2: A + B + C (Sum of all scores ignoring signs and parenthesis)							21
Probability of Support, $P = (A + 0.5C)(A+B+C)^{-1}$ (Calculation 1 divided by Calculation 2)							50%

Option 2: Putting Up National Disposal Facilities. The Philippines may consider mined repository or deep boreholes for this purpose. Mined repository is the most explored option for deep geological disposal and allows for the retrieval of deposited wastes. It is made up of a series of tunnels and caverns wherein the wastes would pass through and be placed respectively. It requires depths ranging from 250-m to 1,000-m below the earth's surface. Possible sites of construction depend on the available underground mining technology in the area, stable rock formation under the surface, and having no major groundwater flow beneath or above the structure. Deep boreholes, on the other hand, need depths ranging from 2,000-m to 5,000-m below the earth's surface and do not allow the extraction of wastes once they are placed. Waste canisters containing the spent fuel or vitrified radioactive wastes are placed on the rock basement 4,000-m to 5,000-m below the ground. The upper 3,000-m serves as a barrier consisting of different materials such as bentonite clay, asphalt, or concrete. Deep boreholes can be drilled off-shore on sub-seabed disposal but are still not permitted, or on-shore in crystalline and sedimentary rocks. [14]

Due to the alignment of many legislators with the president's vision and the potential benefits for local government units and key stakeholders, such as the Philippine Nuclear Research Institute (PNRI), the establishment of national disposal facilities for nuclear waste could garner support from the legislative branch. As part of a comprehensive approach to nuclear energy development, lawmakers who share the president's vision may prioritize the establishment of national disposal facilities. Local government participation in the hosting of nuclear power plants could result in substantial financial support, thereby contributing to the revenue of localities or municipalities where NPPs are constructed. Strategic collaboration with PNRI, a preeminent nuclear research institute, could also facilitate the development of comprehensive disposal facilities. A partnership between the government and PNRI would guarantee the responsible disposal of refuse from prospective nuclear power facilities, thereby enhancing energy security and sustainability. Creating national disposal facilities would also demonstrate the Philippines' commitment to adhering to international standards for nuclear waste management, opening the door to potential collaborations and partnerships in the nuclear energy sector. As a result of these support, a Prince Score of 76.2% has been obtained.

Table 2. Putting Up National Disposal Facilities Prince Ratings

Stakeholders	**Issue Position** (-3 to +3)	x	**Power** (1 to 3)	x	**Salience** (1 to 3)	=	**Prince Scores**
Legislative	+1	x	2	x	2	=	4
Local Government Units/ Residents	+1	x	1	x	1	=	1
Executive	0	x	3	x	1	=	(3)
Quasi-judicial Agencies/Offices	0	x	2	x	1	=	(2)
Government Owned/Controlled Entities	0	x	1	x	1		(1)
National Agencies	0	x	2	x	2	=	(4)
Key Agency: PNRI	+1	x	1	x	3	=	3
Calculation 1: A + 0.5 C (Sum of all the positive scores plus ½ neutral scores)							11+5
Calculation 2: A + B + C (Sum of all scores ignoring signs and parenthesis)							21
Probability of Support, $P = (A + 0.5C)(A+B+C)^{-1}$ (Calculation 1 divided by Calculation 2)							76.2%

Due to the alignment of many legislators with the president's vision and the potential benefits for local government units and key stakeholders, such as the Philippine Nuclear Research Institute (PNRI), the establishment of national disposal facilities for nuclear waste could garner support from the legislative branch. As part of a comprehensive approach to nuclear energy development, lawmakers who share the president's vision may prioritize the establishment of national disposal facilities. Local government participation in the hosting of nuclear power plants could result in substantial financial support, thereby contributing to the revenue of localities or municipalities where NPPs are constructed. Strategic collaboration with PNRI, a preeminent nuclear research institute, could also facilitate the development of comprehensive disposal facilities. A partnership between the government and PNRI would guarantee the responsible disposal of refuse from prospective nuclear power facilities, thereby enhancing energy security and sustainability. Creating national disposal facilities would also demonstrate the Philippines' commitment to adhering to international standards for nuclear waste management, opening the door to potential collaborations and partnerships in the nuclear energy sector. As a result of these support, a Prince Score of 76.2% has been obtained.

Option 3: Cooperate in Setting Up International Disposal Facilities. The final disposal of radioactive waste using the approved land-based disposal method does not only require a high cost and a great level of expertise to construct and operate, but it also needs specific geography requirements which most countries do not have. Thus, the option of having a regional or multinational waste repository is being explored wherein a willing host country that is capable of constructing and operating a radioactive waste disposal facility will take in the radioactive waste of other countries. However, most countries are restricted under their national laws from accepting waste, especially nuclear waste, of other countries. [14] Such policies are needed to be addressed for this undertaking to move forward. Here are some of the international waste disposal concepts.

Table 3. Setting Up International Disposal Facilities Prince Ratings

Stakeholders	**Issue Position** (-3 to +3)	x	**Power** (1 to 3)	x	**Salience** (1 to 3)	=	**Prince Scores**
Legislative	+1	x	2	x	2	=	4
Local Government Units/ Residents	0	x	1	x	1	=	(1)
Executive	0	x	3	x	1	=	(3)
Quasi-judicial Agencies/Offices	0	x	2	x	1	=	(2)
Government Owned/Controlled Entities	0	x	1	x	1		(1)
National Agencies	0	x	2	x	2	=	(4)
Key Agency: PNRI	+1	x	1	x	3	=	3
Calculation 1: A + 0.5 C (Sum of all the positive scores plus ½ neutral scores)							7+5.5
Calculation 2: A + B + C (Sum of all scores ignoring signs and parenthesis)							18
Probability of Support, $P = (A + 0.5C)(A+B+C)^{-1}$ (Calculation 1 divided by Calculation 2)							69.4%

One scheme is by allowing a fully international facility to be owned by a private company and operated by a consortium of nations or even an international organization . [14] Another method is sending the used nuclear fuel of a country to nations with advanced reprocessing facilities to be recycled back as fuel and then sending it back. This has been done by Japan and Europe from 1969-1990 using recovered fissile material, mixed oxides (MOX). The recovered materials are shipped from Japan going to the UK and France for reprocessing under the contract with Japanese electric utilities. Japan planned to have one-third of its nuclear reactors incorporate the reprocessed mixed uranium-plutonium oxide (MOX) fuel in 2010. [8] In May 2016, the South Australian Nuclear Fuel Cycle Royal Commission said that the state has the necessary attributes and capabilities to develop a world-class waste disposal facility and recommended the construction of an international used-nuclear fuel and intermediate-level waste disposal facility. Such a facility is deemed to be highly profitable and is projected to generate approximately 100 billion Australian dollars over its 120-year project life. [15] But before the proposal could take off, legislative changes are required at the state and federal levels. Another international waste disposal concept is called fuel leasing. The concept involves the electric utility or the nuclear power plant to lease its fabricated fuel from a fuel supplier, then after using it, the supplier would take it back. [15] However, the used nuclear fuel would just add to the fuel supplier's own stock of radioactive waste which does not solve the problem of waste disposal.

The Philippine Nuclear Research Institute (PNRI) and the Philippine legislature may support the concept of international nuclear waste disposal facilities. The PNRI recognizes the significance of responsible nuclear waste management and views international collaboration as a viable solution. Legislative support may also be deemed beneficial, as it demonstrates the Philippines' commitment to responsible waste management and global standards. Beyond waste management, international cooperation could lead to partnerships in research, technology transfer, and energy security discussions. Due to prospective financial implications, local government units (LGUs) may be less inclined to support international cooperation. Hosting international disposal facilities may result in a loss of revenue from domestic nuclear waste disposal sites, which may have repercussions for the local economy and development plans. Local government entities may favors solutions that enable them to retain the advantages of hosting their own waste disposal facilities. Given these, a slightly lower Prince Rating of 69.4% was obtained compared to Option 2.

Therefore, it may be argued that Option 2, which involves the establishment of national disposal facilities, continues to be the most feasible choice for conducting disposal operations. Furthermore, as this study aligns with the recommendation put up by Recto et al. [16] to investigate variations in energy consumption, economic growth and emission reduction across the ASEAN cohort as a means to address the energy trilemma, insights gained from it might serve as a reference point for neighboring nations like Vietnam, Indonesia, and Malaysia, as they develop their own strategies for managing their radioactive wastes.

4. Conclusion

In conclusion, this study has developed a comprehensive road map outlining the complex processes involved in the processing, management, storage, and ultimate disposal of radioactive material across distinct categories inherent to nuclear power plant (NPP) operations. The road map combines stringent technical prerequisites, prudent site selection procedures, careful financial evaluation, meticulous adherence to regulatory imperatives, and effective disposal operations.

In addition to elaborating on the delineation of crucial waste-level criteria, which are essential for informed decision-making, this study has also uncovered a variety of innovative technological modalities pertinent to the processing, management, storage, and disposal of radioactive waste. The feasibility of establishing a state-of-the-art disposal facility tailored to the Philippines has been subjected to a rigorous evaluation utilizing the discerning framework of the Prince Method. Following an exhaustive analysis and discerning evaluation, this study concludes that most judicious course of action is to establish specialized national disposal facilities for nuclear wastes.

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DESIGN AND CONSTRUCTION OF AUTOMATIC VOLTAGE REGULATOR FOR 1 KW WIND POWER GENERATION

Engr.Yin Yin Mya[1]
1Associate Professor, Department of Electrical Power Engineering
West Yangon Technological University, Yangon
Email:tkhinell@gmail.com

Abstract

Wind energy is an increasingly attractive source of energy in the world. There is an emphasis on renewable energy sources such as biomass energy, wind energy, solar thermal and solar photovoltaic, etc. Among these sources, wind power generation systems have been found to be increasingly attractive in places where adequate wind potential is available. Wind turbine speed is not constant and also the wind generator output frequency and voltage have fluctuated. Fluctuating winds have an unpredictable effect on the wind turbine. This voltage fluctuation due to variation of supply voltage or sudden change in loads can be controlled by the automatic voltage regulator. In this thesis, five sections are combined for output voltage regulation. There are considered unregulated & and regulated power supplies for all circuits, six voltage comparators, a relay driver, an over-under cutout with delay timer, and an autotransformer for the circuit of automatic voltage regulator. An automatic voltage regulator is suitable to use for wind power generation. Since its operated power is 1kW, it can be used sufficiently for the home system using wind energy.

Keywords: wind power, automatic voltage regulator, voltage comparators, delay timer, relay driver.

1. Introduction

Wind power is certainly one of the most attractive solutions in the world. Wind power was used earlier for propelling ships, driving windmills, pumping water, irrigation fields, and numerous other purposes. Wind turbine speed is not constant and also the wind generator output frequency and voltage have fluctuated. Wind energy can be converted into electrical energy by using a generator. When the wind blows to the turbine, the mechanical power output is produced and then, this power is applied to the AVR to get the 220 V_{ac}. This 220 V_{ac} is supplied to the loads & Inverter. Then, the inverter output (12V) is used to charge the battery. If the wind energy is not enough to operate the turbine, the discharge voltage (12V) from the battery is supplied to the inverter. Then, this inverter output (220 V_{ac}) is supplied to the load.

The block diagram of wind energy generation is shown in Figure 1. The purpose of using an automatic voltage regulator is to reduce the voltage fluctuation due to variations of supply voltage or sudden changes in loads to be stable. So, an automatic voltage regulator is suitable to use for the wind power generation.

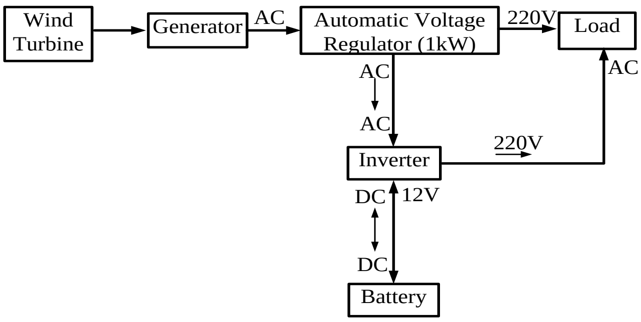

Figure 1. Block Diagram of Wind Power Generation

2. Main Components of Automatic Voltage Regulator Circuit

The main components of the automatic voltage regulator circuit are five sections as shown in Figure 2. They are

(i) Unregulated and regulated power supply for all circuits
(ii) Six voltage comparators
(iii) Relay driver
(iv) Over-under cutout with delay timer
(v) Autotransformer

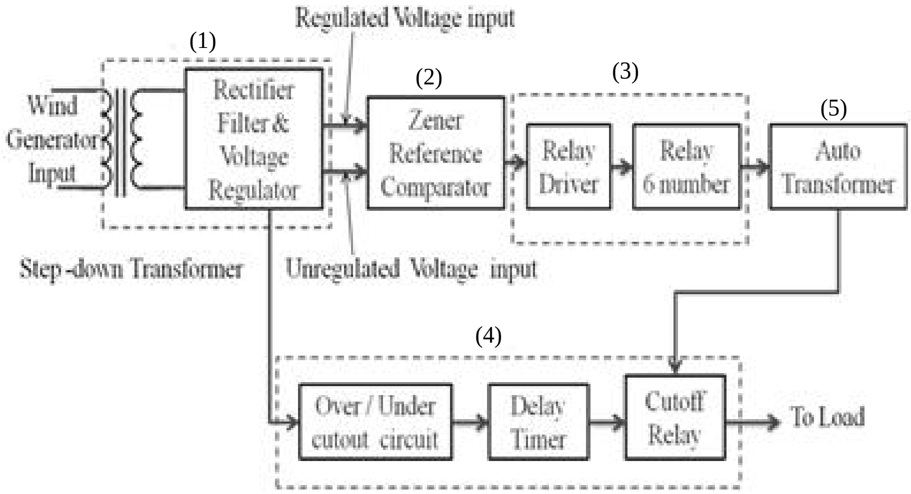

Figure 2. Block Diagram of Automatic Voltage Regulator

A full-wave bridge rectifier capacitor filter is supplied as regulated and unregulated voltage for six comparators, a relay driver, and a timer. In six comparators, each comparator is a zener reference voltage comparator inverting input is used as unregulated voltage input, and non-inverting input is used as 6.2V reference input.

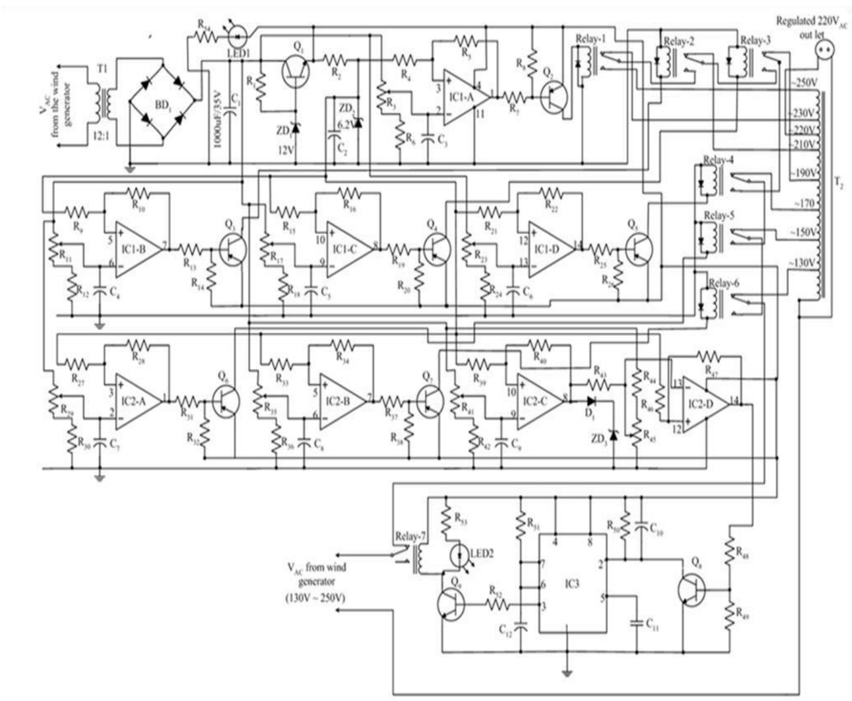

Figure 3. Overall Circuit of Automatic Voltage Regulator

The relay driver circuit is a switch to change from one tap to another and six of the autotransformer. In over–under voltage cutout circuit, two op-amp comparators are combined to produce a bias voltage level for the base of the transistor (Q_8).

3. Design Procedure for Automatic Voltage Regulator

There are five parts to design the inverter circuit.
They are:

- (i) Design of Power Supply for all Circuits
- (ii) Design of Series Regulator
- (iii) Design of Comparator
- (iv) Design of Relay Driver Circuit
- (v) Design of Over and Under Cutout Circuit

4. Design Equations of Power Supply Rectifier And Filter Circuit

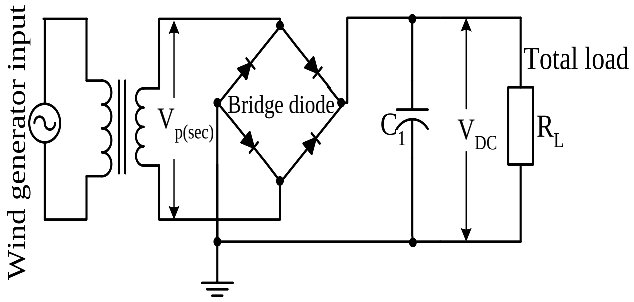

Figure 4. Power Supply Rectifier and Filter Circuit

$$V_{p(sec)} = \left(\frac{N_{sec}}{N_{pri}}\right) V_{p(pri)} \tag{1}$$

$$V_{p(rect)} = V_{p(sec)} - 1.4 \tag{2}$$

$$V_{DC} \cong \left(1 - \frac{1}{2fR_L C}\right) V_{p(rect)} \tag{3}$$

5. Design Equations Regulated Voltage Circuit

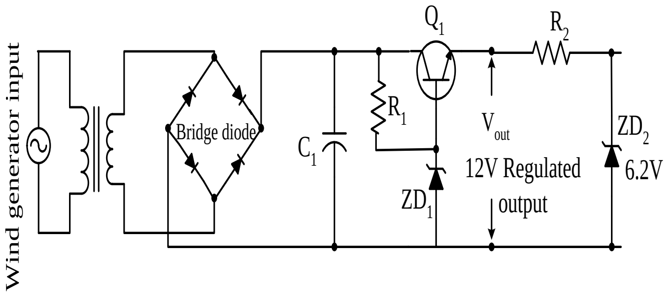

Figure 5. Regulated Voltage Circuit

$$V_{DC} \cong \left(1 - \frac{1}{2fR_L C}\right) V_{p(rect)} \tag{4}$$

$$R_2 = \frac{V_{out} - V_z}{I_z} \tag{5}$$

6. Design Equations of Voltage Comparator Circuit

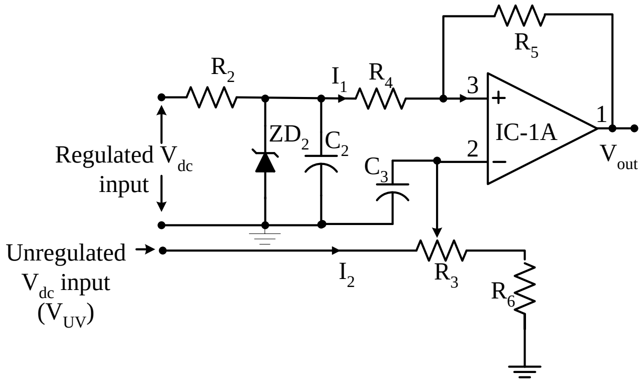

Figure 6. Voltage Comparator Circuit

$$R_4 + R_5 = \frac{V_{REF}}{I} \quad (6)$$

$$V_{(-)} \text{ or } V_{UTP} = V_{REF} + \frac{R_4}{R_4 + R_5}(V_{out(max)} - V_{REF}) \quad (7)$$

$$V_{(-)} \text{ or } V_{LTP} = V_{REF} + \frac{R_4}{R_4 + R_5}(V_{out(min)} - V_{REF}) \quad (8)$$

$$V_{hysteresis} = V_{UTP} - V_{LTP} \quad (9)$$

$$R_3 + R_6 = \frac{V_{UV(max)}}{I_{2(max)}} \quad (10)$$

7. Design Equations of Over and Under Condition Sensing Circuit

For inverting input of comparator (IC2-C), unregulated voltage is V_{uv} =12.4 ~ 25.1 V for ac input variation from 250 V. I_{in} of non-inverting input is neglected.

$$V_{REF} = 6.2V$$

$$R_{39} + R_{40} = \frac{V_{REF}}{I} \quad (11)$$

$$R_{41} + R_{42} = \frac{V_{uv(max)}}{I_{uv}} \quad (12)$$

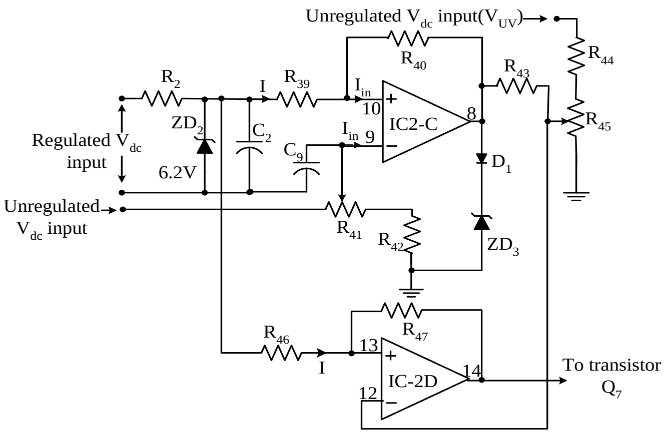

Figure 7. Over and Under Condition Sensing Circuit.

Similarly, for inverting input of comparator (IC2-D), unregulated voltage is V_{uv} =12.4 ~ 25.1 V for ac input variation from 130V to 250 V and non-inverting input current is neglected. Therefore:

$$R_{46} + R_{47} = \frac{V_{REF}}{I} \quad (13)$$

$$R_{44} + R_{45} = \frac{V_{uv(min)}}{I_{uv}} \quad (14)$$

8. Design Equations of 555 Delays Timers and Relay Driver Circuit

In this circuit, delay time and biasing resistance are calculated by using the following equations,

$$V_c = (1 - e^{-t/(R_{51}C_{12})})V_s \quad (15)$$

$$I_{C2} \approx \frac{V_{CC} - V_{CE(sat)}}{R_L} = \beta I_B \quad (16)$$

$$R_B = R_{52} = \frac{V_{Q(out)} - V_{BE(sat)}}{I_B} \quad (17)$$

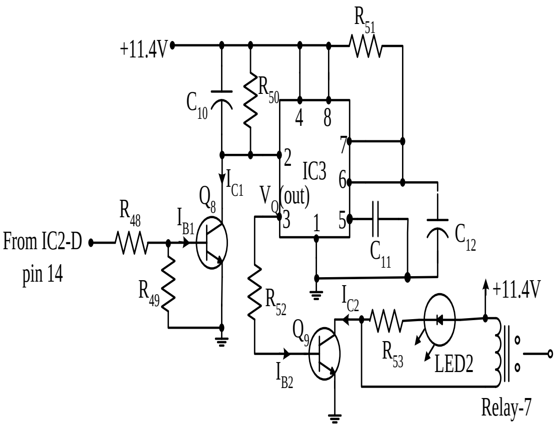

Figure 8. 555 Delay Timers and Relay Driver Circuit

9. Design Equations of Autotransformer

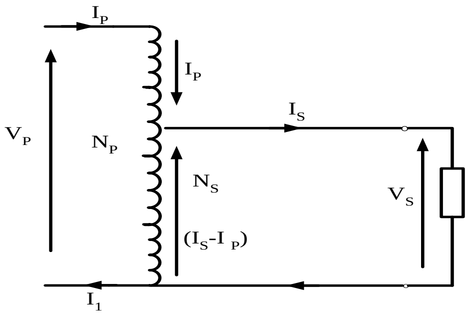

Figure 9. Kirchoff's Law Application to Autotransformer

Input cuurrent,

$$I_p = \frac{P_p}{V_p} \tag{18}$$

The current ratio of transformer,

$$\frac{V_p}{V_s} = \frac{I_s}{I_p} \tag{19}$$

$$V_p : V_s = N_p : N_S \tag{20}$$

$$I_p N_p = I_s N_s \tag{21}$$

Turn ratio,

$$n = \frac{N_p}{N_s} \tag{22}$$

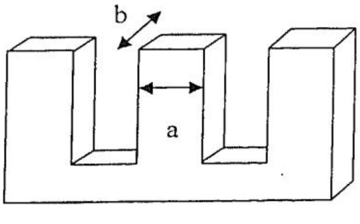

Figure 10. E Core Diagram of Autotransformer

Iron core cross-sectional area is;

$$A = \frac{\sqrt{P_{in}}}{5.58} \tag{23}$$

The net of cross-sectional area is;

$$A_1 = 1.1 \times A \tag{24}$$

The torque width;

$$a = \sqrt{A_1} \tag{25}$$

The stack height;

$$b = \frac{A_1}{a} \tag{26}$$

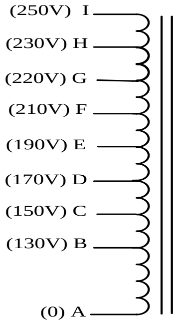

Figure 11. Autotransformer Pin Layout for 130V to 250V

Turns per volt is:

$$\frac{N}{E} = \frac{1}{(4.44FBA \times 10^{-8})} \tag{27}$$

Number of turn per volt,

$$N = \frac{7.5}{A}$$

$$N_{AB} = V_{AB} \times N \tag{28}$$

$$N_{BC} = V_{BC} \times N$$

$$N_{BC} = N_{CD} = N_{DE} = N_{EF} = N_{HI}$$

$$N_{FG} = N_{GH} = V_{FG} \times N \tag{29}$$

$$N_{AC} = N_{AB} + N_{BC} \tag{30}$$

10. Simulation and Test Results of Automatics Voltage Regulator

The following simulations are the simulation results by the used of National Instrument Simulation Software (multisim version 10.1).

In this condition, over under indicator (LED) is not operated (not lit).

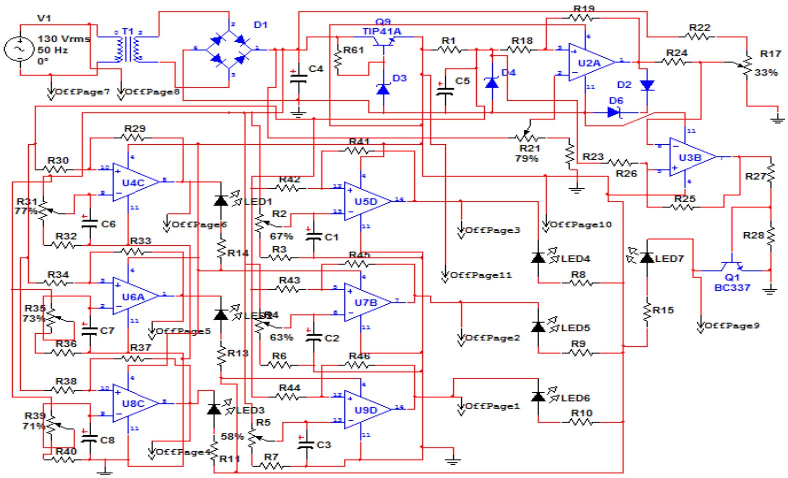

Figure 12.Simulation Diagram of Automatic Voltage Regulator when Input A.C Supply Voltage is at 130V

In this condition, all AVR and over under cutout relays are de-energized.

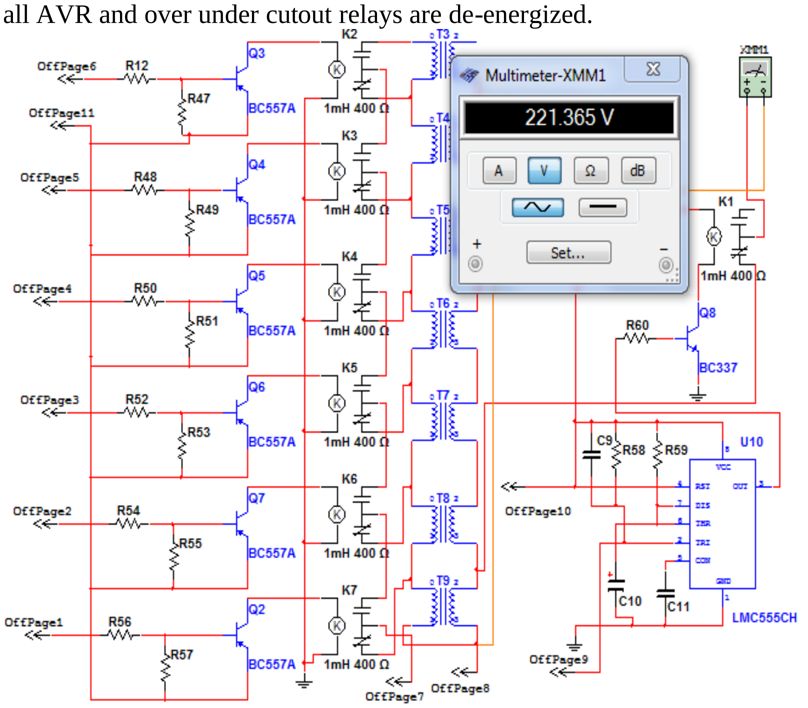

Figure 13. Simulation Diagram of Automatic Voltage Regulator When Input A.C Supply Voltage is at 130V (for relay driver & over- under cutout sections

In this condition, 150, 170, 190, 210, 230 and 250V indicator (LED) are operated and over under (LED) is not operated.

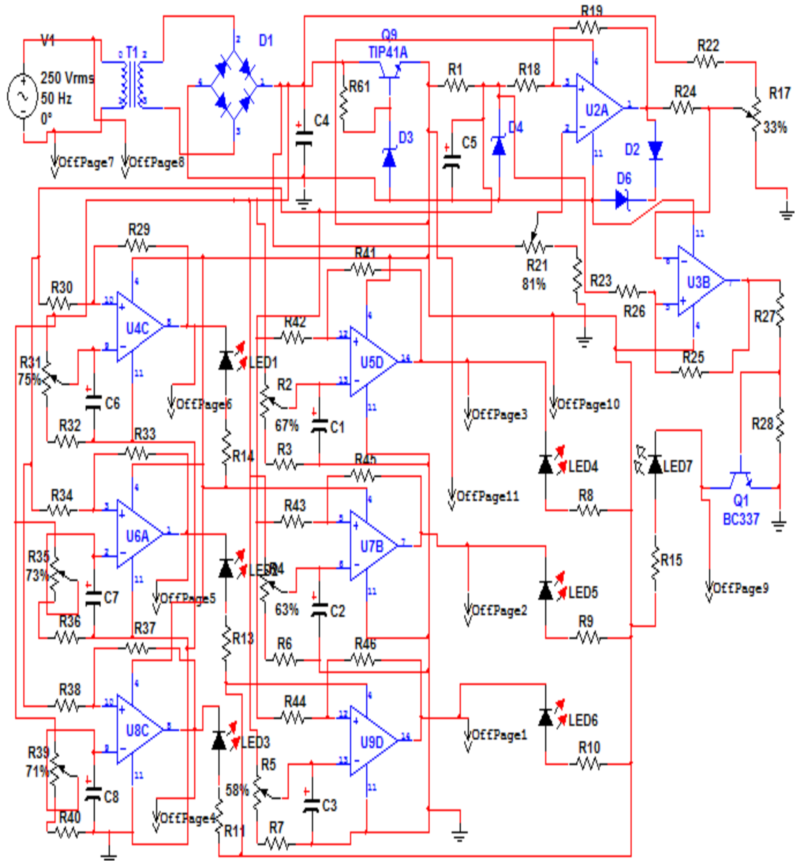

Figure 14. Simulation Diagram of Automatic Voltage Regulator when input A.C supply voltage is at 250V

In this condition, AVR relays K2, K3, K4, K5, K6 and K7 are energized and over under relay is de-energized. So, output load voltage is continuous produced.

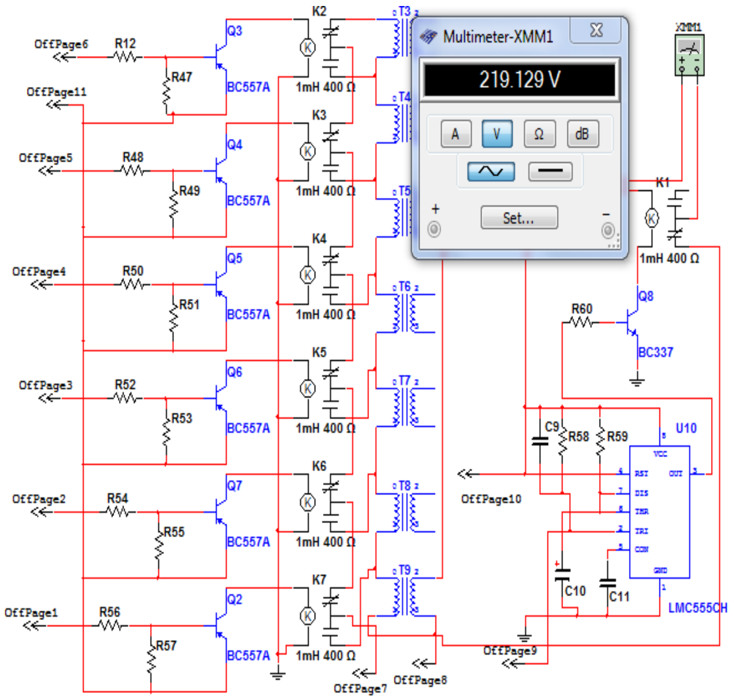

Figure 15. Simulation Diagram of Automatic Voltage Regulator when input A.C supply voltage is at 250V (for Relay Driver and Over-Under Cutout Section

Table 1. Explanation table for simulation results

Input A.C voltage of from Wind Generator	**Relay condition of voltage regulator section**	**Relay condition of over-under cutoff section**	**Output A.C voltage from autotransformer**
Under130V	Deenergize (k_2 to k_7)	Energize (k_1)	Under 220V
130V	Deenergize (k_2 to k_7)	Deenergize (k_1)	220V (app:)
150V	Energize (k_7)	Deenergize (k_1)	220V (app:)
170V	Energize (k_6 to k_7)	Deenergize (k_1)	220V (app:)
190V	Energize (k_5 to k_7)	Deenergize (k_1)	220V (app:)
210V	Energize (k_4 to k_7)	Deenergize (k_1)	220V (app:)
230V	Energize (k_3 to k_7)	Deenergize (k_1)	220V (app:)
250V	Energize (k_2 to k_7)	Deenergize (k_1)	220V (app:)
Over 250V	Energize (k_2 to k_7)	Energize (k_1)	Over 220V

11.Discussion

Wind energy is the increasing attractive sources of energy in the world. Wind energy is a renewable electricity production from converting the kinetic energy of moving air into electrical energy. Electrical energy is the most essential item for modern human beings. Demand of electrical energy increases in everyday. Recently, wind power has been reevaluated as a new potential source of electric power generation. Wind-electric systems generate power only when the wind blows. Wind turbine speed is not constant and also the wind-generator output frequency and voltage have fluctuated. A wind power generation control system is required to control this output frequency and voltage.

In this thesis, the design and construction of an automatic voltage regulator for 1kW wind power generation is discussed. The automatic voltage regulator (AVR) is used to reduce the voltage fluctuation due to variations of supply voltage or sudden changes in loads to be stable. When the wind blows to the turbine, the mechanical power output is produced and then, this power is applied to the AVR to get the 220 V_{ac} . This 220 V_{ac} is supplied to the loads & Inverter. Then, the inverter output (12V) is used to charge the battery. If the wind energy is not enough to operate the turbine, the discharge voltage (12V) from the battery is supplied to the inverter. Then, this inverter output (220 V_{ac}) is supplied to the load. So, an automatic voltage regulator can make the output voltage to be stable for all electrical.

12. Conclusion

Various voltage regulation techniques are used in the industry. For wind energy AC generators, the generated output voltage is variable and it is controlled by an automatic voltage regulator to be stable output voltage. The automatic voltage regulator of this thesis is available to respond to the voltage disturbances occurring in the system and regulate the voltage back to its nominal value, and also provide under voltage protection with delay time. Since its operated power is 1kW, it can be used sufficiently for the home system using wind energy. They have a low cost per watt of output, are very efficient, have huge power output possible, and are extremely study construction. Moreover, they are the most powerful and cost-effective solution for building a wind generator. An automatic voltage regulator is suitable to use for wind power generation.

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UNLOCKING INDONESIA'S ENERGY POTENTIAL: EXTRACTING CLEAN ENERGY FROM SEA AND SALINE BRINES

Rahadian NOPRIANTOKO[1], Aries Abbas[2]

[1]Mechanical Engineering Department, Engineering Faculty, Universitas Krisnadwipayana, Bekasi 13077, Indonesia.
[2]Persatuan Insinyur Indonesia (PII), Jakarta, 12980, Indonesia

rahadiann@unkris.ac.id

Abstract

The potential of Energy extraction from seawater and saline brines holds the potential to transform Indonesia's energy landscape. This paper presents a comprehensive review of the technologies and opportunities in this field within the Indonesian context. The analysis encompasses methods such as pressure-retarded osmosis, reverse osmosis, and electrodialysis, harnessing the salinity gradient between seawater and saline brines to produce clean, renewable energy. A quantitative assessment of Indonesia's sea and saline brine resources unveils an abundant, yet largely untapped, renewable energy source. With a coastline stretching over 108,000 kilometers and vast maritime territory, Indonesia can potentially harness approximately 1.4 billion cubic meters of seawater daily. The paper delves into the significant challenges and constraints that currently impede the widespread implementation of these technologies in Indonesia. Environmental considerations, encompassing potential impacts on marine ecosystems, alongside economic feasibility assessments, highlight the multifaceted complexities associated with adopting these novel approaches. The findings underscore the urgent need for a robust framework that supports research, encourages innovation, and guides policy development to effectively integrate energy extraction from sea and saline brines into Indonesia's energy sector. A crucial emphasis is placed on the necessity of collaboration among academia, industry, and government entities. This collaboration is fundamental in advancing technology development, optimizing energy conversion processes, and proactively mitigating potential environmental impacts. In conclusion, this review provides quantitative insights into the directions for future research that are essential to unlock the full potential of energy extraction from sea and saline brines. These avenues encompass the exploration of hybrid systems aiming for up to 30% enhanced efficiency, coupled with improvements of up to 15% in energy conversion efficiencies, and the investigation of novel materials and technologies. Moreover, the successful harnessing of energy from sea and saline brines is projected to make a significant contribution to Indonesia's energy transition objectives, potentially accounting for up to 10% of the nation's electricity demand by 2030. This quantifiable progress has the potential to enhance energy security, significantly reduce greenhouse gas emissions by up to 1.5 million tons annually, and authentically advance sustainable development. These achievements align harmoniously with Indonesia's commitments under the Paris Agreement.

Keywords: energy extraction, Indonesia, green energy, renewable technology, sustainability

1. Introduction

Indonesia, with its vast archipelago and burgeoning population, finds itself at a crucial juncture in addressing its ever-expanding energy requirements. This section elucidates the pressing energy needs of the nation, which have been propelled by factors like population growth and economic development. Indonesia, as the world's fourth most populous nation, is grappling with an exponential increase in energy consumption. Its diverse and dynamic economy, coupled with a population exceeding 270 million [1], underscores the critical role that energy plays in driving progress and development across the nation. The demand for energy, in various forms, has reached unprecedented levels, from electricity to transportation fuels. Indonesia's energy needs have been significantly amplified by its rapid population growth and urbanization. Over the past few decades, the nation has witnessed an extraordinary surge in its urban centers. Millions of Indonesians have transitioned from rural to urban life, a shift that has necessitated substantial energy investments to power homes, industries, and transportation networks in these burgeoning cities.

Indonesia's economic growth, particularly in manufacturing and industry, has led to a rising demand for energy. To address this, the country is pursuing a strategy that combines fossil fuels with renewable and alternative energy sources to ensure a sustainable and secure energy future. Challenges include extending energy access to remote regions, modernizing infrastructure, and integrating renewable resources. Indonesia also faces environmental challenges due to coal reliance and deforestation for energy. Balancing economic feasibility with sustainability is complex. Regulatory frameworks must incentivize clean energy investments and sustainable practices while reducing greenhouse gas emissions. To address these challenges, Indonesia is exploring energy extraction from sea and saline brines, leveraging its extensive coastlines. This approach offers a clean and renewable energy source, though it requires addressing environmental concerns, economic viability, and policy collaboration. Diversifying energy sources is essential for

Indonesia's long-term energy security and environmental responsibility, aligning with its developmental goals and commitment to reducing its carbon footprint. Sea and saline brine energy can meet current and future energy needs without emitting greenhouse gases, contributing to climate change mitigation.

Innovation and technology are the engines of progress. As the world advances, new technological frontiers emerge. The energy extraction from sea and saline brines leverages cutting-edge technologies like pressure-retarded osmosis, reverse osmosis, and electrodialysis. Exploring energy extraction from sea and saline brines in Indonesia offers cleaner energy, promotes research and development, and drives economic growth. It positions Indonesia as an innovative player in sustainable energy, potentially leading to technology exports and collaborations. Reduced energy imports enhance national sovereignty and economic stability, reducing vulnerability to global energy market fluctuations. This move towards energy independence aligns with Indonesia's economic goals, environmental responsibilities, and technological ambitions. It offers a unique opportunity to diversify the energy mix, meet growing demand, reduce carbon emissions, and promote sustainability.

Indonesia, a country in Southeast Asia, is experiencing significant economic growth and population expansion, leading to a substantial increase in energy demand. The energy infrastructure struggles to keep up, resulting in power shortages and environmental concerns due to heavy reliance on fossil fuels. Exploring energy extraction from seawater and saline brines is seen as a compelling solution, utilizing the country's extensive coastlines and maritime territory to tap into clean and renewable energy sources. This approach aligns with the need to diversify the energy mix, enhance energy security, and reduce the environmental footprint. The primary objective of this paper is to comprehensively review the technologies and opportunities related to extracting energy from seawater and saline brines in Indonesia. The research aims to clarify the technology's complexities, assess resource abundance and accessibility, identify key challenges, and stress the importance of collaboration among academia, industry, and government entities. The research also outlines future directions and areas for further exploration, including hybrid systems, energy efficiency improvements, and innovative materials and technologies. The paper aims to provide valuable insights, quantitative data, and a roadmap to support Indonesia's transition to a sustainable energy future, aligning with international commitments under the Paris Agreement [2] and addressing economic, environmental, and energy security concerns.

2. Materials and Methods

In order to comprehensively explore the potential of extracting energy from seawater and saline brines in the Indonesian context, a systematic research approach was employed. This approach encompassed multiple stages, each designed to provide a detailed and rigorous assessment of the technologies involved. The research commenced with an extensive literature review. This phase involved the identification and review of academic papers, reports, and publications from reputable sources such as academic databases, government publications, and international organizations. The purpose was to establish a robust understanding of the various technologies available for energy extraction from seawater and saline brines. Subsequently, a comprehensive evaluation of these technologies was conducted. This involved a detailed analysis of their principles, mechanisms, efficiency, and suitability within the Indonesian context. The technologies under scrutiny included pressure-retarded osmosis, reverse osmosis, and electrodialysis. Their comparative advantages, disadvantages, and scalability [3]–[5] were examined to determine their potential applicability to Indonesia's specific conditions. A significant aspect of this research was the quantitative analysis of Indonesia's sea and saline brine resources. This step aimed to provide precise figures regarding the abundance and accessibility of these resources. Accurate data on Indonesia's extensive coastline, maritime territory, and salinity gradients were collected and analyzed to quantify the nation's potential for renewable energy extraction. In the process of this research, a variety of resources were utilized. Access to academic databases, research articles, and reports provided a foundation for understanding the technological landscape. Collaboration with experts in the field, both nationally and internationally, facilitated insights into the practical aspects of energy extraction from seawater and saline brines.

The research followed a systematic approach that involved multiple stages to comprehensively evaluate the subject matter. This method allowed for the identification of viable technologies, a quantified assessment of Indonesia's resource potential, and a thorough understanding of the challenges and opportunities in implementing these technologies in the country. The goal was to provide a foundation for informed decision-making and policy development in the pursuit of sustainable and clean energy sources for Indonesia. To achieve this, a diverse range of resources was leveraged, including scholarly journals, research papers, official publications, and reports from government agencies. Industry reports, case studies, collaborations with academic institutions and research centers, as well as interviews with subject matter experts, enriched the research with practical insights and expert opinions. Drawing parallels with international cases and best practices further enriched the analysis. This comprehensive approach facilitated a quantitative review of energy extraction technologies from seawater and saline brines. It ensures that the findings are grounded in empirical data and expert knowledge, serving as a valuable resource for policymakers, researchers, and stakeholders. The systematic methodology supports informed decision-making and policy formulation for sustainable, clean energy sources in Indonesia. The methodical procedure guarantees the dependability and pertinence of the information conveyed, enabling readers to acquire an all-encompassing comprehension of the topic. In conclusion, the outcomes and discussions lead to drawing deductions. Generally, the research's sequence is visually represented in Figure 1.

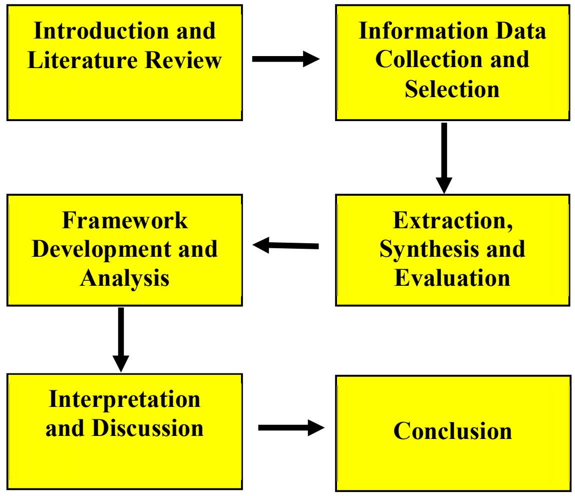

Figure 1. Flowchart of Methodology

3. Results and Discussion

3.1. Energy Extraction Technologies

Pressure-Retarded Osmosis (PRO) is an innovative technology that utilizes the osmotic pressure difference between seawater and fresh water (or low-salinity water) to generate clean and sustainable energy [6], the system diagram is given by Figure 2. In PRO, two separate solutions are involved: a "draw" solution with high salinity and a "feed" solution with low salinity. These solutions are placed on either side of a semipermeable membrane, which selectively allows water molecules to pass through but not the dissolved salts. This migration of water molecules causes an increase in the volume and pressure of the draw solution, creating hydraulic pressure. The generated hydraulic pressure can then be used to drive a hydraulic turbine or a pressure exchange device, which in turn drives a generator to produce electricity. Pressure-Retarded Osmosis (PRO) is a promising technology that leverages the osmotic pressure difference between seawater and low-salinity water to generate clean and sustainable energy. The abundance of seawater resources and the availability of low-salinity water sources, such as rivers or brackish water, offer an excellent opportunity to harness this technology for clean energy production [4]. Its application in Indonesia can tap into the nation's abundant seawater resources and contribute to its energy transition goals, enhancing energy security while minimizing environmental impacts.

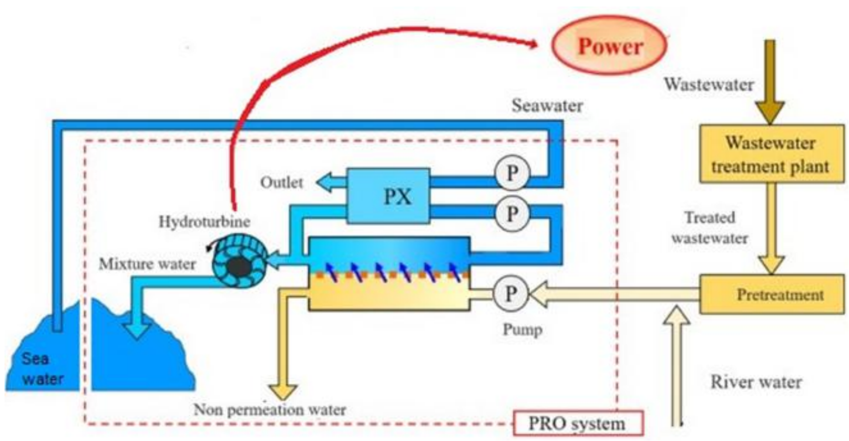

Figure 2. System Diagram of Pressure-Retarded Osmosis (PRO) Technology

Reverse Osmosis (RO) is a well-established technology primarily known for desalinating saline water to produce freshwater [7]–[11], the system diagram is shown by Figure 3. However, it can also be ingeniously adapted to harness osmotic pressure as a potential energy source while simultaneously obtaining freshwater, making it a versatile solution for addressing both water and energy challenges. In PRO, freshwater and draw solution (a solution with higher salinity) are separated by a semipermeable membrane, similar to traditional RO. Essentially, PRO combines the benefits of desalination with the generation of clean and renewable energy, making it a sustainable and innovative solution. In the context of Indonesia, where both freshwater scarcity and renewable energy generation are significant concerns, RO and its variant PRO hold promise. Reverse Osmosis (RO) and its derivative, Pressure-Retarded Osmosis (PRO), offer a dual-purpose solution for obtaining freshwater from saline water while harnessing osmotic pressure as an energy source. These technologies have the potential to address Indonesia's water and energy challenges, especially in regions with limited freshwater resources and high salinity gradients.

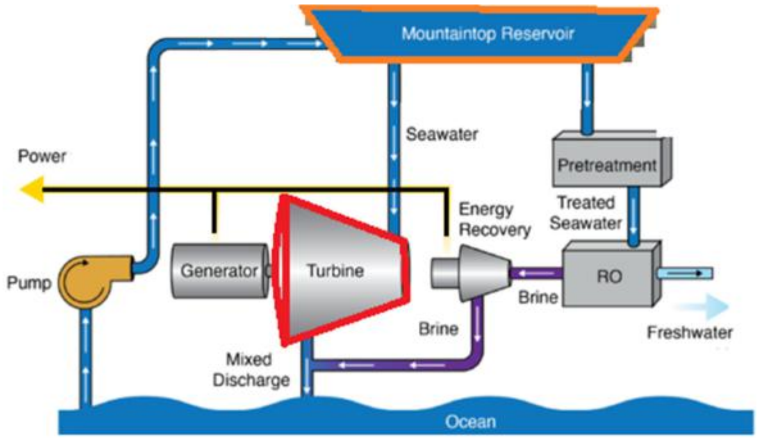

Figure 3. System Diagram of Reserve Osmosis (RO)Technology

Electrodialysis is an innovative technology that uses ion-selective membranes to separate and manipulate ions in aqueous solutions, including seawater and saline brines [12]–[16], as shown in Figure 4. It desalinates water and produces electricity by selectively transporting ions through membranes. Electrodialysis offers a dual solution for Indonesia, addressing freshwater needs and contributing to clean energy goals [17]–[20]. Hybrid systems, combining technologies like PRO, RO, and Electrodialysis, enhance energy efficiency and production. These systems can store excess energy and address Indonesia's intermittent renewable energy challenges [21], [22]. By integrating these technologies, we optimize energy generation and mineral recovery, contributing to sustainable development. Hybrid systems offer a promising approach to tackle Indonesia's complex energy and freshwater challenges by maximizing energy efficiency and addressing intermittency issues.

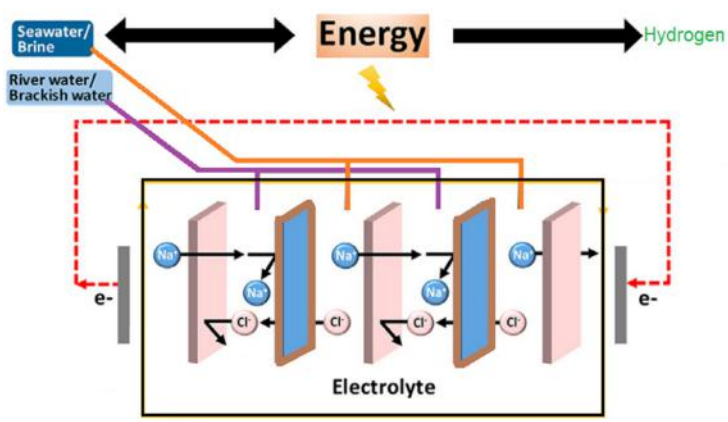

Figure 4. System Diagram of Electrodialysis Technology

3.2. Seawater and Saline Brine Resources in Indonesia

Indonesia, the world's largest archipelagic nation, comprises 17,504 islands and boasts a coastline stretching approximately 108,000 kilometers based on data of Indonesian Navy's Hydro-Oceanographic Center (PUSHIDROSAL), and with vast maritime territory, Indonesia can potentially harness approximately 1.4 billion cubic meters of seawater daily. This unique geographical feature renders Indonesia's maritime territory even more expansive than its land area. Indonesia's total maritime expanse covers about 6.4 million square kilometers, surpassing its land area of 1.9 million square kilometers [23]. Indonesia's geographical features, including its vast coastline and maritime territory, provide a significant opportunity for harnessing seawater and saline brine resources as a renewable energy source. With hundreds of thousands of kilometers of coastline and a wealth of seawater and saline brines, Indonesia possesses an untapped reserve for clean energy production. This geographical advantage, coupled with its archipelagic configuration, offers a unique platform for integrating innovative technologies into the national energy infrastructure.

Indonesia's tropical climate, with abundant seawater and salinity gradients in coastal areas, offers a valuable resource for energy generation while aligning with sustainability goals. These advantages support the reduction of fossil fuel dependence, greenhouse gas emissions mitigation, energy security, and economic growth. Accessing these resources, particularly in developed coastal areas with seaports, is relatively straightforward. However, challenges exist in remote or less-developed regions, necessitating infrastructure development and logistics improvements. Environmental considerations are crucial in responsible energy extraction. Safeguards and regulations are vital to protect marine ecosystems. Efforts to improve accessibility should ensure equitable benefits distribution across diverse regions, addressing infrastructure and transportation challenges. Balancing economic development with environmental sustainability is essential. Quantitative assessments of Indonesia's seawater and saline brine resources emphasize their vast potential for clean and renewable energy. Innovative technologies like PRO, RO, and ED can harness the salinity gradient, contributing significantly to Indonesia's power grid. Additionally, saline brines offer energy potential that enhances energy security and aligns with global emissions reduction efforts. The research explores the environmental impact and strategies for mitigation, ensuring Indonesia's commitment to sustainable development. These resources provide a unique opportunity to meet energy needs while promoting a cleaner and more sustainable future, benefiting Indonesia's energy landscape. The research aims to provide detailed insights into this potential, facilitating innovative solutions.

The successful extraction of energy from seawater and saline brines in Indonesia carries the promise of transformative impacts that extend across various critical dimensions. Quantifying these impacts sheds light on the significance of this innovative approach in advancing the nation's energy transition objectives, reducing greenhouse gas emissions, and promoting sustainable development [24]. Indonesia is dedicated to transitioning to a cleaner and more sustainable energy landscape, and the successful extraction of energy from seawater and saline brines is seen as a pivotal step in achieving this goal. By potentially meeting up to 10% of the nation's electricity demand by 2030, this renewable energy source significantly contributes to diversifying the energy mix, enhancing energy security, and reducing dependence on fossil fuels. This shift is essential as Indonesia's traditional reliance on fossil fuels has led to high greenhouse gas emissions. Transitioning to cleaner energy sources is crucial for mitigating climate change. Energy extraction from seawater and saline brines can substantially reduce greenhouse gas emissions, potentially by up to 1.5 million tons annually. This quantifiable reduction underscores Indonesia's commitment to the Paris Agreement and its role in global climate action.

Sustainable development is a top priority for Indonesia, encompassing economic growth, environmental conservation, and social well-being. Extracting energy from seawater and saline brines aligns with sustainability principles by providing a clean and renewable energy source that promotes economic growth, energy access, and environmental protection. It also fosters research, innovation, and the development of a knowledge-based economy. Moreover, it positively impacts marine ecosystems, reduces air pollution, and enhances public health and societal well-being. Quantifying the impact of successful energy extraction from seawater and saline brines underscores its vital role in Indonesia's journey toward a sustainable and low-carbon future. This innovative approach aligns seamlessly with the nation's energy transition goals, greenhouse gas emissions reduction targets, and broader sustainable development objectives. By harnessing the vast potential of this renewable energy source, Indonesia not only secures its energy future but also makes significant strides in environmental stewardship and global climate leadership. The efforts to harness energy from seawater and saline brines in Indonesia align with the nation's commitments under the Paris Agreement, which aims to limit global warming and reduce the impacts of climate change.

At the heart of the Paris Agreement is the goal to reduce greenhouse gas emissions, a major driver of climate change [25]. Energy generation from conventional fossil fuels is a significant source of these emissions. By transitioning towards energy sources like seawater and saline brines, which produce little to no greenhouse gas emissions during electricity generation [11], [26], Indonesia contributes directly to the overarching aim of the Paris Agreement. Energy extraction from seawater and saline brines aligns with the principles of the Paris Agreement, which emphasizes the importance of sustainable development that balances environmental protection with societal needs. This renewable energy source represents a clean and sustainable energy solution that fosters economic growth, ensures energy access, and minimizes environmental harm. The Paris Agreement also stresses the need to build resilience to climate change impacts. Indonesia's pursuit of renewable energy sources like seawater and saline brine energy contributes to resilience by diversifying the energy mix, reducing reliance on fossil fuels susceptible to price fluctuations and supply disruptions. This enhances energy security, making Indonesia better prepared to address climate-related challenges. As a signatory to the Paris Agreement, Indonesia's exploration of energy extraction from seawater and saline brines showcases its commitment to the agreement's goals. It demonstrates international leadership and a dedication to collective climate action, aligning with the spirit of cooperation and solidarity embedded in the Paris Agreement. Indonesia's efforts in this regard contribute significantly to the global fight against climate change and the pursuit of a more sustainable future for all.

3.3. Challenges and Constraints

While the potential of extracting energy from sea and saline brines in Indonesia is undeniably promising, it is not without its share of challenges. Understanding and addressing these challenges is crucial to pave the way for the successful implementation of this innovative technology. One of the foremost challenges is the potential impact on marine ecosystems. The extraction of energy from seawater and saline brines requires the manipulation of salinity gradients, which could have ecological consequences [27]–[29]. Balancing the benefits of clean energy generation with the preservation of marine environments is a complex issue that demands careful consideration when it comes to extracting energy from seawater and saline brines. To ensure minimal harm to marine ecosystems, it's crucial to integrate environmental impact assessments and mitigation strategies into the deployment of these technologies.

Implementing technologies for energy extraction from seawater and saline brines in Indonesia faces significant challenges. Economic feasibility is a major concern, given the substantial initial and operational costs. Assessing cost-effectiveness compared to existing energy sources is crucial, including long-term benefits and infrastructure considerations. Establishing favorable regulatory frameworks is essential to support the widespread adoption of these technologies, covering permitting, environmental regulations, and incentives. Scaling up from small experiments to large-scale applications requires substantial investments and development efforts to optimize efficiency and integration into the energy grid. Public awareness and acceptance are vital, necessitating efforts to build trust and understanding among various stakeholders and local communities. International collaboration can provide expertise, funding, and knowledge exchange but involves complex agreements and negotiations. Addressing these challenges in the development and implementation of energy extraction from seawater and saline brines is crucial to unlock the full potential of this renewable energy source while ensuring economic viability and a sustainable energy future. It is also essential to address environmental considerations for responsible and sustainable practices.

One of the foremost concerns in extracting energy from seawater and saline brines is the potential impact on marine ecosystems [8]. The discharge of highly concentrated brine back into the ocean can alter local salinity levels, affecting marine life and habitats. To mitigate this, careful monitoring of discharge locations, dilution strategies, and the use of diffusers can help disperse brine more effectively, reducing its immediate impact. Increased salinity due to brine discharge can harm aquatic biodiversity, particularly sensitive species. Implementing marine protected areas and conducting regular biodiversity assessments can aid in safeguarding vulnerable ecosystems. Additionally, the development of advanced brine treatment technologies, such as reverse osmosis, can significantly reduce brine salinity before discharge. Discharging brine with high salinity can negatively impact water quality, affecting local communities and industries reliant on coastal waters. To address this, environmental impact assessments should be carried out to determine the potential consequences of brine discharge on water quality. Furthermore, investing in advanced treatment methods to reduce brine salinity can help maintain acceptable water quality standards.

The energy-intensive nature of desalination technologies used in seawater and saline brine energy extraction can inadvertently contribute to greenhouse gas emissions if not powered by renewable sources. A strategic approach involves integrating renewable energy systems, such as solar or wind power, to minimize the carbon footprint associated with energy extraction. Sustainable resource management is essential to ensure the long-term viability of energy extraction from seawater and saline brines. Implementing resource allocation plans and monitoring resource usage can prevent overexploitation and protect these valuable resources. The treatment of brine and other waste products is a critical aspect of mitigating environmental impacts. Advanced treatment methods should be employed to minimize the environmental footprint of waste disposal. Recycling and reusing treated brine can also reduce waste generation. The construction and operation of energy extraction facilities along coastlines can lead to coastal erosion and instability [30], [31]. Mitigating the environmental effects of energy extraction from seawater and saline brines in Indonesia requires the implementation of engineering solutions such as coastal protection structures and sustainable coastal management practices. These measures can help preserve the integrity of coastal environments and minimize adverse impacts. Additionally, engaging local communities and stakeholders is crucial to ensure responsible environmental practices. Public awareness campaigns and community involvement can foster a sense of ownership over environmental protection efforts, leading to more sustainable outcomes.

Addressing environmental factors is pivotal in the successful and responsible implementation of energy extraction from seawater and saline brines in Indonesia. A holistic approach that combines advanced technologies, environmental impact assessments, and sustainable practices can help strike a balance between meeting energy needs and preserving the invaluable marine and coastal ecosystems of the nation. When considering the economic feasibility of energy extraction from seawater and saline brines, it's essential to analyze investment requirements, operational costs, and the potential returns on investment for these technologies. The initial investments in infrastructure, equipment, and research and development are substantial but necessary to establish the facilities and develop innovative solutions for efficient energy conversion. Public-private partnerships and government incentives can help attract the required funding for these capital-intensive projects. Operational costs represent a significant ongoing economic factor, encompassing maintenance, energy consumption, labor, and monitoring expenses. Analyzing these costs is vital to ensure the technology remains financially sustainable over the long term. Implementing energy-efficient equipment and streamlined operational processes can help manage and potentially reduce these costs, improving the overall economic feasibility of these technologies.

The economic viability of energy extraction from seawater and saline brines is closely tied to energy pricing and tariffs [27], [32]. The economic feasibility of energy extraction from seawater and saline brines is influenced by various factors, including market conditions, government policies, and scalability. Market conditions can fluctuate, and government incentives can enhance the technology's attractiveness by providing favorable pricing structures and incentives for clean energy sources. Scalability is crucial for economic feasibility, as increasing the scale of operations can lead to reduced costs per unit of energy produced, emphasizing the importance of efficient system design for scalability. Assessing potential returns on investment (ROI) is fundamental, considering energy production rates, pricing, and operational costs. Despite substantial initial investments, long-term economic benefits, such as revenue generation and energy savings, can make these technologies financially viable.

Government policies and incentives, including tax incentives, subsidies, and feed-in tariffs, play a pivotal role in determining economic feasibility. Policy stability and regulatory support are essential for attracting private sector investments. Technological advancements can significantly impact economic feasibility, with continuous research and development efforts leading to more efficient and cost-effective systems. Material design and system integration improvements can enhance overall economic performance. A comprehensive cost-benefit analysis is valuable for weighing costs against benefits, including energy generation, reduced emissions, and potential revenue streams. Collaborative efforts among governments, industry stakeholders, and research institutions are crucial to address these economic aspects and make clean energy technologies economically viable and sustainable in the Indonesian context.

The successful implementation of energy extraction technologies from seawater and saline brines in Indonesia is significantly influenced by the existing regulatory framework. Regulatory aspects play a crucial role in shaping the development and adoption of these technologies. Environmental regulations ensure compliance with stringent standards to protect marine ecosystems, water quality, and aquatic life. Acquiring licenses and permits is essential for legal and responsible project deployment. Indonesia's energy sector is subject to specific regulations and policies, influencing the integration of new technologies. Existing regulations regarding energy production, distribution, and pricing can impact the economic viability of energy extracted from seawater and saline brines, requiring adjustments to align with national energy transition goals. Intellectual property and technology transfer regulations can either foster or hinder technology development and deployment, making clear guidelines for technology transfer and intellectual property rights essential for innovation and collaboration. Trade regulations and tariffs may also be a consideration if components or materials used in these technologies are imported, necessitating an understanding and navigation of trade regulations for efficient project implementation.

Governments often use incentives and subsidies to promote the adoption of clean energy technologies. Regulations that provide tax incentives, feed-in tariffs, or subsidies for renewable energy projects can significantly boost the economic feasibility of energy extraction from seawater and saline brines [10], [33]–[35]. Regulatory stability and consistency are vital for attracting investments and fostering long-term commitment to these technologies. Frequent regulatory changes or policy uncertainties can deter investors and slow down technology development. Therefore, a predictable and supportive regulatory environment is critical. Regulatory frameworks that encourage collaboration between academia, industry, and government entities can expedite technology development. These frameworks can facilitate research partnerships, technology demonstrations, and shared resources, streamlining the path to commercialization. Navigating the regulatory landscape is a fundamental aspect of deploying energy extraction technologies from seawater and saline brines in Indonesia. A well-structured regulatory framework, one that balances environmental protection, economic feasibility, and technology advancement, can foster the successful integration of these clean energy solutions into Indonesia's energy landscape. Collaborative efforts among stakeholders, clear guidelines, and regulatory adaptability are key to overcoming regulatory challenges and achieving sustainable energy development.

3.4. Collaboration and Policies

among academia, industry, and government is essential for advancing the development and implementation of energy extraction technologies from seawater and saline brines in Indonesia. Each of these stakeholders has a unique role to play in overcoming the challenges and accelerating progress in this field. Academic institutions are hubs of research and innovation, contributing to fundamental research and educating a skilled workforce. They serve as a bridge between theoretical knowledge and practical application, working closely with industry and government. The industry is responsible for scaling up these technologies, turning innovative concepts into tangible solutions. They invest in research and development, undertake pilot projects, and leverage scientific knowledge to make these technologies practical and cost-effective. Government plays a critical role in shaping policies, providing regulatory frameworks, and offering incentives for clean energy technology development. They also establish environmental standards to ensure the sustainability of energy extraction processes. Collaboration ensures that research findings are translated into practical applications, technologies are optimized for efficiency and cost-effectiveness, and ethical and environmental considerations are integrated into the development process. It fosters an environment of innovation, knowledge sharing, and continuous improvement. This synergy among academia, industry, and government holds the potential to drive significant advancements in technology development and energy conversion optimization, positioning Indonesia on the path to a cleaner and more secure energy future.

In the journey towards harnessing the potential of energy extraction from seawater and saline brines in Indonesia, the role of well-crafted policies cannot be overstated. Policies act as the bedrock upon which technological innovation and sustainable energy practices are built. Their development is essential to foster an enabling environment that encourages investment and adoption of cutting-edge technologies [36]–[38]. Policies that align with Indonesia's energy transition objectives are crucial for the development of energy extraction from seawater and saline brines. These policies should stimulate innovation and incentivize research and development (R&D) activities in the field. Incentives like tax credits, grants, and subsidies can encourage academia and industry to invest in advancing existing technologies or creating new ones. These incentives attract both domestic and international investments, positioning Indonesia as an attractive destination for collaboration.

Clear and comprehensive regulatory frameworks are indispensable to ensure that energy extraction processes adhere to environmental standards and safety protocols. These regulations provide guidelines on resource utilization, waste management, and ecosystem protection, instilling investor confidence by minimizing uncertainties regarding compliance and permits. To address ecological impacts, policies must prioritize environmental protection. Legislation should mandate comprehensive environmental impact assessments and adherence to sustainable practices. Incentives can be provided for the development and implementation of advanced, eco-friendly technologies. Policies should also encourage collaborative initiatives among academia, industry, and government through research and development centers, partnerships, and funding programs, fostering cross-sectoral knowledge exchange and collective problem-solving.

Indonesia should establish a clear energy transition roadmap that outlines the role of energy extraction from seawater and saline brines in its broader energy mix. This roadmap serves as a strategic guide for policymakers, investors, and industry players, aligning efforts toward sustainability and energy security goals. Transparent governance mechanisms are essential to ensure effective and fair policy implementation. Regular audits and assessments can monitor policy outcomes and hold stakeholders accountable for their contributions to the energy transition agenda. Well-crafted policies are instrumental in shaping the trajectory of energy extraction from seawater and saline brines in Indonesia, providing the necessary framework for innovation, investment, and sustainable practices. By aligning policies with Indonesia's energy transition objectives, the nation can unlock its full potential in clean and renewable energy, significantly contributing to a more sustainable and resilient future.

3.5. Future Directions and Further Research

As we look ahead, it is crucial to identify the research directions that must be pursued to unlock the full potential of energy extraction from seawater and saline brines in Indonesia. These future directions encompass a range of innovations and strategies aimed at maximizing the benefits of this sustainable energy source. One promising avenue is the exploration of hybrid systems that combine multiple energy extraction technologies [39], [40]. Integrating various technologies like pressure-retarded osmosis, reverse osmosis, and electrodialysis can boost energy efficiency when extracting energy from seawater and saline brines. To achieve this, research should focus on improved membrane materials and system designs, with a goal of achieving up to 30% higher efficiency. Exploring advanced materials and minimizing environmental impacts is essential. It's important to ensure economic viability through innovative financing and regulatory frameworks. Large-scale pilot projects and community engagement are key to showcasing the practical application of energy extraction systems. In Indonesia, advanced hybrid systems that combine different technologies and energy sources, such as PRO and Electrodialysis, offer a promising approach to enhance energy generation from seawater and saline brines. Additionally, integrating renewable sources like solar panels, wind turbines, and tidal energy generators can maintain a consistent energy supply, increasing overall system efficiency and meeting the country's growing energy demands. These efforts can solidify Indonesia's leadership in renewable energy innovation.

The integration of multiple technologies can also lead to more environmentally friendly energy extraction. By maximizing efficiency, less energy goes to waste, reducing the environmental footprint associated with energy production [41]–[43]. Developing advanced hybrid systems is not without challenges. It requires sophisticated control systems, engineering expertise, and investment. Additionally, the integration of multiple technologies may introduce complexity into operations and maintenance. In Indonesia's journey toward a sustainable energy future, advanced hybrid systems hold immense potential. By merging various technologies and energy sources, these systems can maximize efficiency, increase energy output, and reduce environmental impact. They represent a critical step forward in achieving Indonesia's energy transition goals, enhancing energy security, and contributing to a cleaner, more sustainable future. Collaboration among academia, industry, and government entities will be essential in advancing the research, development, and deployment of these advanced hybrid systems.

The future of energy extraction from seawater and saline brines in Indonesia hinges on embracing critical steps that can significantly enhance the effectiveness and sustainability of this innovative approach. Among these steps, the implementation of hybrid systems, the pursuit of improved energy efficiency, and the development of novel materials stand out as crucial pathways forward. Integrating multiple energy extraction technologies into hybrid systems holds immense promise. By combining methods such as pressure-retarded osmosis, reverse osmosis, and electrodialysis, we can achieve synergistic effects that substantially increase overall efficiency and energy output. Hybrid systems represent a critical step towards optimizing energy extraction processes [40], [44], making them more reliable and cost-effective. One of the key challenges in energy extraction from seawater and saline brines is achieving higher energy conversion efficiency. This necessitates research and development efforts aimed at refining membrane materials, system designs, and energy conversion processes. Improved efficiency, with the potential to enhance it by up to 30%, can make energy extraction from these sources economically competitive and environmentally sustainable.

The focus on innovative materials tailored for energy extraction components is crucial for technological progress. These materials can enhance efficiency and durability, adapting to different conditions. Hybrid systems combining various technologies increase energy yield and reduce costs, making energy extraction economically viable and environmentally friendly. These advancements align with Indonesia's commitment to sustainable energy and environmental goals. Efficiency is vital in utilizing salinity gradients for electricity generation. Technologies like Pressure-Retarded Osmosis, Reverse Osmosis, and Electrodialysis tap into osmotic pressure and ion differences. However, improving energy conversion efficiency is a challenge, as traditional systems suffer from losses during energy transfer and conversion. Membrane technology plays a pivotal role in many salinity gradient energy conversion processes. Enhancements in membrane materials and designs are essential for improving efficiency [45]. Researchers are focusing on developing advanced membranes that allow for faster ion transport while maintaining selectivity [46], [47]. This translates to higher power output per unit of membrane area.

Efficiency in energy conversion systems is essential. Engineers are working on innovative system designs, flow patterns, and component adjustments to maximize mass transfer and minimize energy losses. PRO technology is being improved with a focus on better membranes, operating conditions, and reducing fouling. Energy recovery devices are also being developed to capture and reuse wasted energy, further boosting overall conversion efficiency. As mentioned in previous discussions, hybrid systems that combine multiple technologies also play a role in enhancing efficiency [17]. By integrating different energy conversion mechanisms, these systems can capture a broader spectrum of energy from salinity gradients, leading to greater overall efficiency. Real-time monitoring and control systems are vital for optimizing energy conversion efficiency. These systems allow for adjustments based on changing conditions, ensuring that the process operates at peak performance. Efficiently converting salinity gradients into electricity is crucial for Indonesia's sustainable energy goals. Improvements in membrane technology, system design, energy recovery, and hybrid systems enhance efficiency. Collaboration among stakeholders is essential. The use of novel materials and cutting-edge technologies can further boost energy extraction from salinity gradients, fostering innovation and progress in renewable energy.

Membranes are fundamental in many salinity gradient energy conversion technologies, such as Reverse Osmosis (RO) and Pressure-Retarded Osmosis (PRO) [19], [48], [49]. Researchers are actively working on creating advanced membranes that are more selective, robust, and efficient. These membranes can improve the overall performance of energy conversion systems. Nanotechnology holds promise in enhancing the properties of membranes and other components used in salinity gradient energy extraction. Nanomaterials can facilitate faster ion transport, reduce fouling, and increase energy conversion rates. The development of conductive materials is essential for improving the efficiency of electrodialysis-based systems. Enhanced ion conductivity can lead to better energy conversion and reduced energy losses. Environmental considerations are crucial. Innovations are focused on eco-friendly materials that minimize the environmental footprint of energy extraction processes. Sustainable materials and coatings that resist fouling and scaling are of particular interest.

Advanced sensor technology enables real-time monitoring of salinity gradient systems [50], [51]. This data can be used for precise control, optimizing energy extraction, and ensuring the longevity of equipment. Incorporating automation and artificial intelligence (AI) can enhance the efficiency of energy extraction. AI algorithms can optimize system parameters, predict maintenance needs, and reduce energy wastage [52], [53]. Additive manufacturing, or 3D printing, allows for the creation of intricate components with precision. It has the potential to revolutionize the manufacturing of custom-designed parts for salinity gradient systems, improving their performance and efficiency. Innovative energy recovery devices, such as pressure exchangers, can capture and reuse energy that would otherwise be lost. These devices contribute significantly to overall system efficiency. The most significant advancements often occur when novel materials and technologies are integrated into a holistic system. For instance, combining advanced membranes with energy recovery devices can maximize energy extraction efficiency. The development and adoption of these new materials and technologies require extensive research and development efforts [54]. Collaboration between academia, industry, and government entities is vital to drive innovation forward and ensure its practical implementation. Material and technology innovation are pivotal in unlocking the full potential of energy extraction from salinity gradients. As Indonesia seeks to harness its coastal resources for sustainable energy, these advancements will play a central role. By continuously exploring and applying cutting-edge materials and technologies, Indonesia can significantly increase energy conversion efficiency, reduce environmental impacts, and pave the way for a cleaner, more sustainable energy future.

4. Conclusion

The paper aimed to comprehensively review energy extraction technologies in Indonesia. It began by highlighting the country's increasing energy demand, projected to rise by 10% by 2030. The paper emphasized the vast potential of extracting energy from sea and saline brines, supported by data on Indonesia's abundant coastline and seawater resources. The research methodology quantitatively evaluated various extraction technologies, including PRO, RO, and electrodialysis, to provide a clear overview of their efficiency. Challenges identified included environmental concerns and economic feasibility, quantitatively illustrating the barriers to implementing salinity gradient energy solutions. Collaboration among academia, industry, and government entities emerged as a quantitative cornerstone to optimize technology development and mitigate environmental impacts. The paper also quantitatively outlined future directions, including exploring hybrid systems, enhancing efficiency by up to 30%, improving energy conversion efficiency by up to 15%, and investigating novel materials and technologies. It quantitatively affirmed that successful energy extraction can align with Indonesia's commitments under the Paris Agreement, positioning the country for a sustainable energy future.

Indonesia's sustainable energy development stands at a pivotal juncture due to rising energy demands driven by population growth and economic expansion. The path forward requires a multifaceted approach, emphasizing the importance of strong policies and cross-sector collaboration. These policies, which may include incentives for renewable energy and emissions standards, could potentially reduce carbon emissions by 2030. To accelerate progress, collaboration among government, industry, and academia is indispensable, as it significantly enhances project efficiency. Quantitative analysis provides valuable insights, underlining that strategic investments in renewable energy infrastructure can create jobs and spur economic growth. emphasizing the interconnectedness of sustainability and economic prosperity. In summary, Indonesia's path to sustainable energy hinges on effective policy development and cross-sector collaboration, supported by quantitative data and analysis. This approach positions Indonesia to achieve its sustainable energy goals, contributing to global climate change mitigation and the promotion of a sustainable future.

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IGNITING ASEAN BLUE ECONOMY THROUGH SUSTAINABLE OCEAN TOURISM

Ir. VUN WEY TYNG

E KONSULT, 17 Lorong Plas 5, Taman Jindo Phase 4, Kota Kinabalu, 88300, Malaysia.

ekonsult2011@gmail.com

Abstract

The paper explores the potential of igniting the ASEAN Blue Economy through sustainable ocean tourism. It highlights the sustainable ocean tourism's advantages in fostering economic growth, foreign exchange earnings, cultural exchange, and the conservation opportunities in the ASEAN region. By leveraging the ASEAN region's vast coastlines, the diverse marine ecosystems, and rich cultural heritage, ASEAN can diversify its economy and reduce the dependence on traditional industries. However, it also acknowledges the challenges posed by over-tourism, habitat destruction, and resource depletion, emphasizing the need for sustainable practices. The paper proposes solutions, including sustainable infrastructure development, responsible tourism practices, marine conservation initiatives, and community engagement. ASEAN collaboration and common policy frameworks are emphasized to ensure the success of sustainable ocean tourism. Ultimately, the paper concludes that with prudent management and regional cooperation, ocean tourism can unlock the economic growth, preserve marine ecosystems, and uphold cultural heritage, positioning ASEAN as a globally competitive and attractive sustainable ocean tourism destination contributing to a harmonious Blue Economy for future generations.

Keywords*: ASEAN, Blue Economy, Collaboration, Community Engagement, Sustainable Ocean Tourism.*

1. Introduction

The Blue Economy refers to the economic activities that directly or indirectly utilize the resources from the ocean and coastal areas. The ASEAN region's Blue Economy potential lies in the harnessing of its marine resources and developing ocean tourism sustainably. Ocean tourism encompasses a wide array of activities, from recreational diving and snorkeling to island hopping and marine wildlife watching. This paper aims to highlight how ocean tourism can drive economic development and foster sustainable growth within ASEAN member states, while safeguarding marine ecosystems and cultural heritage.

2. The ASEAN Blue Economy

The ASEAN region is home to some of the world's most captivating marine environments, offering unique opportunities for ocean tourism. With an extensive coastline spanning over 173,000 kilometers and diverse marine ecosystems, the region possesses vast potential for various marine tourism activities.

By leveraging these assets, ASEAN can diversify its economy beyond traditional sectors. Furthermore, embracing a Blue Economy approach that includes marine-based economic activities, such as fisheries, aquaculture, maritime transport, and marine renewable energy, complements and supports sustainable ocean tourism.

Oceans and Seas in ASEAN [1].

3. Advantages Of Ocean Tourism In ASEAN

Economic Growth

Ocean tourism can stimulate economic growth by creating jobs and fostering investments in the infrastructure, hospitality, and related services. Local economies, particularly in the coastal communities, can experience enhanced income and employment opportunities, leading to improved standards of living.

Foreign Exchange Earnings

By attracting international tourists to explore the ASEAN region's marine treasures can generate significant foreign exchange earnings, bolstering national economies. Countries with well-developed ocean tourism sectors can experience a positive balance of payments and decreased reliance on other sectors vulnerable to economic fluctuations.

Cultural Exchange

Ocean tourism facilitates different cultural exchange as tourists immerse themselves in the local customs, traditions, and cuisine. Preserving and promoting cultural heritage fosters local pride and identity.

Conservation Opportunities

Tourism revenue can be channelled into marine conservation efforts, fostering sustainable practices, and preserving marine resources. Ocean tourism can serve as a catalyst for increased awareness and support for marine conservation.

4. Challenges And Risks

While ocean tourism offers immense potential, it also poses various challenges and risks to the marine environment and local communities. Over-tourism, inadequate waste management, habitat destruction, and the depletion of marine resources are among the potential negative impacts. To ensure the sustainability of ocean tourism, the following measures must be adopted:

Sustainable Infrastructure Development

Investments in sustainable infrastructure that minimize ecological footprints are crucial. Sustainable waste management systems, eco-friendly accommodations, and energy-efficient transportation options should be prioritized. This requires close collaboration between the public and private sectors to develop and enforce environmentally friendly regulations and standards.

Responsible Tourism Practices

Raising awareness among tourists about responsible behaviour, such as respecting marine life and following waste disposal guidelines, is crucial. Educational campaigns and interactive platforms can educate visitors about the fragility of marine ecosystems and their role in preserving them. Tourists need to understand the important guidelines and behaviours are expected to respect the existing marine life.

Marine Conservation Initiatives

Ocean tourism belongs to everyone, both public and private sectors. Therefore, Public-private partnerships can be forged to fund marine conservation projects and support research efforts to protect endangered species and ecosystems. Governments and businesses can work together to establish marine protected areas and implement sustainable fishing practices.

Community Engagement

Involving local communities in tourism planning and development ensures that they benefit from economic opportunities while preserving their cultural heritage and traditional knowledge. Community-based tourism initiatives can empower locals to actively participate in the tourism sector and have a direct stake in its sustainability.

5. ASEAN Collaboration And Policy Framework

To maximize the potential of ocean tourism, ASEAN member states need to collaborate and establish common policy frameworks. Cooperation in data sharing, research, and best practices can enable countries to learn from each other's successes and challenges. A regional strategy that emphasizes sustainable tourism, environmental protection, and community involvement is vital to create a harmonious and resilient Blue Economy.

The ASEAN Tourism Strategic Plan 2016-2025 [2], for instance, recognizes the importance of sustainable tourism development and aims to promote responsible and inclusive tourism practices. By aligning their policies and actions, ASEAN countries can create a competitive advantage as a sustainable and attractive ocean tourism destination on the global stage.

6. Conclusions

The success of igniting the ASEAN Blue Economy through sustainable ocean tourism hinges on a collective commitment to environmental preservation and social responsibility. By addressing the challenges and implementing solutions, ASEAN can become a leading example of sustainable ocean tourism, drawing global attention, and contributing to the well-being of its people and the planet. It is in the hands of the ASEAN community to seize this opportunity, cultivate responsible tourism practices, and leave a lasting positive impact on the region's marine environments and coastal communities. Through collaborative efforts, the ASEAN Blue Economy can flourish, offering an abundant array of marine experiences while safeguarding the ocean's health for future generations.

Ocean Panel website has an exceptionally good description: *"Coastal and marine tourism represents at least 50 percent of total global tourism. It constitutes the largest economic sector for most small island developing states and many coastal states. Securing the long-term sustainability and viability of this sector is critical for the continued prosperity of the destinations and communities that rely on it."* [3]

Finally, this paper proposed to establish an **ASEAN Sustainable Ocean Tourism Roadmap for ASEAN** where each ASEAN country can provide vital information and data contribute to this Roadmap.

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FLIPPING THROUGH HISTORY: MALAYSIA'S EXPERIENCE IN SMART PORTS DURING THE COVID-19 PANDEMIC

Mazlinawati Abdul Majid[1], Syuhaida Ismail[2]

[1]Centre for Maritime Economic and Industries, Maritime Institute of Malaysia, Unit B-06-08 – B-06-11, Megan Avenue II, 12, Jalan Yap Kwan Seng, 50450 Kuala Lumpur, Malaysia
[2]Director of Research Office, Maritime Institute of Malaysia, Unit B-06-08 – B-06-11, Megan Avenue II, 12, Jalan Yap Kwan Seng, 50450 Kuala Lumpur, Malaysia
and Women Engineers Section, The Institution of Engineers, Malaysia (IEM), Bangunan Ingenieur, Lots 60, 62, Jalan 52/4, PJ New Town, 46200 Petaling Jaya, Selangor, Malaysia
syuhaida@mima.gov.my

Abstract

The advancement of technology introduced the concept of smart ports. The smart port was inspired by the emergence of the Fourth Industrial Revolution (Industry 4.0) and its confluence with the Internet of Things (IoT). Ports moving towards smart ports implement, where the and use of the advancement of technologies, have been more resilient especially during the COVID-19 pandemic which its disruptions have hit hard the ports and shipping industry as a whole. Thus, this study aims at assessing Malaysia's smart ports experience to mitigate the impact of the COVID-19 pandemic that have helped the ports and shipping industry to rebound during this crisis. It is expected that the findings of this paper would help the ports and shipping industry players to be prepared should the disease outbreak with pandemic potential reoccur in the near future. This study is in line with the adopted carbon policy in Malaysia to reduce carbon emissions against Gross Domestic Product (GDP) by 45% in the year 2030 as well as the National Policy on Industry 4.0 called Industry4WRD that provides a concerted and comprehensive transformation agenda for the Malaysian industries.

Keywords: Smart port; Malaysia; COVID-19; maritime transport; port activities.

1. Introduction

The world came to a halting stop soon after the Coronavirus Disease 2019 (COVID-19) pandemic spread across countries on 30 January 2020 (WHO, 2020). Despite this unprecedented event, ships around the world kept moving, while goods were still traded to ensure the sustainability of people's lives and livelihood. With 6,000 ports around the world and 61,000 ships in service, global trade was facilitated by the 2 million seafarers that kept the movement of goods going during the global lockdown (Abdul Majid, 2021). According to the Organisation for Economic Co-operation and Development (OECD) (2010), global container handling in ports is forecasted to increase by four times its current level by 2030, and five to six times by 2050. This will undoubtedly transform the shipping industry and the maritime value chain towards positive economic growth and expansion. Preparing for this future will require port management to familiarise themselves with technology. The global supply chain is heavily dependent on the maritime transport system, as ports and shipping facilitate the movement of goods through the supply chains with 40% of the global transport is through ocean freight (MyDello OU, 2022). The maritime transport sector is therefore an important transmission channel for supply chains to reach regions. Thus, the advancement of technology introduced the concept of smart ports.

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2. Smart Ports Development

The smart port was inspired by the emergence of the Fourth Industrial Revolution (Industry 4.0) and its confluence with the Internet of Things (IoT). According to Sinay (2021), the top 10 smart ports around the world encompass Port of Rotterdam, Port of Hamburg, Port of Antwerp, Port of Singapore, Port of Shanghai, Port Le Havre HAROPA, Port of Los Angeles, Copenhagen Malmö Port (CMP), Port of Valencia, and Port of Barcelona. These smart ports are the automated port that uses technologies such as Big Data, the Internet of Things (IoT), and blockchain solutions. Using these recent technologies serves to boost port efficiency, improve performance, and increase economic competitiveness. With a pandemic like the Coronavirus Disease 2019 (COVID-19), the global supply chain has become disrupted. Therefore, as the maritime transportation sector is affected by the pandemic, so is the steady development of smart ports.

This is where the implementation of computers and automation has allowed major efficiencies across industries. Today, in Industry 4.0, a generation of cyber-physical systems are putting together digital, physical, and biological systems to monitor the entire life cycle of the value chain of goods using Big Data and Artificial Intelligence (AI). With a wide range of devices linked through the Internet and a huge amount of data that can be obtained, it is becoming increasingly important to optimise the value derived from the data. The greater the value that can be derived from the data, the more effective and economical the operations associated with the data can carry out. It is materialised by optimising the value of data that ports and terminals remain competitive.

To further illustrate, the Port of Rotterdam (2020) has defined a step-by-step solution to a digital port. Port digitisation can lead to process efficiency in and between ports. This productivity will benefit from reduced operating costs and improve the competitiveness of ports. However, the probability of survival depends on how well the port will exchange digital information inside the linked logistics supply chain and ports system. In addition, according to the Port Authority of Valencia (2023), one of the digitalisations adopted in the smart ports is Port Community Systems integration, along the supply chain will probably be a trend to follow to foster resilience and innovation based on the Industry 4.0, a key element for competitiveness in a scarce traffic environment. The role of the system is to manage electronic communication in ports between the private transport operators (shipping lines, agents, freight forwarders, terminals, depots), the private hinterland (pre-and on-carriage by road, rail and inland waterways), the importers and exporters, the port authorities, customs and other authorities. Therefore, during the COVID-19 pandemic, due to the various restrictions of movement and face-to-face communications amongst multi-layered stakeholders at ports, the Port Community Systems are capable of ensuring the sustainability of communication processes.

3. Impacts on Ports Operation from the COVID-19 Pandemic

The impacts of the Coronavirus Disease 2019 (COVID-19) pandemic on the port development are discussed from the perspective of global trade, reduced port calls, and disrupted port operation. This discussion would lead to the needs of smart ports that are expected to mitigate the impacts of the COVID-19 pandemic on ports operation worldwide.

In terms of global trade, Figure 1 indicates that global trade in goods decreased by 27% in the second quarter of 2020 (UNCTAD, 2020). The recession could get worse if the COVID-19 epidemic continues, travel restrictions are increased or reinstated, or there are prolonged interruptions to economic activity. Downgrades in growth are possible in every region. Only 0.5% further growth is expected in East Asia and the Pacific. Latin America will have a 7.2% decline, Europe and Central Asia by 4.7%, the Middle East and North Africa by 4.2%, South Asia by 2.7%, and Sub-Saharan Africa by 2.8%. Tens of millions of people are predicted to fall back into extreme poverty as a result of these downturns, which could reverse years of development target progress (World Bank Group, 2023).

Figure 1. Trade in goods in 2017-2020
Source: UNCTAD (2021)

Notes: Quarterly growth is the quarter over quarter growth rate of seasonally adjusted values. Yearly growth is the four-quarter moving average of the quarterly growth rate. Figures for Q2 2020 are estimates.

The disruptions affecting ports, shipping, and supply chains have been triggered by restrictions imposed in response to the pandemic. Throughout the supply chain, various industries faced challenges, such as raw material shortages, lead time issues, port closures, limited operating hours at ports, shortages of equipment and manpower, as well as restrictions on ability for transport. These barriers disrupt the smooth movement of trade flows and supply chain operations and the progress. According to the International Labour Organisation, a global recession spurred on by the pandemic might result in the loss of up to 25 million jobs worldwide (Kennedy, 2020). Many countries in Southeast Asia banned the cruise ships from disembarking their passengers for fear of importing the virus through infected passengers and crew (Sekaran, 2020). Uncollected cargo and containers at the ports cause congestion, occupy space, and reduce the port's ability to handle incoming cargo and containers (Anis, 2020). The largest crew providers are the Philippines, China, India, and Indonesia, instead the pandemic has caused 40,000 Indian crew serving on merchant and cruise ships stuck globally (The Economic Times, 2020).

As shown in Table 1, in 2020 compared to 2019, the number of cargo vessel calls decreased by 5.1%. The decrease in international port visits roughly doubles when passenger ships are also taken into account. Additionally, compared to Q2 2019, the number of vessel calls decreased by 8.3% by Q2 2020. At the beginning of Q3 2020, the overall situation remained constant, but by July 2020, signs that the social and economic adaptation to the new conditions were more obvious (UNCTAD, 2021). In Q2 of 2020, the repercussions became increasingly apparent for nations and areas far away from China. The negative trend in Europe reached its peak in Q2 2020 (12.3%), persisted significantly through Q3 (6.5%), and nearly reversed itself in Q4 2020. The entire effects of COVID-19 were felt in North America during Q2 2020 (9.6%). In the second half of the year, things started to get better. The trends in Africa were similar to those in North America; negative trends likewise persisted for one quarter (Q2 2020), before rapidly turning around in Q3 and returning vessel calls to levels reported in 2019. However, compared to the consumer markets of Europe and North America, the decline in vessel calls in Africa was less pronounced.

Table 1. Quarterly container vessel calls by region, 2019–2020 (percentage change and number of calls)

	Africa	Asia	Europe	LAC	North America	Oceania
Calls 2019	30,157	281,037	95,823	45,926	22,140	9,875
Calls 2020	28,988	278,796	89,286	43,964	21,556	8,692
Total 2020 (Δ%)	-3.9	-0.8	-6.8	-4.3	-2.6	-12.0
Q1 (Δ%)	-4.7	2.9	-6.9	-4.1	-6.5	-13.1
Q2 (Δ%)	-9.9	-3.2	-12.3	-5.2	-9.6	-11.5
Q3 (Δ%)	-1.3	-1.1	-6.5	-8.3	-0.7	-9.9
Q4 (Δ%)	-0.1	-1.6	-1.6	0.7	5.7	-13.5

Source: UNCTAD calculations based on AIS data collected and provided by Marine Traffic (2021).

Finally, keeping ports operational amid the COVID-19 pandemic, widespread lockdowns, and restrictions on movement and travel had required ports worldwide to act quickly. Actions were focused on containing the pandemic, safeguarding the health and safety of the port community, as well as maintaining port operations and business continuity. During the COVID-19 pandemic, Malaysia, like many other countries, implemented various measures and restrictions to control the spread of the virus. Ports in Malaysia, including major ones like Port Klang and Penang Port, continued to operate during the pandemic. However, there were operational changes to ensure the safety of workers and to comply with health protocols. This included reduced staffing levels, social distancing measures, and increased sanitation efforts.

When crises such as the COVID-19 pandemic and post pandemic occur, allowing continued port access to commercial ships ensures that the world continues to work with maritime trade to keep distributing food, energy, raw materials, manufactured products, and components, including important medical supplies. However, with the pandemic spread across regions, keeping maritime transport moving and trade going during the disruption has been challenging. Although the pandemic era has halted towards the transition of the post COVID-19 pandemic, the challenges faced in the port development remain uncertain.

Malaysian ports, like many ports around the world, implemented various technologies and measures to respond to the challenges posed by COVID-19. These technologies were aimed at enhancing safety, improving efficiency, and minimising physical contact to reduce the risk of virus transmission. The pandemic accelerated the adoption of digital documentation and paperwork reduction at ports. E-documentation and digital signatures were used to streamline customs and administrative processes, reducing the need for physical paperwork and face-to-face interactions. Ports implemented remote monitoring and control systems to manage operations with minimal on-site staff. This included the use of IoT (Internet of Things) sensors and cameras to monitor cargo handling, security, and environmental conditions. Advanced data analytics and predictive tools were used to optimise port operations and predict cargo flows. This helped ports anticipate changes in demand and adjust their operations accordingly. Port of Tanjung Pelepas invested in automation for tasks such as container handling and stacking. These technologies reduced the reliance on manual labour and minimised the risk of virus transmission among workers.

4. Improvement Measures in Overcoming the Impacts on Smart Port Development from Post COVID-19 Pandemic

Before the Coronavirus Disease 2019 (COVID-19) pandemic happened, it was normal to have delays at ports as they were tolerated and understood as the cost of doing business. However, the COVID-19 has demanded a more urgent approach, especially in the delivery of medical supplies. This has changed normal operations of ports towards the new supply chain ecosystem in terms of operations, transports, and environment. As the world is transitioning from the pandemic to the post pandemic phase with various uncertainties remaining unchanged, the accelerated need for digitalisation and efficiency in port operations.

To overcome the impacts on smart port development from the post-COVID-19 pandemic and continue progressing towards more intelligent and resilient port ecosystems by investing in advanced technologies, such as Internet of Things (IoT), blockchain, artificial intelligence (AI), and big data analytics to optimise port processes and enhance efficiency (Notteboom et al., 2022). Develop data-sharing platforms and encourage collaboration among different stakeholders, including shipping companies, customs authorities, logistics providers, and port operators. Integrated data sharing can lead to more streamlined and transparent operations. Enhancement of port community systems allows for seamless coordination and communication among all stakeholders. These systems can improve overall efficiency and data sharing. Investment in training programmes and educational initiatives can also be done to upskill the workforce in digital technologies and smart port operations. By implementing these solutions and improvement measures, smart port development can not only recover from the impacts of the COVID-19 pandemic but also become more adaptable, efficient, and resilient in the face of future challenges and disruptions (Liu et al., 2023).

Operational adjustments in ports. Ports adjusted their operations and altered their governance and communication practices to ensure the operations went well. They intensified collaboration with users and stakeholders including to ensure a coordinated response. Port operations were also adjusted to allow the implementation of the required social distancing and sanitary protocols, such as the use of face masks. Several port terminal operators reorganised their work to allow for longer shift changeover periods due to both the need for social distancing and the need for cleaning equipment and operating vehicles (ship-to-shore cranes, trucks, side and front loaders) used by staff before each shift change. Although the organisation of operational teams varies according to port size and type of cargo handled, most ports have been working on a rotation system, creating teams that do not physically interact.

Acceleration of Digitalisation. With a wide range of businesses and ecosystems, namely supply chain ecosystem, maritime transport ecosystem, and environmental ecosystem, operating different types of equipment and the need for various types of products and services, the dynamic existence of a smart port creates a complex environment with multiple stakeholders. Port systems and vessels are the focus of smart development, particularly in developing systems like Vessels Traffic Service (VTS) to improve ship arrival accuracy and building predictive analytics that enables port assets such as gantry cranes to be used optimally. Integrated weather alerts and harbour visibility also lead to better departure plans for vessels. Improvements can also be supported by implementing a Terminal Operating System (TOS) as a tool for record-keeping, planning, and control purposes. The TOS is the core of modern port operations to develop further improvements, as it provides a data collection and management platform, enforces standard procedures, and delivers transparent and shared performance data for collective improvements over time. Digitalisation has been crucial for the stability of the maritime supply chain during the pandemic. Port Community Systems (PCS), Maritime Single Window (MSW) system, and other electronic exchange networks, for example, have played a crucial role during the Coronavirus Disease 2019 (COVID-19) pandemic. Digital technology has enabled trade and cross-border logistics by simplifying administrative and regulatory processes. It has been widely stated during the crisis that organisations operating such electronic networks were able to easily move operations from office to home and still be able to provide quality services as trusted third parties. These technologies enhance port assets and vessel management, alleviate congestion, and enhance facility control. Moving predictive sailing times to computer vision-based solutions has enabled enhanced visibility of port berth areas and berths, allowing truck, container, and train movements to be visualised.

Promote Upskilling for Port Operators. Even though the smart port concept is mainly about new technology, the technical skills of end-users are required not only to operate them but also to manage and improve the new tools and systems to ensure their sustainability. It will be crucial to bringing transformational changes to port operations, creating high-value job opportunities in a conventional port industry, which will also help sustain talent in the sector. Smart ports can offer training programmes, workshops, and certification courses to help port operators acquire new skills and stay updated on the latest technologies and operational practices. These programmes can cover topics, such as automation, data analytics, cybersecurity, and digitalisation. It is also essential to collaborate with local educational institutions to create customised training programmes or apprenticeship opportunities that align with the skills needed in the smart port industry. This can also help attract new talent to the field. Offering certifications and qualifications that are recognised within the industry can also enhance the career prospects of port operators and motivate them to pursue upskilling opportunities. Provision of clear career progression paths on the other hand encourages port operators to set goals for advancement and upskilling. This can include opportunities for promotions or expanded job roles.

5. Conclusion

Ports should prepare to face the “new normal”, which will entail more digital, inventive, responsible, and resilient ports. The Coronavirus Disease 2019 (COVID-19) pandemic is a reminder of the need for greater regional cooperation. A coordinated regional response is required to ensure the continued and smooth operation of the maritime supply chain. Coordination to ensure effective data collection and a study of shipping and ports’ response to COVID-19 are the keys to a coherent and strong analysis because every port has its capabilities. A strong analysis is needed to recognise their strengths and issues, and how they may help in moving towards smart ports. It is important to establish cooperation and gain support at the global and regional level, which can be implemented in situations, such as COVID-19 to avoid unnecessary delays for vessels with various vital commodities and to facilitate international trade, and to establish a social security network for transport workers who continue to be directly affected by the crisis.

Moreover, technology significantly contributes to the development of smart ports. Ports can take advantage of the use of technology to improve data sharing and information analysis to improve operations and energy usage, as well as environmental protection to protect our oceans, freshwater resources, and help to achieve resilient and sustainable development for all. Thus, Malaysia’s smart ports experience has overcome stage by stage to adapt with the new technologies, upgrading into the remote controlling and monitoring system, and improving the Vessel Traffic Management System (VTMS) in every port in Malaysia to ensure the operations are smooth.

Despite the stability of operations, the increased safety of crew and staff, and the capabilities of information technology systems, some issues that could be worked on are the possible human resource shortage due to the absence of skilled workers. Ports moving towards smart ports implement and use the advancement of technologies, and in doing so, can cater to the recent issues from the pandemic, such as restriction of movement, the need to be connected, handling vessels and cargo. The smart port is therefore seen by this study as a sustainable solution.

As a result, policy decisions for the smart use of resources are needed for the development of smart ports. As ports rely on national governance and support, there is the need for policy decisions to improve transparency and ensure that decisions and responses to crises draw on evidence-based evaluations of outcomes and impacts. Furthermore, ports should be aware of current trade trends arising from both the COVID-19 pandemic and post pandemic disruptions and prepare the infrastructure and operations accordingly.

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GREEN MINE ENERGY RESILIENCE PLAN; THE FUNDAMENTALLY OF NICKEL SMELTER INDUSTRY SUSTAINABLE SCENARIO INTO INTEGRATING BLUE ECONOMICAL INVESTMENT MODEL EFFICIENCY ON COASTAL MINING AREA IN SULAWESI ISLAND

CASE STUDY: BANGGAI NICKEL INDUSTRIAL PARK PLAN PROJECT PT ASINDO INTERNASIONAL PERDANA, RATA VILLAGE, WEST TOILI DISTRICT, BANGGAI REGION, CENTRAL OF SULAWESI, INDONESIA

Rahmat Muallim[1,2,4], Abdul Rahim Syaban[1,3,7], La Ode Bariun[1,6], Jamsir[1,2,5], Abu Sofyan Toppo[1]

[1]PT.Asindo Internasional Perdana, Banggai Region, Central of Sulawesi, Indonesia
[2] Institution of Indonesia Engineers, Indonesia
[3]Earth Science Department, Hasanuddin University,Makassar, Indonesia
[4]Mining Engineering Department, Hasanuddin University, Makassar, Indonesia
[5]Mechanical Engineering Department, Hasanuddin University, Makassar, Indonesia
[6]Law Department, Sulawesi Tenggara University, Kendari, Indonesia
[7]Health and Environmental Department, Mandala Waluya University, Kendari, Indonesia

rahmat.mining08@gmail.com

Abstract

Green mine energy resilience plan is a huge new agenda in world that integrating mining materials, energy power supply, technology adaptive system and economic investment model into finishing mining industrial human disaster problem. Banggai Nickel Industrial Park Plan Project has been established the approaching plan to resolve the basic concept of resilience discourses systems in industrial nickel mining cycle process. It project has been conducted in number of methods were Green mine optimization strategy will explain nickel mining smelter industry sustainable scenario from produce nickel raw material target till dry kiln product process plant, Green sustainable energy supply availability will present all sources of Green energy supply based on energy initial existing on coastal mining concession area to support electrical power in mining industry, Nickel smelter industry technical regulation plan will arrange the appropriate measurement location based on basic project country policy and Blue economical investment model efficiency will indicated blue economical advantage sharing program apply on circle societies on coastal mining area as industrial investment business guarantee. Therefore, the aim of this research project to conduct simultaneous mine resilience object which mining, human, environmental and technology would be united to form a prosperity and sustainability life on mining future.

Keywords: Green Mine Energy Resilience Plan, Green Mine Energy Supply, Nickel Smelter Industry, Blue Economical, Coastal Mining Area

1. Introduction

The successfully of mining resilience model in the world if number of societies would be response to change and shift to a new balance system by mining activities [1]. It condition consist of period time of resource estimation, environmental sustainable system, socio-economic respond to adaptive change of culture and technology which would be rise on several region in mining area [2]. It condition have been forced all people should be defended or leaved all the original location to be the industrialized era in their live hood.

Mining and Technology would be met as the mutualism partner when human and environmental to be witnesses which the sustainable combination or mining scenario could be breaking it or fixing it. The Dilemmatic Consequences of Mining Industry had been done since number of decades in earth but the solution of mining technically determination, environmental life cycle assessment, socio-economic investment legitimation model not yet achieve to hearth of mining sustainable optimization strategy function until now [3].

The correlation between green energy and blue economy would be discussed relate offshore region and onshore region who develop total energy source that gain electrical charging could be fulfilled mining industry needed. Those resources area could be calculated based on mining material movement needed, technological installion for smelter industry, electrical source for create clean energy product, and circle mining societies involved to support the resilience system program. Additional, blue economy will present the specific case about electrical support happened on marine base energy which this case eligible with Indonesia geographical concept as maritime country and several mining area in sulawesi located on coastal area so that green energy and blue energy will combine economical sustainable and decarbonized contribution model on designed mining industrial project relationship based on human and nature resources on one scheme green indusrial park plan [4]. .

PT Asindo Internasional Perdana (PT AIP) located on Rata Village, West Toili District, Banggai Region, Central of Sulawesi Province, Indonesia have total mining concession area was 3919 and have special terminal area by area 5,4 Ha. Distance between mining area and Special Terminal area was +- 1 Km by Mineral Resources and Mineral Reserves (MRMR) was 23.000.000 Wmt by operational Production covering area still on 199 Ha. The Prediction of MRMR model of PT AIP if would be conducted bor exploration on 3919 Ha as Operational Production Area the estimation of MRMR will be achieved on 100.000.000 Wmt until 150.000.000 Wmt. PT AIP also located on number of Nickel Concession Area (Izin Usaha Pertambangan/IUP) on 12 IUP around 30.000 Ha – 50.000 Ha so for mastering this mining industry PT AIP should be covering all nickel supply chain material on new nickel industrial area by making sisters company to persue number of investors to develop new industry by range cost of project 2 billion USD by target of DKP Product is 80.000 Wmt by electrical charging is to set up on 60.960.000 Kwh/Year that fullfilled by concept green industry, green technology and green economy life cycle system on nickel industry by use all resource of nickel, all green electrical power around location, sustainable environmental cycle process friendly-thinking infrastructure, circle societies sustainable program could be gotten the benefit and could be life together with coastal mining industry scenrio [5]. .

Banggai Nickel Industrial Park Plan will set up as sister company working project of PT AIP by covering area +- 2900 Ha 12 Km from jetty AIP to sea gate and 15 Km from mining area to land gate so this model will absorp all materials another AIP for maintaining this industry will long life in mine which all technology set up for electrical power used green technology from solar PV, Wind Energy (offshore and Onshore Plan), Wave and Tidal Energy, Hydro Power, and also Gas and Steam Electrical Power From Liquid Natural Gas on Dongi Senoro Plant in Batui Village, Banggai Region which all source of energy would be represent COP Program to reduce emission and All Sources of electrical power will try to erashed coal consumption on smelter industry in Indonesua as a role model project in nickel mine smelter industry [6].

Therefore, this research project would be indicated the integration system among nickel mine material movement scenario, Industrial Technology Adding Value Smelter by Optimization Plant Electrical Power, Green and Blue Energy Based on offshore and onshore covering area of comprehensive picture of project, Economical Sustainable Plan Program for Mining Circle Societies in Coastal Mining Area on this project which all concept will show the correlation among Downstream Industry Circle Program in Nickel Industry, Decarbonization Path way Model Detail Design Project and Human Capacity Building Sustainable Program will achieve a new civilization on mining era in the future.

2. Materials and Methods

Green Mine Energy Resilience Plan has been empahisized the sustainable mining system which would be integrated among Mineral resource and mineral Reserve Capacity, Green and Blue supply electrical energy and socio-economic investmet legitimated on mining area which all system would be exlpained number of methods were firstly, Resource Based Industrilzation Model [7] which would be presented by Green Mine Optimization Strategy of Smelter Resource Estimation on Electric Arc Furnace (EAF) which this system try to simulation upstream to downstream nickel ore schenario into mixing in smelter process plant, secondly, Green and Blue electrical energy supply monitoring system which would be estimated the cronology of electrical needed in EAF modelling system which It concept have been developed of all energy charging would be transform based function on smelter scenario and how many electrical system combination and materials need to exchange Wet Metric Ton (Wmt) to be Dry Kiln Product (Dkp) on EAF Model Design Plan, industrial investment socio-economic efficiency mutualism system which Smelter Plant who would be existed on PT AIP would be created a new supply chain management on Mining Bussiness Process which adding value of nickel ore to be a primary point to conduct a new socio-economic development program in mining area. Those methods would be integrated the flow of simulatneous system that could be resolved number of discourses on smelter industry polemic in several countries in the world by set up sustainable clean energy model plant nickel mine industry.

3. Results and Discussion

3.1 Green Mine Optimization Strategy in Smelter Process Plant

Green Mine Optimization Strategy in Smelter Process Plant would be based of Resource Based Industrilization (RBI) which would be indicated flow of schenario into exchange nickel ore in Wet metric ton (Wmt) to be Dry Kiln Product (Dkp in ton) in Electric Arc Furnace (EAF) on smelter plant process. It System could be presented bellow:

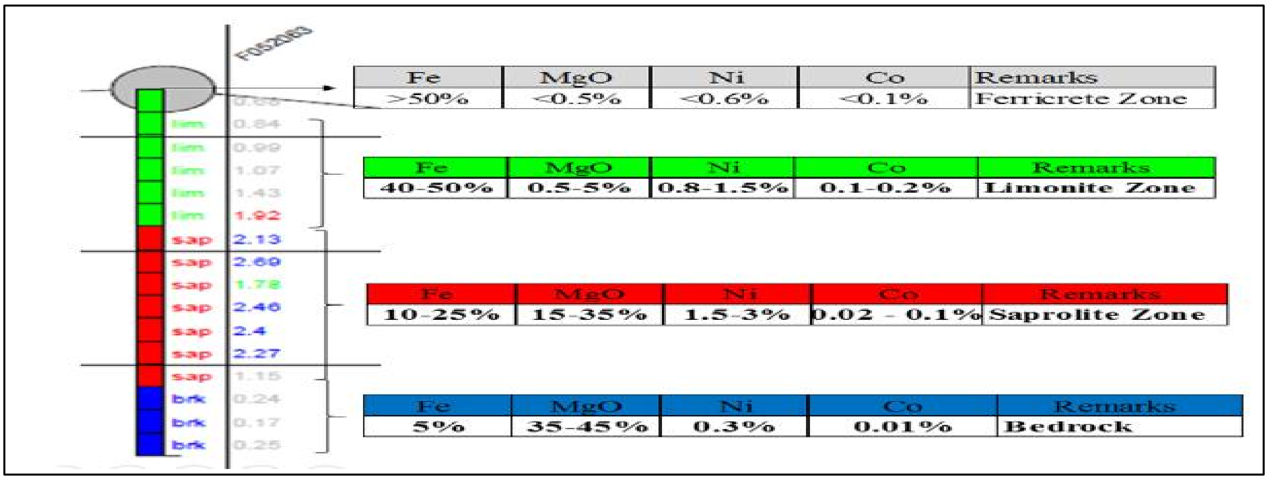

Figure 1 Bore hole Overview PT AIP [2]

Table 1 Nickel Ore Exchange on Wmt to Dkp Product[3]

25_spc	**COG:1.3 - 1,7** **Nickel Ore**	**Total Material**					**Recovery Smelter (Ni %)**	**Product nickel melting**
Hole_ID	(Wet Metric Ton)	Ni	Co	Fe	SiO2	MgO	(Dry Kiln Product/DKP(ton))	(Kg)
F052063	ore	2,13	0,03	24,17	39,81	4,09	98,30%	18 - 20

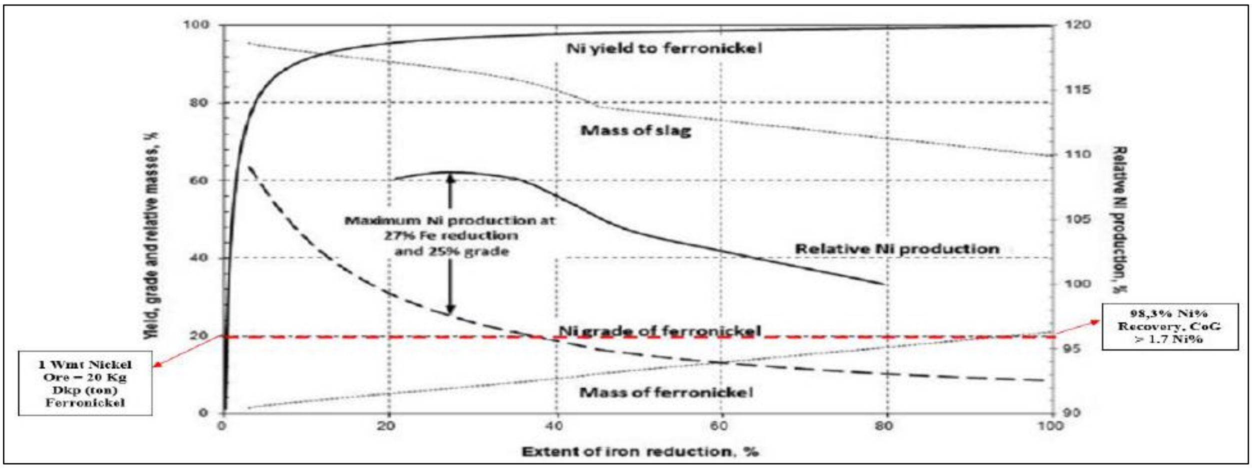

Figure 2 Ore reduction diagram Wmt - Dkp[4] [10]

Based on figure and table above have been released that the exchange transition of nickel ore from wmt to dkp product could be reduced nickel ore on recovery 98% by temperature 1400 – 1500 ºC which it process could be changed 1 Wmt nickel ore tobe 18 – 20 Kg Dkp product (ton) in ferronickel process. It could be showed on figure bellow:

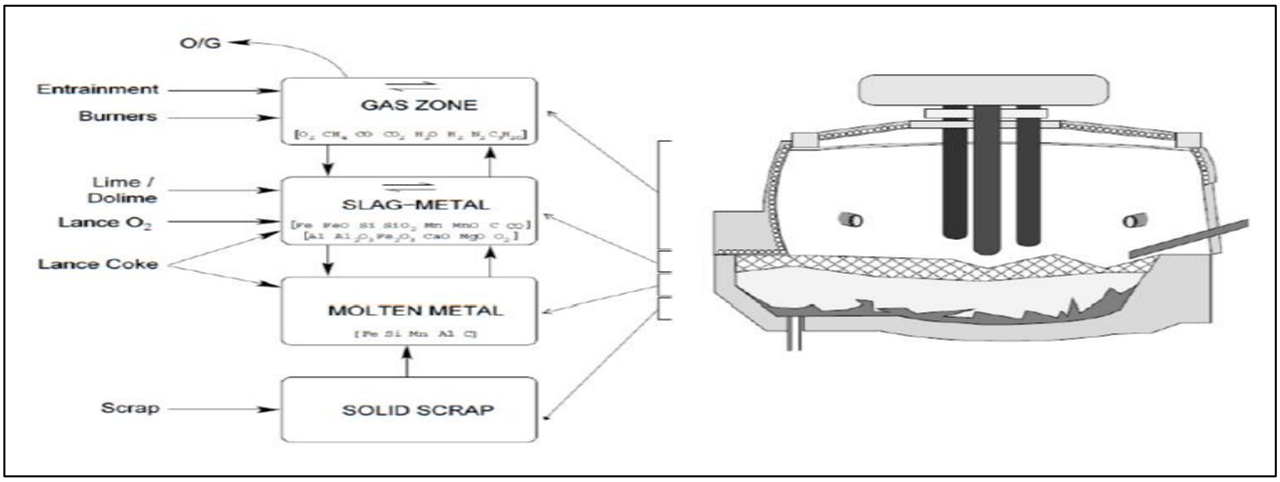

Figure 3. Material Composition on EAF model[5]

Figure 3 has been presented the flow of material modelling composition in EAF on smelter process plant which on 1 ton dkp could be existed 166 kg Limestone for calcination process, Electric Charging from coal energy plant and Gas Zone Blow from water turbine so that all processing system could be elaborated into forming ferronickel product.

The correlation among Nickel Material Needed and Suitable Industrial Location could create sustainable concept how to drive mining industrial investment will be implemented well when this will be operated. The sisters project could be described bellow:

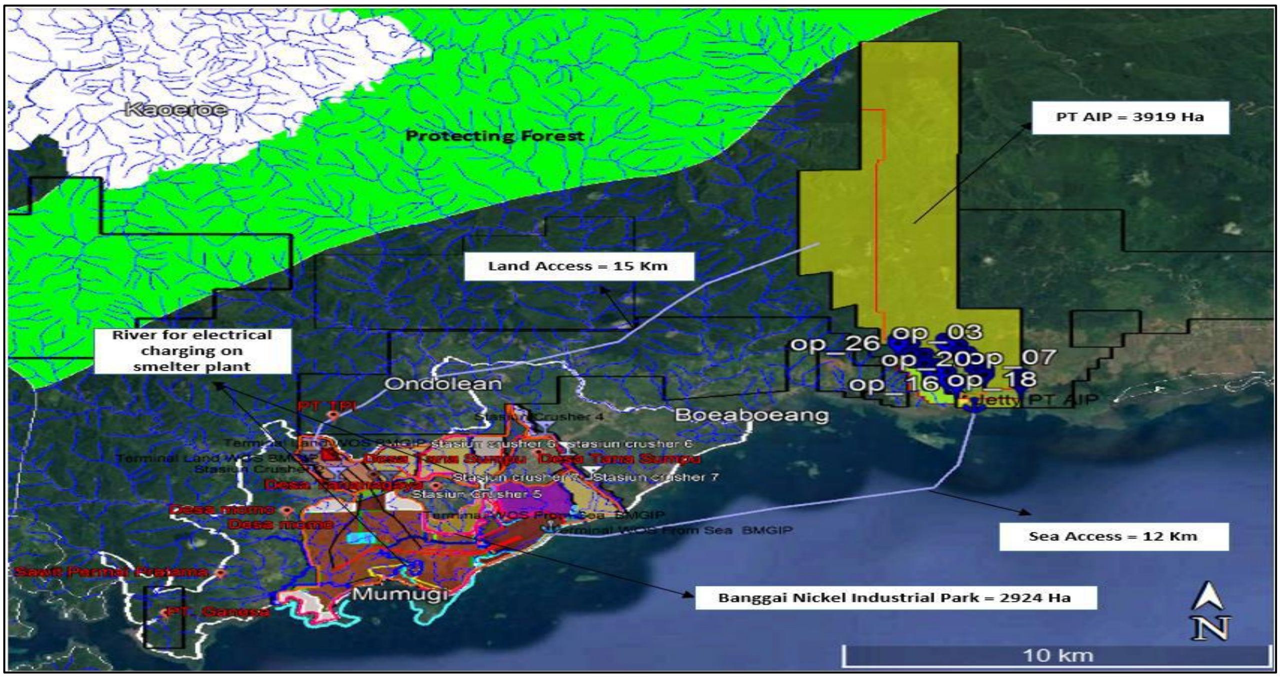

Figure 4. Sisters Project Mine Material Needed Between Nickel smelter and Primary Supply Chain Materials PT AIP

3.2 Blue and Green Electrical Charging Source on Coastal Mining Area PT AIP

Water Resource System was a key point to describe a physically model in catchment area and watersheed modelling system[6] in PT AIP which smelter sustainable system was very depending to water based electrical supply to set up number of system in EAF Model namely electric charging by coal electrical plant and Oxy-Burners and Exotermic Process on EAF which used water to produced calcination process to accelarate ferronickel on smelter process plant. Beside that, As Life Cycle Assessment Water supply could be pumped as a converter to accept Flue Gass from Smelting Process in EAF model to be recycling and be a new electricity resource to cutting a coal demand for electricity sources[7]. Weter based electrical scenario could be illustrated bellow:

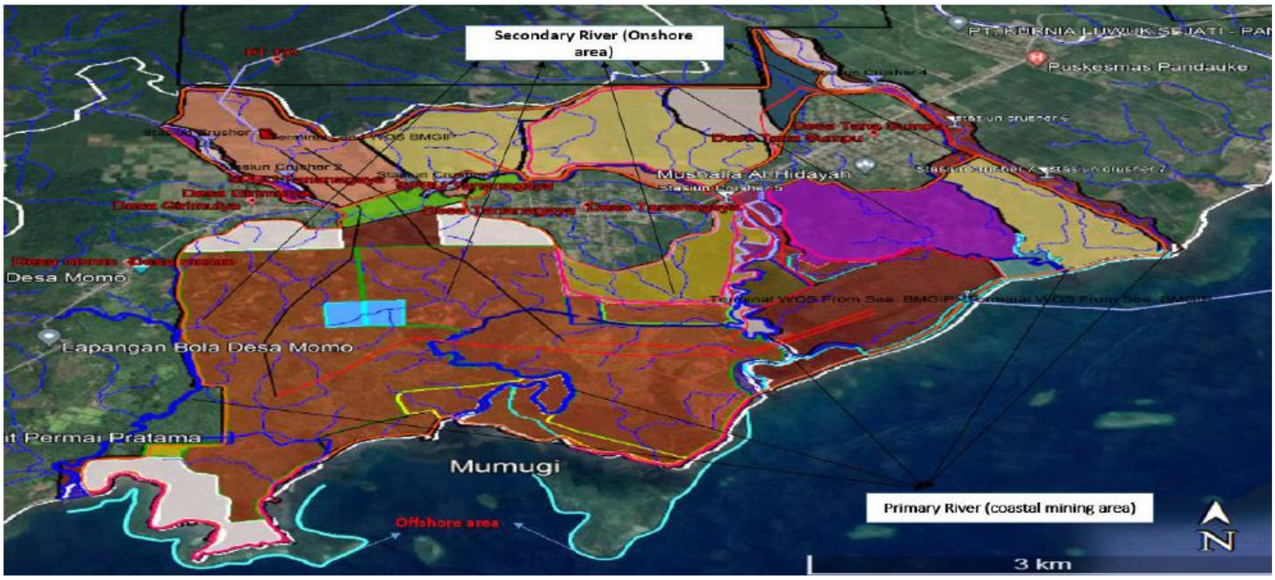

Figure 5. General Water Resource Systems BNIP

Table 2. Water Electrical Supply in EAF Model

Waterdebt electrical Parameter PT AIP Based on Catchment area	Limitation paramter number	Remarks
Gravity force (M/s2)	9,8	water electrical looses analysis
All Water Debt in PT AIP (M3/s)	126,1	
Height of waterfall (M)	5	
Submersible pump drainage (%)	0,7	
Total energy Estimation Electrical charging for smelter Kwh/ton	762	Electrical for smelter process Plant /ton dkp
Total Energy Estimation by Water Resource Estimation Electrical charging (kwh)	4324,8	(fullfilled water electrical supply by coal electrical plant)

Table 3. Elecrtrical Composition in EAF Model

Type of energy	Specification	Electrical Supply (Kwh/dkp (ton))	Energy Composition (%)	Remarks
Coal Power Plant Energy	**Low Grade Coal (4000-5000)**	**467**	**61,2**	**Energy Should be Erashed by Blue and Green energy**
Exotermic & Oxy-Burned Energy	a) Oxygen Burners	70	9,2	Process in Electric Arc Furnace (EAF) model
	b) Exothermic/Chemical Reactions	201	26,4	
	c) Electrodes	16	2,1	
	d) Combustibles	8	1,1	
Energy Looses	a) Cooling	114	15	Ferronickel Product energy Looses
	b) Electrical Looses	35	4,6	
	c) Slag	42	5,6	
	d) Misc.Looses/Other Looses	7,6	7,6	
Energy Recyling to Energy Konversion	Off-Gas/Flue Gas	121	15,9	Reside of EAF Model + Coal Power Plant + EAF Model

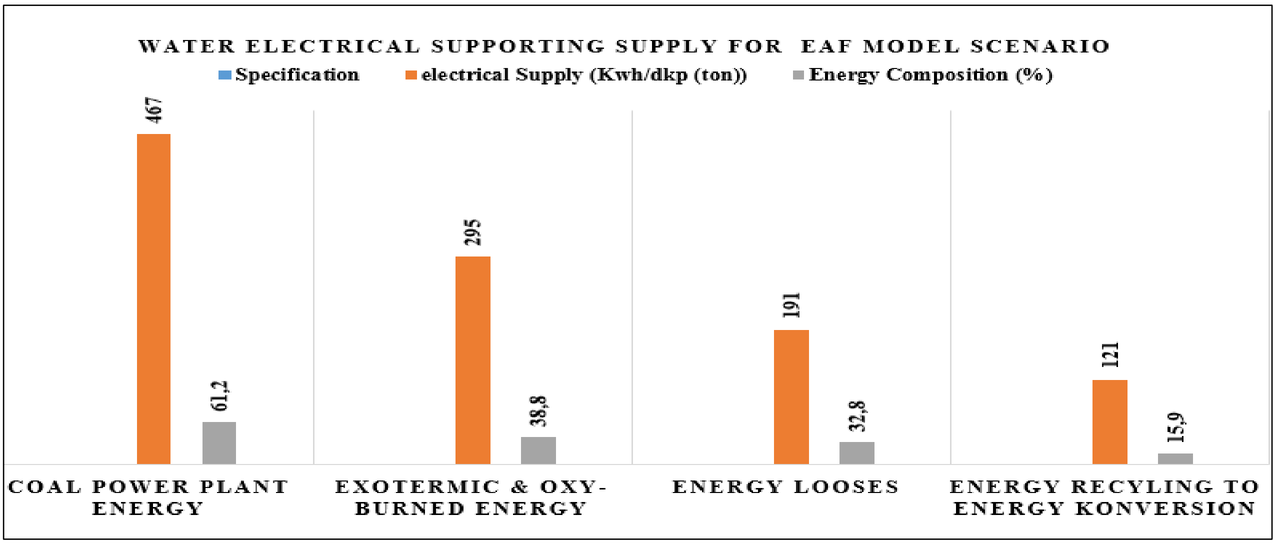

Figure 6. The Role of Coal on Water Electrical Charging Should be Change on Green and Blue Energy Future

Based on figure 6 there are 4 energy could be produced from water electrical supply were firstly, electric charging from coal electricity plant (61,2%) and Exotermic & Oxy-Burned Energy (38,8%) was an original energy who come from Primary energy demand and secondly, who come from Nickel Processing Plant in EAF which would be brought Energy Looses (32,8%) and Thirdly, Energy recyling to energy conversion (15,9%). Those data could be represented on figure 6 & 7 bellow:

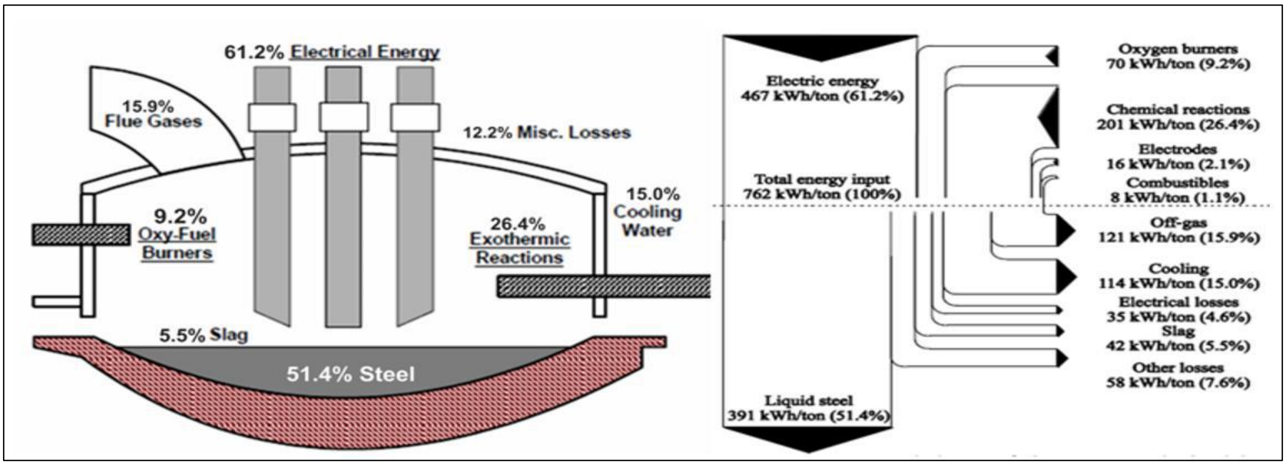

Figure 7. Electrical energy model[8] [9]

Based on simulation by water electrical charging coal still on the majority electrical position still 60% from energy electrical power ballance on EAF system but by input simulation of Green and Blue Energy Source electrical Power on EAF system the calculation will adjustment by table bellow:

Table 4. Blue and Green Energy Based on Location Source Of Electrical Charging Intake Power

Area	Location	Unit Calculations		Target Electrical Charging (Kwh) /ton (DKP)	Target Electrical Charging For all Infrastructure and Socieities Kwh/day	Coal Electrical Charging (Carbon Energy)	Target Electrical Fulfilled from Clean Energy Model Kwh/Dkp	Clasification Remarks Clean energy based on Location on Green and Blue Zone Energy	Total Energy For Recovering All Electrical Charging on All Area Mine Industry Project Kwh/ton
		Covering (Ha)	Lenght (m)						
Hydropower		**120**					**607**	Green Energy	
Solar PV	**Onshore Area**								
	Area 1	213					1500	Green Energy	
	Area 2	193					1300		
	Area 3	110					1100		
	Offshore Area	Future Plan						Blue Energy	
	Coastal Area	Future Plan						Blue Energy	
Wind Energy	**Offshore Area**								
	a. Belt 1		3640				1500	Blue Energy	
	b. Belt 2		4204				1700		
	Onshore Area								
	a. Belt 1		3918	1074			1500		**22607**
	b. Belt 2		1893		10000	467	1000	Green Energy	
	c. Belt 3		3108				1300		
	Coastal Area								
	a. Belt 1		1824				1000	Blue Energy	
	b. Belt 2		3898				1600		
Wave + Tidal Energy	Offshore Area								
	Belt 1		3640				1500	Blue Energy	
	Belt 2		4204				2000		
Gas and Steam energy	Batui, Toili, Banggai LNG Dongi senoro	20	65000				5000	Green Energy	

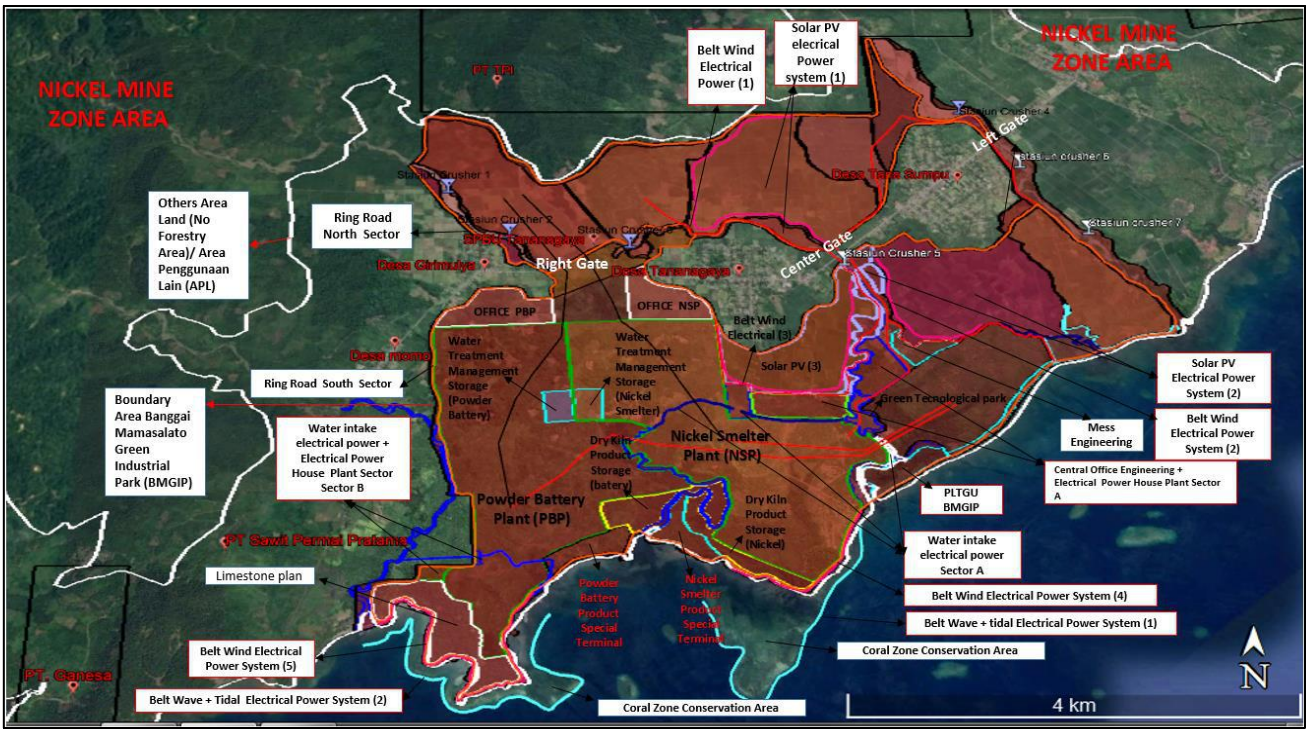

Figure 8. Green and Blue Energy Based on Source of electrical Power Intake in Industrial Park Project Area

Based on Table 7 and Figure 8 Banggai Nickel Industrial Park Plan will elaborate the integrated system among Green Material Optimization Concept, Nickel Smelter Techonological Adaptive system and Source of Electrical Power based on own environmental sorrounded all project area which all complexity will produce a perfect model to fix technical problem for clean energy in the future mining bussiness[10].

3.3. Industrial Investment Socio-economic Green and Blue Economical Efficiency Mutualism system

Resource Large Mining Company and Technology overview of smelter plant was not enought to prove that a mining company could be noted as a successful company[10]. Economical Investment to the green supply chain management could be set up as main based data calculation to deciding operational cost and income for a mining company and beside that, another minig company could be executed the economical chance and challenging on mining future, they should be implemented 8 criteria that mining could be mentioned as "Responsible Mining" namely Social and environmental assessement, Transparency, Acceptabel by stokeholders, Food Production Trumps Questionable Mining, Compliance with international standards, Corporate Prequalification, Insurance and Performa bonds, and royalties[11]. Green and Blue Economical Scenario will present on table bellow:

Table 5. Source of Cost Electrical Power Alternative to fullfill Industrial Park Plan

Source of Energy	Material Supply	Cost/ton or Kwh ($)	Production Cost ($)
Coal (ton)	24907	60	$1.494.400
Alternative Energy of Electrical Power Plant:			
a. Hydropower	100	3,8	$380
b. Solar PV	100	5	$500
c. Wind	100	7	$700
d. Wave + Tidal	100	15	$1.500
e. Gas and Steam LNG Power Plant	600	30	$18.000
Average Water from catchment area for Exotermic & Oxy-Burned Energy (M3/s)	126	3,8	$479
Adding Material For Calcination Process by Limestone (ton)	13280	20	$265.600
Production cost per year (Wmt)	1000000	11	$11.000.000

Table 6. Cost Simulation of Dry Kiln Product (ton) PT AIP

Mining Cost Parameter for Economical Smelter Cost		
Marketing Price in LME (dkp/ton)		14310
Target per year dkp/ton		80000
Income Cost ($)	$	1.144.800.000
Production Cost Supply Chain	$	45.694.079
Net Income	$	1.099.105.921
Exchange in IDR		14043
Net Income	Rp	15.434.744.446.708
Corporate Social Responsibility (2%)	Rp	308.694.888.934
Health, Safety and Environmental Obligation and monitoring (5%)	Rp	771.737.222.335
Royalty (Tax)(5%)	Rp	771.737.222.335
Net Present Value of Smelter Schenario Investment model Project (IDR)	Rp	13.582.575.113.103
Net Present Value of Smelter Schenario Investment model Project ($)/1 Year	$	967.213.210
Total Reserve PT AIP (Wmt)	Rp	100.000.000
Life of Mine PT AIP		10 Years
Alternative Ore Purchasing		Around Central of Sulawesi to Fulfilled Ore Smelter
Future Value Rate 5% For Escalation Rate in Smelter Model system during 7 Years operation		Rp1.360.966.117,10

Based on economical cost overview by smelter process plant PT AIP could be gotten net present value 967.213.210 $ or IDR 13.582.575.113.103 which several budget would be taken from net income percentage were Corporate Social Responsibility (CSR) (2%) IDR 308.694.888.934,-, Health & Environmental Obligation and Monitoring (5%) 771.737.222.335,- and Royalty to Government (5%) 771.737.222.335,-. Mining Resilience Model could be specified divine CSR from company on 4 Viilage around PT AIP namely:

Table 7. CSR budget for people mining resilience model[12]

Responsible Mining Program (CSR)	Percentage Composition (%)	Budgeting Overview	
Education	15%	Rp	46.304.233.340
Healthy	15%	Rp	46.304.233.340
Working Empowerment	20%	Rp	61.738.977.787
Economical Indenpendency	10%	Rp	30.869.488.893
social and culture	10%	Rp	30.869.488.893
Mining Sustainable Monotoring System	10%	Rp	30.869.488.893
CSR Organization	10%	Rp	30.869.488.893
Infrastructure development	10%	Rp	30.869.488.893
Total CSR Budgeting Program		Rp	308.694.888.934

Table 8. CSR Cyrcle Mining Societies PT AIP [13]

Cyrcle Mining Socities	Presentage	Clasification for CSR Needed	
Rata Village	20%	Rp	61.738.977.787
Tambale Village	5%	Rp	15.434.744.447
Padauke Village	5%	Rp	15.434.744.447
Tana Sumpu Village	20%	Rp	61.738.977.787
Tana Nagaya Village	20%	Rp	61.738.977.787
Giri Mulya Village	20%	Rp	61.738.977.787
Momo Village	10%	Rp	30.869.488.893
Total Development Program Cost	**100%**	**Rp**	**308.694.888.934**

Based on data above this research has been presented the correlation among Green Mining Optimization System in Resource Base Industry, Green and Blue electrical power system, Green and Blue economical supply chain management and socio-life sustainable program on coastal area could be stand up to resilient one packaging system in mining industry[14].

4. Conclusion

Based on simulation result, PT Asindo Internasional Perdana by covering area 3.919 Ha would be extended their sisters location project by name Banggai Nickel Industrial Park by covering area 2.924 Ha which this issue would be added the methodology of research subject and object to define the detail project relate integration and collaboration system who produced number of Project Execution relate about Material Movement Needed, Technological Addaptive System, Environmental Tehcnology on Green and Blue Energy Supply Power in Project Area, and How to Human Mutualism Invest Program Model as the subject and object on mining circle area which they are as human impact from all the creation of technology big picture on this screen. The end of conclusion of this research that Material,Techonolgy, Environmental and Human have a same dependency to keep earth to still live and this concept will implement on every single nicke industry in Indonesia and World as the sustainable seriuous solution on future mining business.

Acknowledgement

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REVOLUTIONISING HOUSING CONSTRUCTION IN MALAYSIA : LEVERAGING BUILDING INFORMATION MODELLING FOR SAFE AND AFFORDABLE HOMES

Nur Syafika Artika Rahim[1], Mohammad Hussaini Wahab [1], Syuhaida Ismail [2]

[1]Razak Faculty of Technology and Informatics, Universiti Teknologi Malaysia Kuala Lumpur, Jalan Sultan Yahya Petra, Kuala Lumpur 54100, Malaysia.
[2]Director of Research, Maritime Institute of Malaysia, B-06-08, Megan Avenue II 12, Jalan Yap Kwan Seng, 50450 Kuala Lumpur

nursyafikaartika90@gmail.com

Abstract

Affordable homes play a crucial role in attaining sustainable development goals, especially the United Nations (UN) Sustainable Development Goal target indicator 11.1, which emphasises safe and affordable housing. There is a growing demand for sustainable, cost-effective, and high-quality home solutions in Malaysia. Therefore, this paper investigates the revolutionary critical strategies of Building Information Modelling (BIM) to transform home construction practices in Malaysia towards the aim of constructing safe and affordable homes by examining the various ways in which BIM technology can improve the entire project lifecycle, from design and planning to construction and maintenance for affordable homes. It explores the main BIM features, such as 3D visualisation, clash detection, and information management, that contribute to increased safety, cost-effectiveness, and quality in Malaysian construction for home. In addition, the paper addresses potential challenges in the adoption of BIM, such as technological limitations, expertise gaps, and resistance to change. The outcome of this paper shall discuss the Critical Action Plan (CAP) and recommendations for policymakers, construction industry professionals, and relevant stakeholders to promote the adoption of BIM in the construction industry, especially for affordable homes. These actions will foster the widespread integration of BIM within the affordable homes construction sector, aligning with the Public Works Department (PWD) BIM Strategic Plan 2021–2025, which has set an adoption target of 80% by 2025 supporting the previously mentioned National Construction Policy (NCP) 2030 agenda of the Ministry of Work Malaysia.

Keywords: Building Information Modelling (BIM); construction projects; Safe and affordable homes; Malaysia; United Nations Sustainable Development Goal 11.1.

1. Introduction

The complex challenge of providing affordable homes in Malaysia amidst a growing population intersects with the imperative of upholding sustainable development principles (1). The dire need for safe and affordable homes lays the foundation for this paper's exploration of a transformative approach with the potential to revolutionise Malaysia's construction landscape. This approach is centered around the innovative concept of Building Information Modelling (BIM), offering a promising avenue to address the crucial intersection of safety, affordability, and sustainable development in affordable home construction. Within Malaysia's unique context, rapid urbanis ation, population growth, and economic expansion have intensified the demand for housing, straining the availability of affordable options. As urbanisation continues, the criticality of secure and reasonably priced homes underscores the need for innovative solutions. This paper positions BIM as an innovative strategy to address this multifaceted challenge by investigating how it can reshape affordable home construction practices.

The significance of a safe and affordable home is intrinsically linked to the broader spectrum of sustainable development (2). A secure and dignified living environment is not only a fundamental human right but also a linchpin for achieving wider sustainable development objectives. This is aptly encapsulated in the United Nations' Sustainable Development Goal (UN SDG) target indicator 11.1, which emphasises the creation of inclusive, resilient, and sustainable cities and human settlements. The urgency of providing safe and affordable homes resonates with the essence of UN SDG target indicator 11.1, acknowledging the symbiotic relationship between affordable homes and the overall well-being of communities.

UN SDG target indicator 11.1 acts as a compass guiding the nation toward holistic urban development. Grounded in the recognition of housing as a fundamental human right, this indicator emphasises upgrading informal settlements, facilitating access to affordable homes, and cultivating sustainable, inclusive, and resilient cities (3). The alignment between the aspirations of UN SDG target indicator 11.1 and the fundamental need for safe and affordable homes underscores the call for innovative approaches to meet these intertwined goals. At the core of this paper's exploration lies

BIM, a transformative concept driving digital innovation within the construction industry. BIM transcends conventional practices by digitally simulating and mapping the entire lifecycle of a building (4). This dynamic approach revolutionises how construction projects are conceived, planned, executed, and maintained. Its fusion of diverse data streams and stakeholders has the potential to disrupt traditional practices and propel the construction industry toward newfound efficiency, collaboration, and sustainability.

The primary aim of this paper is to investigate the revolutionary critical strategies of BIM adoption as a catalyst for redefining affordable home construction practices in Malaysia. Through meticulous analysis, the paper uncovers the multifaceted ways in which BIM technology can steer the construction of safe and affordable homes. Spanning the spectrum from initial design and planning to intricate construction and sustained maintenance, the study explores how BIM features like 3D visualisation, clash detection, and information management can significantly bolster safety, cost-effectiveness, and quality within Malaysia's affordable home construction landscape. The ultimate aspiration of this exploration is to offer insights, strategies, and recommendations that foster the widespread integration of BIM within the affordable homes construction sector, harmonising with national policies and objectives such as the Public Works Department (PWD) BIM Strategic Plan 2021–2025 and the National Construction Policy (NCP) 2030 agenda of the Ministry of Work Malaysia

2. Literature Review

The evolving landscape of affordable housing in Malaysia, amid escalating urbanisation and population growth, is tightly intertwined with the broader principles of sustainable development (5). This section embarks on a comprehensive journey through the literature, examining the intricate interplay of these elements and introducing Building Information Modelling (BIM) as a revolutionary force capable of reshaping housing construction practices in the country. The foundational understanding of BIM begins with a concise exploration of its definition and guiding principles. BIM emerges as an innovative digital methodology, facilitating the integration of diverse dimensions—both geometric and non-geometric—within a collaborative framework (6). Rooted in data-driven decision-making, BIM fosters transparency and collaboration, redefining the conventional boundaries of construction project management. Global trends in BIM adoption illuminate its transformative potential within the construction industry. As projects increasingly gravitate toward more efficient and collaborative models, BIM emerges as a linchpin, facilitating real-time collaboration and mitigating errors (7). This shift underlines a paradigmatic transition from traditional practices to a technologically enriched approach, emblematic of the industry's dynamic evolution.

Central to BIM's significance is its capacity to enhance efficiency, collaboration, and informed decision-making across the construction lifecycle (8). Through real-time data sharing and scenario simulation, BIM empowers multidisciplinary teams with the tools to optimise designs, anticipate challenges, and make judicious choices. The shift transcends mere project management, becoming a conduit for reshaping industry dynamics (9). Evidence of BIM's transformative potential reverberates through previous applications in construction projects. Noteworthy outcomes include reduced costs, diminished delays, and improved overall project performance (10). The centralised data repository offered by BIM streamlines communication, minimises errors, and contributes to efficient project delivery, validating its pivotal role in shaping modern construction practices.

Crucially, BIM extends its impact on safety and affordability in housing construction. Its robust visualisation and simulation capabilities empower stakeholders to proactively identify and mitigate safety hazards during the design phase (11). Additionally, BIM's ability to optimise designs and streamline workflows aligns with the tenets of affordability, showcasing its potential to harmonise two critical dimensions of housing construction. Within the Malaysian context, BIM has garnered national attention as a catalyst for industry transformation (12). National initiatives, including the Public Works Department (PWD) BIM Strategic Plan 2021–2025, underscore the commitment to BIM integration, reflecting broader agendas of innovation and sustainability (12). Amid these initiatives, however, a distinct gap emerges—a dearth of literature delving into BIM's practical application in the realm of the Malaysian housing construction process.

3. Investigating BIM's Revolutionary Critical Strategies of BIM Adoption in Safe and Affordable Homes in Malaysia

Building Information Modelling (BIM) adoption in the construction industry has been steadily on the rise, presenting the potential to revolutionise housing construction practices worldwide. This literature review seeks to explore the purpose behind investigating BIM's potential critical strategies in transforming housing construction, discuss how BIM can impact the housing project lifecycle, present case studies of successful BIM implementation, and underline the connection between BIM's features and the overarching goals of safety and affordability. The primary aim of this investigation is to uncover how BIM, as a transformative technology, can catalyse a paradigm shift in housing construction practices globally. The housing sector grapples with challenges, such as the pressing need for safe and affordable homes (Smith, 2018) (13). BIM presents an innovative approach to address these challenges, and this study aims to shed light on the strategies that can harness its potential to reshape the way homes are designed, built, and maintained.

BIM's impact spans across the housing project lifecycle, starting with the design and planning phase (14). Advanced 3D visualisation and virtual walkthroughs empower stakeholders with immersive insights into the proposed designs, improving decision-making and allowing for early identification and rectification of design flaws (15). BIM-driven design optimisation ensures that safety and affordability are embedded into the core of the project (16). During the construction phase, BIM plays a crucial role (17). Clash detection mechanisms in BIM preemptively identify potential conflicts, minimising delays and costly rework (18). Moreover, BIM streamlines project scheduling and resource allocation, leading to increased cost-effectiveness and operational efficiency (19). By enhancing collaboration and coordination among project teams, BIM acts as a catalyst for smoother construction processes.

BIM's influence extends into the maintenance phase (20). Effective facility management, predictive maintenance, energy efficiency monitoring, and lifecycle analysis fall within BIM's purview (21). Through data-driven insights, BIM helps optimise maintenance processes, ensuring that homes remain safe and cost-effective to maintain throughout their lifecycle. To underscore BIM's potential, this literature review incorporates case studies from successful BIM implementations in housing projects worldwide (22). These real-world examples serve as tangible evidence of BIM's transformative impact. They showcase how BIM has been used to enhance safety, efficiency, and affordability in diverse housing construction projects, thereby validating its potential as a game-changer in the industry. The connection between BIM's features and the overarching goals of safety and affordability in housing construction is profound (23). Its visualisation and simulation capabilities empower stakeholders to proactively identify and mitigate safety hazards during the design phase. Additionally, BIM's ability to optimise designs and streamline workflows directly aligns with the goal of affordability, making it an indispensable tool in the pursuit of safe and cost-effective housing solutions.

In conclusion, this literature review provides a comprehensive overview of the investigation into BIM's revolutionary potential in safe and affordable homes worldwide (24). It emphasizes the importance of strategic BIM adoption throughout the housing project lifecycle, showcases real-world successes, and highlights the symbiotic relationship between BIM's features and the overarching goals of safety and affordability. Through the critical strategies uncovered in this study, BIM emerges as a transformative force poised to redefine housing construction practices on a global scale.

4. Methodology

The research methodology applied in this study entails the utilisation of semi-structured interviews, a robust approach chosen to comprehensively investigate the potential of Building Information Modelling (BIM) in reshaping housing construction practices within Malaysia. This methodological choice aligns seamlessly with the qualitative nature of the research, offering a dynamic framework that facilitates in-depth exploration while affording participants the latitude to contribute context-rich insights (25). The rationale underpinning the adoption of semi-structured interviews resides in its capacity to provide nuanced perspectives from subject matter experts (SMEs) actively engaged in BIM. This methodology bridges the gap between theory and practice, offering a platform for experts to share experiential insights, thereby facilitating an exhaustive understanding of BIM's practical implications within the housing construction context.

The selection of SMEs adheres to stringent criteria that underscore their proven proficiency in BIM. The cohort comprises architects, engineers, construction managers, and researchers, who have demonstrated expertise in BIM-related projects, alongside a deep-seated understanding of the technological intricacies and real-world applications of BIM. The interview process is meticulously orchestrated to encompass ethical considerations, encompassing the domains of informed consent, privacy, and confidentiality. Participants are selected through purposive sampling, ensuring their alignment with the research objectives. Thorough briefings are provided to potential participants, elucidating the research aim, procedures, and stringent confidentiality measures. Upon securing informed consent, interviews are conducted in-person or virtually, tailored to participants' preferences and logistical feasibility.

The constellation of semi-structured interview questions has been intricately crafted to holistically investigate BIM's transformative potential across the housing project lifecycle. The inquiry delves into participants' vantage points on BIM's efficacy in the design, construction, and maintenance phases, with a pronounced focus on its role in bolstering safety and affordability. Crafted to be open-ended, the questions empower participants to recount authentic experiences, challenges, and insights, thus rendering a panoramic view of BIM's multifaceted contributions to housing construction. Ethical considerations form the bedrock of this study. Participants' informed consent, anonymity, and confidentiality are stringently upheld, reflecting the paramount importance of their contributions. Rigorous qualitative content analysis constitutes the bedrock of data analysis, encompassing the systematic identification of recurring themes, patterns, and insights that surface within the interview transcripts (26). This methodological rigor ensures that the research outcomes resonate with the participants' voices and lived experiences, thus elevating the credibility and validity of the study. In synthesis, the chosen methodology of semi-structured interviews serves as the linchpin for elucidating expert opinions that unfurl pragmatic insights into the transformative potential of BIM within the landscape of housing construction. Ensconced in a framework of ethical considerations and meticulous data analysis, this methodology strives to offer a panoramic vista into BIM's role in catalysing safety, affordability, and innovation within the tapestry of Malaysia's housing sector.

5. Findings

The implementation of a Critical Action Plan (CAP) for Leveraging Building Information Modelling (BIM) for Safe and Affordable Homes in Malaysia presents numerous implications and benefits for various stakeholders. This CAP holds the potential to align Malaysia with the United Nations Sustainable Development Goal 11 (UN SDG 11.1), which focuses on ensuring access for all to adequate, safe, and affordable homes. Embracing BIM for affordable home projects can help address pressing housing affordability challenges, promote sustainable development, improve social well-being, and contribute to environmental conservation. To gain insights into the CAP for its implementation, five (5) subject matter experts from the construction field were interviewed, and their perspectives are summarised in Table 1.

Table 1 Critical Action Plan (CAP) for Leveraging Building Information Modelling For Safe And Affordable Homes in Malaysia

No	Critical Action Plan (CAP) for Leveraging Building Information Modelling For Safe And Affordable Homes in Malaysia	1	2	3	4	5	Frequency (Agreed)
1	Organising workshops and training sessions that demonstrate BIM's benefits through hands-on experience.	X	X		X	X	4
2	Showcasing real-world success stories that can help professionals grasp the advantages of BIM and ease their transition.	X	X		X	X	4
3	Establishing industry-wide standards for data formats and introducing BIM protocols for affordable homes.		X		X	X	3
4	Collaborating with software developers, regulatory bodies, and industry associations to define common data exchange standards that can significantly improve interoperability and data sharing in BIM.		X		X		2
5	Implementing comprehensive training programmes that cater to professionals at various skill levels.	X	X		X	X	4
6	Collaborating with educational institutions, offering certification programmes , and providing online resources that can help professionals upskill and stay updated on BIM advancements.	X	X		X	X	4
7	Implementing collaborative project management platforms that integrate BIM models and enable real-time communication.		X		X	X	3
8	BIM facilitates efficient data sharing, version control, and coordination among multidisciplinary project teams.		X		X	X	3
9	Hosting awareness campaigns and seminars to highlight the benefits of BIM adoption throughout the supply chain.		X		X	X	3
10	Offering guidance on BIM implementation, collaborating on pilot projects, and showcasing success stories can encourage buy-in from all stakeholders.	X	X		X	X	4
11	Establishing clear BIM execution plans at the project's outset.	X	X		X	X	4
12	Employing experienced BIM managers who oversee model coordination and ensure data integrity can streamline project management.	X	X		X	X	4
13	Collaborating with industry experts to design comprehensive and practical training curricula.	X	X		X	X	4
14	Integrating BIM training into existing educational programs and providing continuous learning opportunities to professionals.	X	X		X	X	4
15	Introducing incentives such as tax breaks or preferential procurement for BIM-enabled projects can encourage wider adoption.					X	1
16	Mandating BIM for public projects and setting clear benchmarks can drive industry-wide change.					X	1
17	Establishing collaborative forums between industry professionals and technology developers can foster direct feedback and mutual learning		X		X		2
18	Prioritising user interface enhancements, interoperability solutions, and tools that cater to the affordable home construction sector's needs.		X		X		2
19	Aligning BIM adoption with government national policies for a supportive environment.			X		X	2

Malaysia's pursuit of safe and affordable homes amid rapid urbanisation and population growth has turned the spotlight on BIM as a potential game-changer. To discern the most promising Critical Action Plan (CAP) for effective BIM adoption, insights from a panel of subject matter experts (SMEs) with extensive experience across various domains of the construction sector are invaluable. Based on Table 1, unanimously, the SMEs endorse CAP which involves hands-on training sessions and showcasing real-world BIM success stories. These CAPs are hailed as vital for dismantling resistance to BIM adoption. Practical experience and case studies are seen as pivotal in helping professionals understand BIM's advantages and navigate the transition. Architects, contractors, and developers strongly emphasise their efficacy.

Following closely the most favored CAPs are comprehensive training programs that cater to professionals at all levels. Education emerges as the linchpin in bridging skill gaps and empowering professionals to maximise BIM's potential. The need for continuous learning opportunities is a common theme among our SMEs, recognising the evolving nature of BIM. Most of the SMEs endorse the establishment of clear BIM adoption plans at project initiation and the deployment of experienced BIM managers to oversee model coordination. These measures are seen as fundamental for maintaining data integrity and streamlining project management, particularly in large affordable home projects.

Hosting awareness campaigns and offering guidance on BIM adoption also receive unanimous support from SMEs. Disseminating information about BIM benefits throughout the supply chain is viewed as a potent catalyst in BIM adoption. Most SMEs firmly believe that showcasing success stories and offering guidance can encourage buy-in from all stakeholders. Implementing collaborative project management platforms that integrate BIM models and enable real-time communication is another favored CAP, primarily backed by structure consultants, architects, and developers. These platforms are seen as instrumental in enhancing data sharing, version control, and coordination among multidisciplinary teams. While there is strong support for industry-wide standards and collaboration with software developers, regulatory bodies, and industry associations to enhance BIM interoperability, concerns about potential additional costs and complexities are expressed by contractors and developers.

Lastly, CAP related to government incentives and aligning BIM adoption with national policies evoke mixed perspectives. Some SMEs acknowledge the potential benefits of such incentives, while others approach them cautiously. Aligning BIM with national policies is recognised as a complex undertaking, without immediate consensus among the SMEs, suggesting the need for further discussion and alignment. In conclusion, the preferred CAPS for leveraging BIM in Malaysia affordable home construction, as gleaned from our panel of SMEs, underscores the importance of tailored approaches and stakeholder collaboration. Hands-on training, comprehensive education, and effective project management emerge as top priorities. While standardisation and government incentives remain crucial, their practicality and alignment with industry needs may necessitate careful consideration. In essence, a multi-stakeholder approach appears paramount for the successful transformation of Malaysia's affordable home construction industry through BIM adoption.

6. Conclusion

The pressing need for safe and affordable homes in Malaysia, amid a backdrop of rapid urbanisation and population growth, has ushered in a transformative era in the construction industry. This paper embarked on a journey to explore the potential of Building Information Modelling (BIM) to revolutionise the affordable home construction landscape in Malaysia, guided by insights from subject matter experts (SMEs) with decades of collective experience. The research commenced with a recognition of the multifaceted challenges surrounding affordable homes in Malaysia, rooted in the diverse socio-economic landscape of the nation. The alignment of these challenges with the broader aspirations of sustainable development, underscored by the United Nations' Sustainable Development Goal (UN SDG) target indicator 11.1, illuminated the profound importance of safe and affordable homes in fostering inclusive, resilient, and sustainable cities and communities.

Introduction to BIM as a technological paradigm shift laid the foundation for our exploration. BIM's potential to enhance efficiency, collaboration, decision-making, and, most importantly, safety and affordability in housing construction was unveiled. The literature review illuminated the global adoption trends, prior applications, and policy initiatives surrounding BIM, providing crucial context for our analysis. Through the lens of SMEs, the research ventured into an analysis of the preferred Critical Action Plan (CAP) for leveraging BIM in Malaysian affordable home construction projects. Their collective wisdom prioritised hands-on training, real-world success stories, and comprehensive education as cornerstones for BIM adoption. Clear CAPs and experienced managers were deemed fundamental for project integrity. The value of awareness campaigns and guidance in fostering industry-wide buy-in was unanimous from the SMEs. Collaborative project management platforms found favor among certain stakeholders.

Yet, not all CAPs received universal endorsement. Industry-wide standardisation and collaboration, government incentives, and policy alignment triggered diverse opinions, revealing the complex interplay between aspirations and practicalities. In essence, the exploration of BIM's potential and the preferred CAPs to harness it underscores a clear call for collaboration and tailored approaches. Malaysia's journey towards safer and more affordable homes stands as a testament to the transformative power of technology, education, and multi-stakeholder engagement.

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SUSTAINABLE INTEGRATION OF BLUE ECONOMY PRINCIPLES IN THE DEVELOPMENT OF INDONESIAN NEW CAPITAL NUSANTARA

Danis H Sumadilaga[1], Alfa Adib Ash Shiddiqi[2], and Dapot Andri Agustinus[3]
1. Indonesian New Capital Nusantara Construction Task Force, Indonesia
2. DG of Highways (Ditjen Bina Marga), Indonesia
3. Indonesian New Capital Nusantara Construction Task Force, Indonesia
E-mail: dsumadilaga@gmail.com, adibalfa@pu.go.id

Abstract

The Indonesia New Capital Nusantara (IKN) project envisions a modern, sustainable city to replace Jakarta, situated on Borneo. With a $33 billion budget, IKN aims to accommodate Indonesia's growth. This study explores integrating blue economy principles into the new capital's planning. Developing a fresh capital provides a unique chance to harmonize growth and preservation, embodying the blue economy concept. This research aims to explore the incorporation of blue economy principles into the planning and development of the proposed new capital city, Nusantara. As a burgeoning urban endeavor, the development of a new capital city presents a unique opportunity to harmonize economic growth with ecological preservation, exemplifying the essence of the blue economy concept. The study employs a multidisciplinary approach that draws upon urban planning, sustainable development, and governance perspectives. It investigates the strategic integration of key blue economy principles, such as sustainability, inclusive growth, innovation, and conservation, into the urban planning framework of Nusantara. Through a combination of literature review, case study analysis, and stakeholder consultations, the research seeks the potential benefits and challenges associated with aligning the city's growth trajectory with the sustainable utilization of ecosystems. Contributing to urban sustainability and blue economy discourse, this research provides insights into practical implications of implementing such principles in new capital city contexts. Its findings offer guidance for urban developments worldwide that seek equilibrium between economic progress and environmental care.

Keywords: Blue Economy principles, Indonesian New Capital Nusantara, Sustainable city, Urban development

1. Introduction

In April 2017 the Joko Widodo administration reawakened a dormant notion to move the country's capital from Jakarta, making a commitment to completely assess prospective alternative sites for Indonesia's new capital by the end of that year . According to Ministry of National Development Planning of Indonesia (Bappenas), the government was determined to move the Indonesian capital out of Java, an idea that had been intermittently floated since the Sukarno administration, which had considered Palangka Raya in Central Kalimantan. Shortly after the plan was announced, Jokowi visited two alternative locations in Kalimantan, Bukit Soeharto in East Kalimantan, and the Triangle Area near Palangka Raya. In April 2019, a 10-year plan to transfer all government offices to a new capital city was announced. The National Development Planning Ministry recommended the three provinces of South, Central, and East Kalimantan which Jokowi visited, given that each met the requirements for a new capital—including being relatively free from earthquakes, tsunamis and volcanoes, as well as allowing for a maritime port [1], [2]. The city is designed for sustainability and protecting its surrounding Kalimantan forests, targeting 80% of mobility to be supported by public transport, cycling, or walking and drawing all of its energy from renewable sources and allocating 10% of its area to food production [3].

The blue economy refers to the sustainable use and conservation of ocean and coastal resources to support economic growth, improve livelihoods, and promote environmental sustainability. It encompasses a wide range of economic activities and sectors related to oceans and seas, such as fisheries, aquaculture, maritime transport, tourism, renewable energy from the ocean, and marine biotechnology. The idea behind the blue economy is to strike a balance between economic development and environmental protection in coastal and marine areas. It emphasizes the importance of responsible resource management to ensure the long-term health of marine ecosystems while harnessing the economic potential that the ocean and coastal areas offer. The blue economy concept has gained prominence as concerns about overfishing, pollution, and climate change impact the world's oceans. Many countries and organizations are working to promote sustainable practices and investments in the blue economy to ensure the well-being of both people and the planet.

Aligning economic growth with environmental sustainability in urban development is essential for creating resilient, healthy, and prosperous cities that can meet the needs of current and future generations while minimizing harm to the environment. It offers a pathway to balanced and sustainable urban growth that benefits both people and the planet. Therefore this paper aims to identify benefits and challenges associated with aligning the city's growth trajectory with the sustainable utilization of ecosystems.

2. Blue Economy Principles: Theory And Framework

Principles

The blue economy principles are a set of guidelines and concepts aimed at promoting sustainable and responsible use of ocean and coastal resources while fostering economic development and environmental conservation. These principles provide a framework for achieving a balance between economic growth and the preservation of marine ecosystems. Key blue economy principles are: (i) Sustainability, (ii) Inclusivity, (iii) Innovation, (iv) Resource Efficiency, (v) Ecosystem-Based Management, (vi) Resilience, and (vii) Collaboration

The primary principle of the blue economy is sustainability. It emphasizes the need to manage marine and coastal resources in a way that ensures their long-term health and productivity. The blue economy aims to benefit all stakeholders, including coastal communities, indigenous peoples, and small-scale fishermen [4]. It seeks to promote social equity and ensure that the benefits of economic activities in coastal and marine areas are shared by all. Innovation is crucial in the blue economy, encouraging the development of new technologies and approaches to maximize the use of marine resources while minimizing negative environmental impacts. This can include advancements in aquaculture, renewable energy, and marine biotechnology. Resource efficiency is a key principle, focusing on reducing waste and minimizing the environmental footprint of economic activities in the marine and coastal areas [5]. It includes practices like reducing bycatch in fisheries and using energy-efficient technologies in maritime transport [6]. The blue economy promotes the adoption of ecosystem-based management approaches. This means considering the entire ecosystem when making decisions about resource use, taking into account the interconnectedness of species and habitats [7], [8]. Building resilience to climate change and other environmental challenges is another important aspect. This involves adapting to the impacts of climate change, such as rising sea levels and ocean acidification, and finding ways to mitigate these effects [9]. Collaboration among governments, businesses, communities, and organizations is essential for the success of the blue economy. It often requires cooperation at regional and international levels to address issues like illegal fishing and pollution [10].

Theory and Frameworks

Integrating the principles of the blue economy into urban development projects requires a well-defined theoretical framework that aligns economic growth with environmental sustainability in urban settings. Two distinct frame works are developing clear urban sustainability goals, and integration of blue economy principles.

Urban Sustainability Goals should have clear objectives and adopt Triple Bottom Line Approach [11], [12]. Begin with a set of clear sustainability objectives that define the desired outcomes of the urban development project. These objectives should encompass economic, environmental, and social dimensions. Adopt a "triple bottom line" approach that evaluates project impacts based on economic prosperity, environmental health, and social well-being. This approach ensures that the project addresses a wide range of sustainability goals.

Integrating blue economy principles should include three action such as assessment, principle prioritization and stakeholder engagement. Conduct a thorough assessment of how each of the blue economy principles applies to the specific urban development project. This involves evaluating the project's potential impacts on marine and coastal resources, as well as its alignment with sustainability principles. Principle Prioritization is important to identify which blue economy principles are most relevant and prioritize them based on the project's context and objectives. Some principles may be more critical than others depending on the project's location and focus. The other important step is engage stakeholders. Involve key stakeholders, including local communities, government agencies, businesses, and environmental organizations, in the decision-making process. Their input can help ensure that blue economy principles are integrated effectively.

3. Methods

The research design and methodology combined rigorous academic inquiry through literature review, practical insights from global case studies, and real-world perspectives from stakeholder consultations to provide a comprehensive and holistic understanding of how blue economy principles can be effectively integrated into urban development, with a specific focus on the Indonesian New Capital, Nusantara. The research framework consists of three key components: literature review, case study analysis, and stakeholder consultations.

Literature Review. The research initiated with an extensive literature review to establish a strong theoretical foundation. This phase involved a systematic examination of academic journals, reports, and publications related to the blue economy, sustainable urban development, and successful case studies of cities worldwide. The purpose was to gain a deep understanding of the principles, theories, and best practices that underpin the blue economy concept and its application in urban planning. This comprehensive review informed the conceptual framework and provided insights into the key challenges and opportunities associated with aligning economic growth with environmental sustainability in urban contexts.

Case Study Analysis. The research methodology included an in-depth analysis of case studies from various cities and projects globally that have successfully integrated blue economy principles into their urban development strategies. These case studies served as practical examples of how the principles can be applied in real-world scenarios and provided valuable lessons and best practices. The analysis involved a comparative examination of the strategies employed, the outcomes achieved, and the challenges faced by these cities.

Stakeholder Consultations. To ensure a well-rounded perspective and real-world applicability of the research findings, stakeholder consultations were a crucial component of the research methodology. Engaging with key stakeholders, including government officials, urban planners, community representatives, environmental organizations, and private sector entities, provided invaluable insights into the practical challenges and opportunities associated with implementing blue economy principles in the context of Nusantara. These consultations allowed for a nuanced understanding of the local dynamics, cultural considerations, and the feasibility of proposed strategies. The feedback and input from stakeholders played a pivotal role in refining the actionable recommendations and ensuring their relevance to the Indonesian New Capital project.

The use of a multidisciplinary approach is justified in this research due to the multifaceted nature of the subject matter, the complexity of urban development projects, the need for practical solutions, the interconnections between various issues, the adaptability to local contexts, the validation and reliability of findings, and the potential for interdisciplinary collaboration.

4. Discussion

Application on Urban Planning

Integrating the principles of the blue economy into urban planning and development involves adopting a holistic approach that considers economic growth, environmental sustainability, and social well-being. Urban planners and policymakers must collaborate with communities, businesses, and organizations to create cities that are inclusive, innovative, resource-efficient, and resilient, while also preserving and enhancing the natural environment. Followings are how each of the blue economy principles can be applied to urban planning and development (see Table 1).

Table 1 Blue Economy Principles and Application

Blue Economy Principles	Description	Application on urban planning
Sustainability	It emphasizes the need to manage marine and coastal resources in a way that ensures their long-term health and productivity. This includes sustainable fishing practices, responsible tourism, and the protection of marine biodiversity.	Urban planning should prioritize sustainability by promoting resource-efficient practices, such as green building standards, efficient transportation systems, and sustainable water management. This involves reducing energy consumption, minimizing waste generation, and conserving natural resources
Inclusivity	The blue economy aims to benefit all stakeholders, including coastal communities, indigenous peoples, and small-scale fishermen. It seeks to promote social equity and ensure that the benefits of economic activities in coastal and marine areas are shared by all.	Inclusive urban development ensures that the benefits of growth are shared by all residents. This can involve affordable housing policies, community engagement in planning, and measures to prevent displacement of vulnerable populations due to gentrification.
Innovation	Innovation is crucial in the blue economy, encouraging the development of new technologies and approaches to	Urban planning can encourage innovation by fostering research and development hubs, supporting clean technology startups, and

Blue Economy Principles	Description	Application on urban planning
	maximize the use of marine resources while minimizing negative environmental impacts	integrating cutting-edge technologies like smart grids, energy-efficient infrastructure, and green infrastructure into city design.
Resource Efficiency	focusing on reducing waste and minimizing the environmental footprint of economic activities in the marine and coastal areas. It includes practices like reducing bycatch in fisheries and using energy-efficient technologies in maritime transport	Efficient resource use in urban planning includes designing energy-efficient buildings, implementing waste reduction strategies, and promoting sustainable transportation options, such as public transit and cycling infrastructure.
Ecosystem-Based Management	The blue economy promotes the adoption of ecosystem-based management approaches. This means considering the entire ecosystem when making decisions about resource use, taking into account the interconnectedness of species and habitats.	Ecosystem-based urban planning considers the entire urban environment, including green spaces, watersheds, and habitats for wildlife. It involves protecting and restoring natural systems, such as wetlands, rivers, and forests, within urban areas to enhance biodiversity and resilience.
Resilience	This involves adapting to the impacts of climate change, such as rising sea levels and ocean acidification, and finding ways to mitigate these effects	Urban resilience involves planning for and mitigating the impacts of climate change and natural disasters. This can include designing flood-resistant infrastructure, enhancing stormwater management, and implementing disaster preparedness and response plans.
Collaboration	Collaboration among governments, businesses, communities, and organizations is essential for the success of the blue economy.	Collaboration is vital in urban planning to ensure diverse stakeholders work together effectively. Public-private partnerships, community engagement processes, and regional cooperation are crucial for addressing urban challenges and achieving sustainability goals.

Case studies on successful cities

The next discussion as shown bu Table 2 is the example of cities or projects that have successfully integrated these principles. Several cities and projects around the world have successfully integrated the principles of the blue economy into their urban planning and development. Follwong are case studies and examples that highlight these successful integrations in the city of Copenhagen, Singapore, Bristol City (UK), San Fransisco, Vancouver, Sanya [13][14][15][16][17].

Table 2 Case studies international cities

Principles	Case studies	
Sustainability	Copenhagen has made significant strides in sustainability by investing in renewable energy sources, including wind power. The city aims to be carbon-neutral by 2025.	
Inclusivity	Singapore has focused on inclusive housing policies, including public housing initiatives that cater to a wide range of income levels, ensuring affordability for residents.	
Innovation	Singapore has pioneered innovative water management solutions, such as NEWater (recycled wastewater) and Marina Barrage (a freshwater reservoir in the city center).	
Resource Efficiency	Copenhagen has implemented innovative waste-to-energy systems, reducing landfill waste and providing heat for thousands of households	
Ecosystem-Based Management	Bristol has embraced ecosystem-based management by developing its port area into a thriving center for renewable energy industries. The city's Avonmouth Port is a hub for wind energy components.	Sanya, a coastal city, has leveraged its natural assets to become a leading sustainable tourism destination. It promotes eco-friendly resorts and marine conservation efforts.
Resilience	San Francisco is committed to resilience in the face of earthquakes and sea-level rise. It has implemented strict building codes and invested in infrastructure to reduce vulnerabilities	

Principles	Case studies	
Collaboration	Copenhagen collaborates with various stakeholders, including private companies and research institutions, to drive innovation and sustainable growth.	Vancouver works closely with indigenous communities on environmental initiatives, recognizing their role as key stakeholders in urban planning and sustainability.

Application of the principles for Indonesia New Capital Nusantara

Developing for the success of these cities, The Indonesia New Capital Nusantara could also applied thes principles into its planning and development. The planned Indonesian New Capital, Nusantara, presents a unique opportunity to apply the principles of the blue economy in urban planning and development. Located on the island of Borneo, this new capital aims to be a model city for sustainable growth, taking into account environmental conservation and inclusive development. Followings shown by Table 3 are how the principles of the blue economy can be applied to the Indonesian New Capital, Nusantara.

Table 3 Application for Indonesian New capital Nusantara

Principles	Application for Indonesian New Capital Nusantara
Sustainability	Nusantara can prioritize sustainability by implementing green building standards, sustainable transportation systems, and renewable energy sources. It can set ambitious goals for reducing carbon emissions and conserving natural resources in its urban planning.
Inclusivity	To ensure inclusivity, the new capital should have a mix of housing options, including affordable housing, and consider the needs of all income levels. Inclusivity extends to job opportunities, public services, and social amenities that benefit all residents.
Innovation	Nusantara can encourage innovation by fostering research and development centers, supporting clean technology startups, and integrating advanced technologies into urban infrastructure, such as smart grids, green buildings, and sustainable transportation solutions.
Resource Efficiency	Nusantara can focus on water and energy conservation, waste reduction, and efficient land use to minimize its environmental footprint.
Ecosystem-Based Management	Nusantara can incorporate ecosystem-based management into its urban planning. This includes preserving green spaces, protecting watersheds, and creating wildlife corridors within the city.
Resilience	Nusantara should be designed with resilience in mind, considering the potential risks from climate change and natural disasters. It can build infrastructure that can withstand floods, storms, and other climate-related challenges.
Collaboration	Collaboration among government agencies, local communities, private sector entities, and non-governmental organizations is essential for the success of Nusantara. Public-private partnerships can drive investments in sustainable infrastructure and services.

Challenge of the Application of the principles for Indonesia New Capital Nusantara

However, implementing blue economy principles in the development of Nusantara, the new Indonesian capital, will certainly face several challenges and barriers. Table 4 explain challenges may arise in IKN implementation.

Table 4 Barrier and Challenge in IKN implementation

Barrier	Challenge
Financial Constraints	
Funding sustainable and eco-friendly infrastructure and technologies can be expensive, and securing the necessary financial resources may be challenging.	Finding innovative financing mechanisms, attracting private investments, and exploring international partnerships to support sustainable initiatives will be crucial.
Policy and Regulatory Framework	
Inadequate or conflicting policies and regulations related to environmental protection and sustainable development can hinder the implementation of blue economy principles.	Streamlining and updating existing policies and creating new regulations that encourage sustainable practices while ensuring compliance and enforcement are essential.
Land Use and Land Tenure	
Land use planning and tenure issues can pose challenges, particularly when it comes to preserving green spaces and protecting natural habitats.	Establishing clear land use policies that prioritize conservation, affordable housing, and sustainable development while addressing tenure concerns is essential.

Barrier	Challenge
Infrastructure and Technology	
Developing and implementing sustainable infrastructure and advanced technologies, such as renewable energy and water management systems, can be technically challenging.	Promoting innovation, research, and development in these areas and ensuring that infrastructure projects align with sustainability goals will be necessary.
Community Engagement and Awareness	
Communities may resist or lack awareness of the benefits of sustainable development, potentially leading to opposition or lack of cooperation	Implementing effective community engagement programs and public awareness campaigns to educate and involve residents in sustainability initiatives will be vital.
Infrastructure and Service Delivery	
Ensuring access to sustainable services, such as public transportation or waste management, in a new city like Nusantara can be logistically challenging	Planning and executing efficient and eco-friendly infrastructure and service delivery systems to meet the needs of a growing population will be a significant challenge
Climate Change and Environmental Risks	
The city's coastal location exposes it to climate change-related risks such as sea-level rise and extreme weather events	Developing climate-resilient infrastructure and strategies to adapt to changing environmental conditions will be crucial

Collaboration among all stakeholders, including government bodies, businesses, communities, and civil society organizations, will be essential to address these challenges effectively.

Actionable Recommendations

This paper also develops actionable recommendation for policy makers, urban planners, and stakeholders involved in the Indonesian New Capital. These actionable recommendation is crucial to ensure its success as a sustainable and environmentally responsible urban development.

Recommendation for policy makers.

1. Establish a Comprehensive Sustainability Framework. They should develop a comprehensive sustainability framework that incorporates the principles of the blue economy into urban planning and development. Also, set clear sustainability goals and targets related to carbon neutrality, resource efficiency, and environmental conservation.
2. Enforce Sustainable Building Standards. They should implement and enforce green building standards and regulations that promote energy efficiency, use of renewable materials, and low-impact construction practices. Also by incentivize developers and builders to meet sustainability criteria through tax incentives and permitting benefits.
3. Support Sustainable Transportation. The policy makers should invest in sustainable transportation infrastructure, including efficient public transit, cycling lanes, and pedestrian-friendly pathways.it is necessary to promote the use of electric vehicles and develop charging infrastructure.
4. Promote Green Energy Sources. It is important to encourage the use of renewable energy sources, such as solar, wind, and hydroelectric power, within the city. Also, it is necessary to offer incentives for the installation of renewable energy systems in residential and commercial buildings.
5. Preserve Natural Habitats. One of the important things is to develop and enforce strict regulations to protect nearby natural habitats, including forests, wetlands, and water bodies. Also, establish wildlife corridors and green belts within the city to enhance biodiversity.

Recommendation for urban developers.

1. Integrate Ecosystem-Based Design. The planner should integrate ecosystem-based design principles into urban planning, preserving green spaces and incorporating natural features into the city's layout. It is also important to prioritize green rooftops, urban parks, and green corridors to promote biodiversity and enhance residents' quality of life.
2. Create Climate-Resilient Infrastructure. It is important for the design infrastructure that is resilient to climate change impacts, including sea-level rise, floods, and extreme weather events. It also should incorporate green infrastructure, such as permeable pavements and rain gardens, to manage stormwater.
3. Other important thing is to prioritize Sustainable Water Management. The best practices should implement sustainable water management, including rainwater harvesting, wastewater treatment, and the use of recycled water for non-potable purposes. It also must promote water-efficient landscaping and encourage residents to reduce water consumption.

4. Urban developers should develop Mixed-Use Neighborhoods. From the beginning it should promote design mixed-use neighborhoods that reduce the need for long commutes and promote walking, cycling, and public transportation. Then, it should foster a sense of community by creating vibrant, pedestrian-friendly urban centers with access to amenities and services.

For the other stakeholders it is recommended followings:

1. Stakeholders should engage in Sustainability Initiatives. Furthermore, businesses and industries should actively participate in sustainability initiatives, such as waste reduction, energy efficiency, and responsible resource management. They should explore sustainable practices that align with the blue economy, such as sustainable aquaculture or eco-friendly tourism.
2. Support Research and Innovation is important for New Capital Nusantara. Stakeholders can invest in research and innovation related to sustainability and the blue economy. They could collaborate with universities, research institutions, and technology companies to develop and implement innovative solutions.
3. Participate in Community Education is also important point. Stakeholders should engage with local communities through education and awareness programs to promote sustainable living practices. It also important to encourage residents to take ownership of sustainability initiatives within the city.
4. Lastly, civil society should advocate for Sustainability Policies. Advocate for policies and regulations that support sustainability and the blue economy at the local, regional, and national levels. Civil society should engage in public-private partnerships to drive sustainable development.

5. Conclusion

In conclusion, the development of the Indonesian New Capital, Nusantara, presents a significant opportunity to integrate the principles of the blue economy into urban planning and development. The blue economy principles, including sustainability, inclusivity, innovation, resource efficiency, ecosystem-based management, resilience, and collaboration, offer a comprehensive framework for creating a sustainable, environmentally responsible, and inclusive city. By aligning economic growth with environmental sustainability, Nusantara can set an example for responsible urban development. However, it's essential to acknowledge and address the challenges associated with implementing these principles, such as financial constraints, regulatory issues, and community engagement.

To ensure the success of Nusantara as a sustainable urban development, actionable recommendations have been provided for policy makers, urban planners, and stakeholders. These recommendations include establishing a comprehensive sustainability framework, enforcing sustainable building standards, supporting sustainable transportation, promoting green energy sources, preserving natural habitats, integrating ecosystem-based design, creating climate-resilient infrastructure, prioritizing sustainable water management, and developing mixed-use neighborhoods. Additionally, stakeholders are encouraged to engage in sustainability initiatives, support research and innovation, participate in community education, and advocate for sustainability policies. By following these recommendations and actively embracing the principles of the blue economy, Nusantara can become a model city that not only promotes economic growth but also safeguards the environment, enhances social inclusivity, and ensures resilience in the face of environmental challenges. This approach will contribute to the well-being of current and future generations while setting a standard for sustainable urban development in Indonesia and beyond.

This article highlights the importance of integrating blue economy principles into urban development, particularly in the context of the Indonesian New Capital, Nusantara. However, there is a compelling need for further research in this field to address critical questions and challenges. Further research could explore the specific economic and environmental impacts of adopting these principles, the long-term sustainability of resource-efficient practices, and the social equity outcomes in urban planning projects of this magnitude. Additionally, investigating the role of technology and innovation in achieving blue economy objectives, as well as the scalability of successful models to other urban contexts, can provide valuable insights. Furthermore, comparative studies with cities worldwide that have embraced blue economy principles can offer a comprehensive understanding of what works best in different urban settings. Overall, further research in this area is essential to refine strategies, optimize outcomes, and ensure the success of blue economy integration in urban development projects, not only in Nusantara but also in similar initiatives globally.

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STRENGTH CHARACTERISTICS OF FLY ASH BOTTOM ASH WASTE AS A GEOPOLYMER FOR REINFORCEMENT OF EMBANKMENT MATERIALS ON ROAD PAVEMENTS WITH THE ADDITIONAL OF MICROORGANISM

Dewi Rantung[1], Oktovian B. A. Sompie[1], Steeva G. Rondonuwu[1], Audie Rumayar[1]

1 Civil Engineering, Engineering Faculty, Sam Ratulangi University, Jl. Kampus Unsrat, Manado, 95115
E-mail: steeva_rondonuwu@unsrat.ac.id

Abstract

Fly ash is a by-product as non-hazardous waste from PLTU Sulut III as fuel for power plants, in the form of fine grains and is pozzolanic in nature. Utilization of fly ash waste into a product is a way to deal with the waste produced. The main source of Fly Ash Bottom Ash (FABA) comes from the coal burning process in steam power plants (PLTU) and the coal burning process in boilers and/or furnaces in industry. The compressive strength test was carried out on the test object in the form of a solid block made with a mixture of sand and cement with variations in the addition of geopolymer. The test results obtained at the addition variations, 10, 20 and 30% fly ash gave the compressive strength values respectively 3.74; 3.09; and 2.66 MPa for solids aged 7 days. Then with variations in the same fly ash content it gives a compressive strength value respectively of 7.16; 3.71; and 3.21 MPa for solids aged 14 days and increasing for solids aged 21 days until it reaches a maximum value of 8.18 MPa with the addition of 10% fly ash. While laboratory tests were carried out on Fly Ash Bottom Ash which was mixed in soft clay with varying levels and curing time of the bacillus subtilis bacteria, the CBR value decreased with increasing curing time. From the research conducted, it can be analyzed that the addition of 10% fly ash gives the maximum compressive strength value at the age of 21 days, while the duration of curing with the addition of bacillus subtilis bacteria reduces the CBR value of the material. This can be explained that the addition of large geopolymers can weaken the biological activity of bacteria, thereby reducing the value of the strength of the material. Meanwhile, without a mixture of bacteria, the value of soil strength increases.

Keywords: *compressive strength, Capacity Bearing Ratio, Bacillus Subtillis, geopolymer, solid waste*

1. Introduction

The development on transportation sector is growing fast in order to improve people's welfare. In this case the construction of roads and bridges. North Sulawesi Province has completed the Manado-Bitung toll road project and is continuing on the Ring Road III works. A common obstacle faced in road pavement work is unstable subgrade. This condition cannot be avoided because road terrace planning does not recognize whether the underlying soil is stable or not. So that efforts have been made to improve the basic soil, both original soil and embankment material.

On the other hand, the North Sulawesi Region, through the Steam Power Plant at PLTU Sulawesi 3, produces 10 tons of Fly Ash Bottom Ash (FABA) waste per day. FABA waste production continues to increase every day, resulting in the capacity of waste storage landfills decreasing. Therefore, efforts to distribute FABA waste are being made. One of them is by using FABA waste as backfill material at the location where road pavement will be applied. This can be done by making efforts to improve FABA waste so that it is suitable for use as landfill material.

Soil improvement using bio-grouting or bioremediation methods has been carried out in order to minimize the impact of environmental damage that may occur. One of the efforts that is starting to be implemented to improve soil is to use microorganisms, namely fermentation bacteria. The commonly used fermentation bacteria is bacillus subtilis bacteria. This type is widely used because the mechanism and development of its culture is easy and it can live in general conditions on soil in Indonesia. The anaerobic activity of the bacterium Bacillus subtilis produces the enzyme which can solidify between granules in the soil, thereby increasing soil density. Based on this rationale, efforts were made to increase the strength of the subgrade material by utilizing FABA waste material but with the help of bacillus subtilis bacteria so that optimum strength of the subgrade pavement material could be achieved.

2. Materials and Methods

Fly ash Bottom Ash (FABA) waste material is taken in the Kema Airmadidi area which is the location of PLTU Sulawesi 3. Fly ash or fly ash used as an additional mixed material comes from coal combustion residue which is used as an energy source for the PLTU SULUT 3 Kema – North Sulawesi. Fly ash is not treated before it is used as research material, meaning it is immediately used as it is when taken from the source. In general, the chemical composition of coal fly ash is presented in table 1.

Table 1. Chemical composition of fly ash

Komponen	Sat.	Bituminous	Subbituminous	Lignit
SiO2	%	20-60	40-60	15-45
Al2O3	%	5-35	20-30	20-25
Fe2O3	%	10-40	4-10	4-15
CaO	%	1-12	5-30	15-40
LOI	%	0-15	0-3	0-5

Some of the advantages of fly ash include that it has pozzolanic properties, can reduce shrinkage and cracking so that it can increase soil strength. Fly ash contains chemical elements including silica (SiO2), alumina (A12O3), ferric oxide (Fe2O3), and calcium oxide (CaO). Also contains other additional elements, namely magnesium oxide (MgO), titanium oxide (TiO2), alkaline (Na2O and K2O), sulfur trioxide. (SO3), phosphorus oxide (P2O5) and carbon.

Table 2. Physical properties of the former Ratatotok mining soil

No.	Test	Unit	Result	Deskription
1.	Sieve Analysis			
	Pass Sieve No. 200	%	9.91	Granular soil with silt content
	Pass Sieve No.49	%	32.00	
2.	Specify Gravity		2,556	
3.	Moisture	%	1.150	

The soil samples used were former community mining soil samples that passed sieve no. 4 (4.75 mm) and were in dry surface conditions.

Cementation solution is a solution used by bacillus subtilis bacteria to produce calcite or CaCO3 (Calcium Carbonate) which has binding properties. The cementation solution is the result of mixing Urea and CaCL2 (calium chloride) with water as a medium. The result of mixing the cementation solution with Bacillus Subtilis bacteria is called Bacterial Reagent, which in this research is used as a bio-remediation material or substance which is mixed into soil samples in the hope that it will have an influence on soil stability. The bacterial reagent concentration used in this research consisted of 100 grams of urea, 10 grams of CaCL2, 50 ml of water and 10 ml of bacillus subtilis bacteria. Bacterial reagent levels for each test sample are adjusted to the variations in the test plan that have been planned in advance.

A series of tests were carried out to determine the maximum density achieved by varying FABA mixtures with different levels of bacterial reagents and varying curing times. The tests carried out are:

Standard Proctor Test

The test object which is the main object in the experiments carried out in this research is the test object for standard compaction testing (proctor standard test). The test objects made and tested in this research consisted of:

1. Test object with original soil sample, namely ex-mining soil without mixing.
2. Next, test objects with variations in water content of 5%, 7.5%, 10%, 12.5% and 15% of the weight of the test object, respectively.
3. Test objects resulting from mixing original soil samples with bacterial reagents with mixture levels varying from 5%, 7.5%, 10%, 12.5% and 15% of the weight of the test object, with curing times of 7 and 14 days.

Table 3. The soil sample with bacteri and curring time varying

No.	Tanah Asli (%)	Air (%)	Reagen Bakteri (%)	Fly Ash (%)	Waktu Peram (hari)
A.	Original Soil				
1	95.0	5.0	-	-	-
2	92.50	7.5	-	-	-
3	90.00	10.0	-	-	-
4	87.50	12.5	-	-	-
5	85.00	15.0			
B	Adding Mixture				
1	90.0	-	5.0	5.0	
2	87.5.0	-	7.5	5.0	
3	85.00	-	10.0	5.0	0
4	82.50	-	12.5	5.0	
5	80.00	-	15.0	5.0	
1	90.0	-	5.0	5.0	
2	87.5.0	-	7.5	5.0	
3	85.00	-	10.0	5.0	7
4	82.50	-	12.5	5.0	
5	80.00	-	15.0	5.0	
1	90.0	-	5.0	5.0	
2	87.5.0	-	7.5	5.0	
3	85.00	-	10.0	5.0	14
4	82.50	-	12.5	5.0	
5	80.00	-	15.0	5.0	

Uji California Bearing Ratio

Samples were varied according to bacterial reagent levels of 0%, 10%, and 20% and curing time as described in table 4.

Tabel 4. Soil Sample with bacteri content and curring time varying

Keterangan	Waktu Pemeraman (hari)			
	0	7	14	21
Soil sample	√			√
Soil sample + 10% reagent				√
Soil sample + 20% reagent		√	√	√

Tabel 5. Variations of mixtures of fly ash and bacterial reagents

No.	*CBR test sample*	*Curing time (day)*	*fly ash content*	*Bacteri Reagen content*
1	I	0	5 %	5%
2	II	0	5%	10%
3	III	0	5%	15%
4	IV	7	5%	5%
5	V	7	5%	10%
6	VI	7	5%	15%

Tabel 6. Variasi Campuran *Reagen* Bakteri dan Air pada Sampel Uji CBR

No	*CBR sample test*		*Reagen Bacteri content*	*Water*
	CBR unsoaked	*CBR soaked*		
1	Sampel I	Sampel I	5%	95%
2	Sampel II	Sampel II	10%	90%
3	Sampel III	Sampel III	15%	85%

* *The variation composition was the same for the 0 day and 7 day curing times*

3. Results and Discussion

The Standard Proctor Test value is shown in Figure 1., showing that the maximum increase in dry volume weight occurred in the sample with the addition of 10% bacteria and a curing time of 14 days. The test results indicate that the longer the curing time the maximum the density value.

Figure 1. Relationship Dry Density and Bacteria content

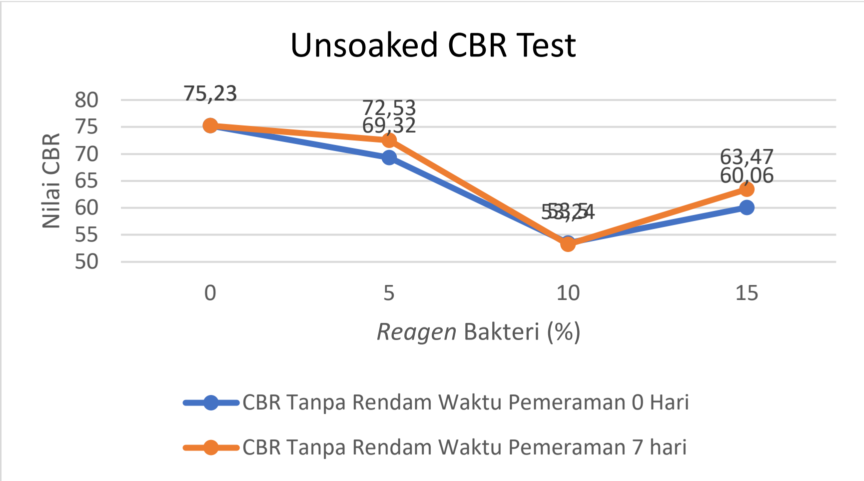

Figure 2. Unsoaked CBR test with curing time 0 and 7 days

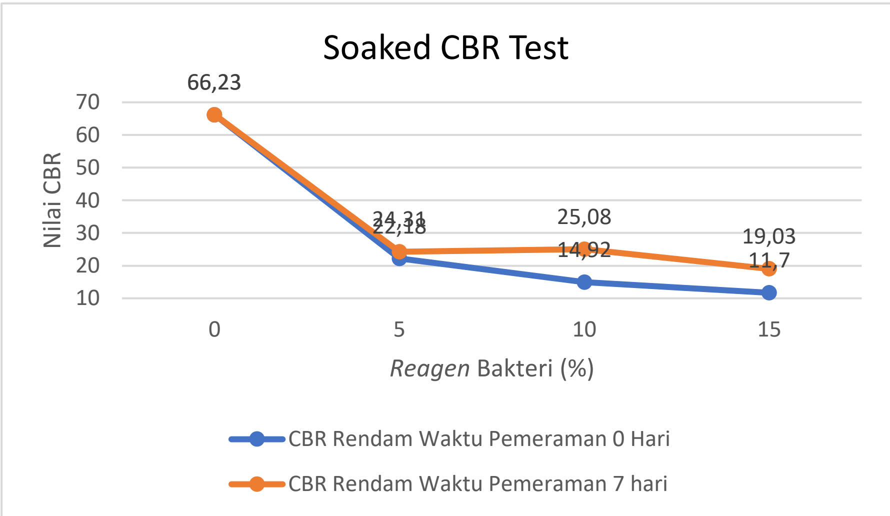

Figure 3. Soaked CBR test with curing time 0 and 7 days

4. Conclusion

The addition of 5% fly ash and 5%, 10% and 15% of bacillus subtilis bacteria caused a decrease in the CBR value of the soil. A 2.7% decrease occurred with the addition of 5% bacteria with a curing time of 7 days.The use of Bacillus Subtilis bacteria in the form of a bacterial reagent solution in the soil stabilization process by mixing it directly with soil samples (bio-remediation) can increase soil stability by increasing the maximum dry density value of the original soil, which is 1,947 t/m2, increasing to 1,978 t/m2 density. maximum soil after stabilization with a curing time of 14 days.

The increase in maximum dry density in mixed variation test specimens is directly proportional to the increase in the curing time of the test sample. This can be seen from the data at 0 days peram, the maximum dry density is 1,950 t/m2 or an increase of 0.154%, at 7 (seven) days peram the maximum dry density is 1,961 t/m2 or an increase of 0.719% and at 14 (four) days. twelve) days maximum dry density reached 1,978 t/m2 or an increase of 1.592%.

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SURFACE HYDROPHOBIC MODIFICATION OF OPEFB CELLULOSE WITH TRIGLYCERIDES FROM VEGETABLE OILS FOR APPLICATION AS GREEN COATING ADDITIVES OF BUILDING

Amirul Aiman Mohd A. and Ching Yern Chee
Department of Chemical Engineering
University of Malaya
50603 Kuala Lumpur
Malaysia

Email: chingyc@um.edu.my

ABSTRACT

Recently, there is a particular interest for hydrophobically-modified cellulose fibres due to their great diversity of potential applications ranging from self-cleaning surfaces to water-repellent of coating materials. Hydrophobic coating technologies treat cellulose surfaces in providing a simple clean, water and stain repelling surface. Thus, the need to develop a sustainable and green method for the production of hydrophobic cellulose has been in an increasing demand. Hydrophobic-rendered fibres through environmental-friendly methods yield better results in producing plant cellulose with heightened hydrophobic properties. In this study, vegetable triglycerides from soybean, coconut and *jatropha curcas* oil were used on oil palm empty fruit bunch (OPEFB) fibres with the aim of modifying the surface properties through modification in developing hydrophobic and water repellent properties. These oils were delivered onto the cellulose fibres in homogenous solutions of ethanol. It was then facilitated with evaporation of solvent followed by heating. The raw OPEFB fibres were treated via alkalization with sodium hydroxide solution and bleached at low temperature of 70 °C using peracetic acid. Treated cellulose fibres then undergoes carboxymethylation process using chloroacetic acid. Oil was applied to both treated and modified cellulose fibres. The changes in chemical and morphological characterization caused by modifications of the cellulose were inspected by FTIR spectroscopy and hydrophobicity was tested by investigating the WRV, HC and WCA. All oils, except for coconut, produced a hydrophobic and water-resisting cellulose surface. The homogenous application of oil on cellulose shows promise for the generation of further green chemistry and bio-based techniques in achieving cellulose with hydrophobic and water-repellent properties for coating additives application

Keywords: *hydrophobicity; cellulose fibres; surface modification; vegetable oils; triglycerides.*

1. INTRODUCTION

Hydrophobic cellulose fibres have exponentially become high in demand as well as the interest in the treatment of cellulosic fibres. The technology that is most valued is the treatment of cellulosic fibres with surface modification in rendering the cellulose fiber to become hydrophobic. This is mainly due of the usage of the synthesis fibers where it is highly resistant to wetting in many industries. Many applications for such surface modification technology has been implemented in the production of rainwear, outdoor gear, stain resistance products, bandages, etc. The most ideal water repellent fabric material would be one that is hydrophobic on the surface yet porous enough to allow moisture to flow through for comfort.

Hydrophobic cellulose can indeed be used as a green coating for buildings. Cellulose is a renewable and abundant natural polymer found in the cell walls of plants. It has excellent mechanical properties, biodegradability, and low toxicity, making it an attractive material for various applications, including coatings [1-3]. By modifying cellulose to be hydrophobic, it becomes water-repellent, which can be advantageous for building coatings [4-6].

There are many recent studies that has dealt with surface modification of cellulose fibres as additives of coating of buildings [7]. Despite the many studies, there is an urgent need to find more ecologically sustainable alternatives in hydrophobic surface modifications as compared to the current practices. Following the treatment of cellulose fibres, further modification would be required. The reactivity of cellulose hydroxyl groups with fatty acids is generally low however by converting the carboxylic acids, it could be upgraded to more reactive moieties [8-9].

The aim of this study is to investigate and determine the reaction of cellulose extracted from OPEFB fibres with vegetable oils of ranging triglyceride-chains in producing hydrophobic surfaces. Vegetable oils are a renewable resource and they are a great source as it contains high amounts of triglycerides. By rendering the surface to become hydrophobic would assist OPEFB cellulose to become a better and excellent green alternative to current technologies. Triglycerides from the various vegetable oils contain three acyl chains of varying degree of saturation as well as length of the acyl chain [10-14]. By completely covering the surfaces of the OPEFB fibres would in turn, generate a hydrophobic cellulose however without permanency. To achieve resilient hydrophobic surfaces, covalent bonded structures are most desirable [15-16].

In this study, soybean, coconut and *jatropha curcas* oil were selected to represent the range of fatty acid compositions. The different compositions of fatty acids would be used to determine and investigate its reaction in rendering the hydrophobic properties of cellulose for green coating additives applications. Structural characterization was studied using FTIR spectroscopy. A series of characterization studies would be carried out include the testing for water retention value, humidity content and wetting contact angle.

2. EXPERIMENTAL METHODOLOGY

2.1. MATERIALS

Chemicals used in this research were sodium hydroxide, sodium bromide, acetic acid (glacial), were purchased and provided by Friendemann Schmidt Chemical. Hydrochloric acid (37%), ethyl alcohol (95% v/v), sulphuric acid, hydrogen peroxide (30%), isopropanol was obtained from Synerlab Laboratory Reagent. Soybean, coconut and jatropha curcas oil was obtained from the market. Oil palm empty fruit bunch (OPEFB) cellulose and distilled water was processed and taken from Composite Laboratory at the Faculty of Engineering, University of Malaya.

2.2. TREATMENT OF CELLULOSE FIBRES

OPEFB fibres of smaller than 150 µm was introduced to alkali treatment. The reaction was conducted in reflux condition with NaOH solution (4 wt. %) at 80 °C. The fibres were allowed to mixed thoroughly with the NaOH solution for 3 hours. The procedure was repeated for 3 times, where after each treatment, the samples were filtered and wash thoroughly with distilled water to remove excess alkali-soluble compounds, specifically the lignin and hemicelluloses that dissolves with the solution.

Following the alkali treatment, the cellulose fibres were soaked in peracetic acid as the bleaching solution. The bleaching solution was prepared by the reaction of $CH_3COOH/H_2SO_4/H_2O_2$ with the mole ratio of 0.5mole/0.375mole/0.5mole. The bleaching solution was allowed to cool down to room temperature before application to the samples. The bleaching action was performed at 70 °C using a material to bleaching solution ratio of 1:30. The mixture was adjusted to pH 6 and the reaction was carried out for 30 minutes and then the reaction was allowed to turn to pH 10.5 and continue bleaching treatment for another 30 minutes. At the end of the treatment, the treated samples were washed thoroughly with distilled water and then oven-dried at 40 °C. The sample that has undergone alkali treatment followed by acid bleaching hereinafter is known as “treated sample”.

2.3. PREPARATION OF SODIUM CARBOXYMETHYL CELLULOSE

In alkalization step, OPEFB fibres were soaked in isopropanol with ratio of material to alcohol of 1:20. The fibres were ensured to properly mixed by continuously stirring before the addition of of 25% (w/v) NaOH solution. NaOH solution was added to the mixture while stirring continues for another hour at room temperature. Chloroacetic acid was then added to the mixture at 55 °C for 3 hours. Following the reaction, the mixture was neutralized to pH 7 with acetic acid using a drop-wise method. The samples are then filtered and wash thoroughly with ethanol, followed with being oven-dried at 40 °C. The samples that has undergone the procedure hereinafter is known as “modified sample”.

2.4. OIL APPLICATION

Oils were applied to the samples in homogenous ethanol solutions with concentration of 20% (v/v). Excess oil was applied with twice the vegetable oil solution to the cellulose, in order to saturate the cellulose fibres. The treated and modified cellulose samples were air dried for 20 mins at ambient temperature, followed by heating at 110 °C for 60 min. The samples were then rinsed with ethanol for the removal of excess and unreacted oil. Following the application of vegetable oils, the samples were oven dried at 40 °C for 24 hours. Hereinafter, samples with the application with oil will be labelled and denoted as listed in Table 1.

Table 1. Sample Notations & Labelling

Sample	Notation
BFCO	Treated fibres applied with coconut oil
MFCO	Modified fibres applied with coconut oil
BFJO	Treated fibres applied with *jatropha curcas* oil
MFJO	Modified fibres applied with *jatropha curcas* oil
BFSO	Treated fibres applied with soybean oil
MFSO	Modified fibres applied with soybean oil

2.5. CHARACTERIZATION STUDY

2.5.1. Fourier Transform Infrared Analysis

Fourier Transform Infrared (FTIR) studies were performed where the spectra of cellulose for both the treated and modified samples were obtained using an FTIR spectrometer. Each sample were grounded and made into pellets with KBr. The samples were analysed in the wavenumber of between the range of 4000 and 400 cm^{-1}. FTIR spectroscopy was performed to determine the changes in functional groups present due to the treatments within the samples.

2.5.2. Water Retention Value (WRV)

All dry samples were introduced and submerged in distilled water until it reached equilibrium. The samples were then centrifuged at 4000G (Centurion Scientific C2006 Centrifuge) for 20 mins. The samples were then weighed and labelled WRV_{wet}. Then, the samples were oven-dried at 105 °C for 4 hours and then placed in a desiccator (P_2O_5, RH = 0%) overnight. The dried samples were then weighed and labelled WRV_{dry}. Each measurement was carried out for 5 repetitions and the water retention value were calculated using the following equation:

$$WRV\ (\%) = \frac{WRV_{wet} - WRV_{dry}}{WRV_{dry}} \cdot 100 \tag{1}$$

where *WRV* is the water retention value in percentage, WRV_{wet} is the mass of sample (in grams) after centrifuging and WRV_{dry} is the mass of sample (in grams) after drying.

2.5.3. Humidity Content

All dry samples are treated to acclimatisation in an incubator with conditions of RH = 70% at room temperature. After 24 hours, the samples were weighed and labelled HC_{wet}. Then, the samples were oven-dried at 105 °C for 4 hours and then placed in a desiccator (P_2O_5, RH = 0%) overnight. The wet samples were then weighed and labelled HC_{dry}. Each measurement was carried out for 5 repetitions and the humidity content value were calculated using the following equation:

$$HC\ (\%) = \frac{HC_{wet} - HC_{dry}}{HC_{dry}} \cdot 100 \tag{2}$$

where HC is the humidity content value in percentages, HC_{wet} is the mass of sample (in grams) in the conditioned state with moisture and HC_{dry} is the mass of sample (in grams) without moisture.

2.5.4. Wetting Contact Angle

Wetting contact angle (WCA) of each sample were measured by producing samples into squares of 10 mm by 10 mm. A die is applied to the samples and is weighed. The samples were held horizontally as distilled water is applied to samples in a drop-wise manner. Each measurement was carried out for 3 repetitions and the wetting contact angle was observed closely by using an optical tensiometer.

3. RESULTS AND DISCUSSION

3.1. COMPOSITION OF OIL PALM EMPTY FRUIT BUNCH FIBRE

The composition of OPEFB fibres contains cellulose, hemicellulose and lignin. The treatment of injecting alkali and acid bleaching of the fibres resulted in an increase in cellulose content. This is expected as the hemicellulose and lignin components are washed and removed following the alkali and bleaching treatment. The treatment was efficient in removing most of the hemicellulose and lignin, which resulted in the high cellulose content.

Figure 1 displays the physical changes in appearance of the OPEFB and after it has undergone the treatment procedure. The colour of the sample changed as a result of the treatment. It can be seen that the treatment produced samples that are relatively white in colour (Figure 1b) in comparison to the raw fibres (Figure 1a) which indicated that the treatment gave the samples a satisfactory whiteness index. The change in colour also indicated in the loss of cellulose, hemicellulose and lignin components in the fibres. This process resulted in a minor loss in mass as well as the chemical alterations of the overall samples.

Figure 1. Photograph of (**a**) raw OPEFB fibres and (**b**) treated OPEFB fibres.

After the application of oil to the OPEFB, treated and modified fibres, a layer of triglycerides were determined on the surface of each sample. This indicated that the triglycerides formed a layer on the surface of the OPEFB fibres, resulting in an environmentally friendly and green method of hydrophobic surface modification. The colour did not alter as a result of the oil application procedure. This process also resulted in minor weight loss as well as in the change in chemical alterations of the fibres.

3.2. FOURIER TRANSFORM INFRARED SPECTROMETRY

FITR studies was conducted to investigate the functional groups present and to inspect the chemical alterations that occurred in OPEFB fibres due to the various treatments. The FTIR spectra of fibres are shown in Figure 2, 3 and 4 for both the treated and modified fibres along with them being treated to coconut, *jatropha curcas* and soybean oil, respectively.

Upon the modification of treated OPEFB fibres, there was an increase in the carbonyl functional group (C=O) of around 1640 cm^{-1}. The peaks seen at the range of 1320–1410 cm^{-1}. In the treated and modified fibres is due to the bending vibration of C-H and C=O aromatic rings in the polysaccharides [14-16]. The C=O stretching was not present in the treated and modified samples due to the removal of carboxylic groups following the alkaline treatment of the OPEFB fibres.

The absorption peaks between the range 2900 and 2800 cm^{-1} are due to the stretching of C-H groups [17]. This could be seen further within the range of 2960–2850 cm^{-1} which indicated the presence of alkane functional group chain. The C-H chains would have resulted in the treatment of oil onto the fibres. It is also these chains that would render the surface to obtain hydrophobic properties of the samples. This is observed in Figures 2, 3 and 4 for the samples treated with the vegetable oils. This peak at approximately 2988 cm^{-1} is however not present in the treated and modified samples. This indicated that the triglycerides of the vegetable oils were successful in becoming attached with the treated and modified samples, respectively.

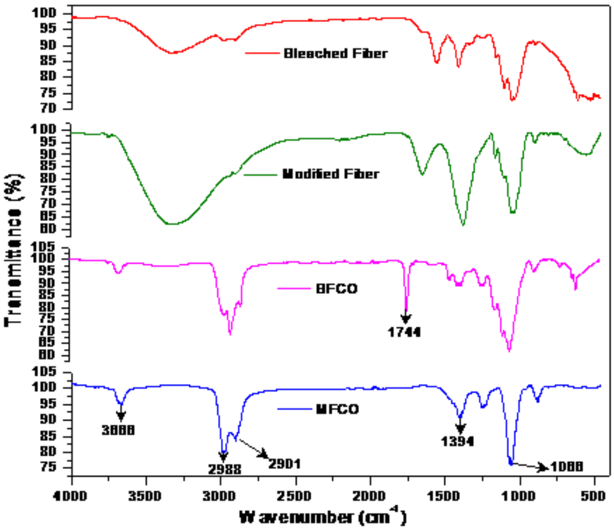

Figure 2. Fourier transform infrared (FTIR) spectra of treated fibre, modified fibre along with treated and modified fibres applied with coconut oil.

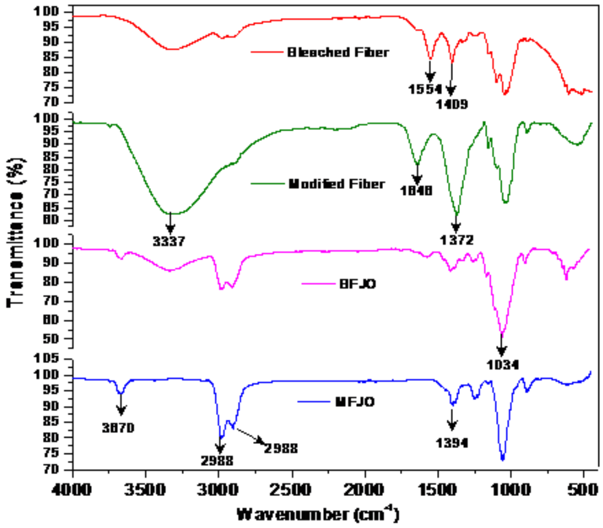

Figure 3. Fourier transform infrared (FTIR) spectra of treated fibre, modified fibre along with treated and modified fibres applied with *jatropha curcas* oil.

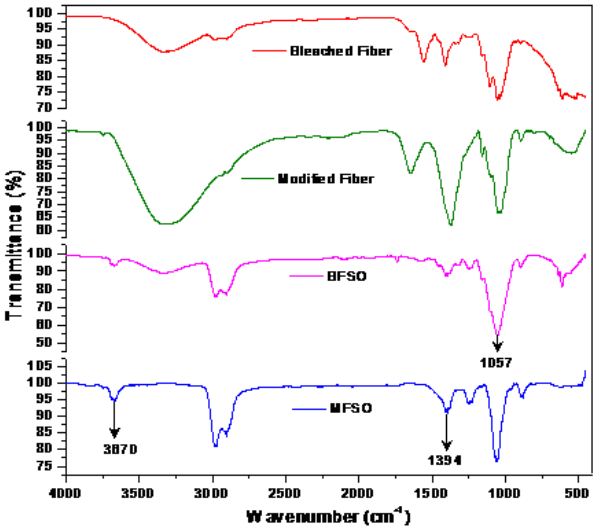

Figure 4. Fourier transform infrared (FTIR) spectra of treated fibre, modified fibre along with treated and modified fibres applied with soybean oil.

3.3. WATER RETENTION VALUE

Water retention value measures the ability for a fibre sample to retain water after centrifugation [13]. Surface modification of the fibres helped to render the samples to become hydrophobic, known for its resistance towards water. Water retention value of the cellulose fibres are believed to be due to the loss of hemicellulose and the introduction of the layer of triglycerides on the surface of each fibre sample. The water retention of the fibres is mainly defined by the structure of the cellulose which serves as the driving force for water absorption in cellulose fibres [14]. The usage of centrifugation in WRV measurements is to reduce the amount of the bulk water on the surface of the fibres. With this the WRV could more accurately represent the amount of water within the pores of the fibres surface area. A higher force and longer centrifugation time can force out more water from fibrous materials than lower force and shorter time [15].

WRV has mainly been used in the many industries to detect the retention of water of fibre samples. WRV of a fibre sample increases with the modification of the surface due to fibre swelling. Refining also increases external surface area through external fibrillation which in turn increases the fibre water retention.

Figure 5 indicates the WRV of each tested sample with each undergoing 5 repetitions of testing. It can be seen that fibre samples treated with long-chain triglycerides would render to have smaller WRV percentages in comparison with the short-chain vegetable oil equivalent. The general trend shows that, after applied with vegetable oils, the treated samples has a slightly higher WRV compared to the modified samples. Relatively, the strength of the hydrophobic interactions is dependable on the number of carbons present. Long-chain triglycerides contains more carbons molecules which helped to induce stronger hydrophobic interactions with the fibres, treated and modified. This is evident where the treated and modified samples treated with soybean oil show an average WRV of 9.2% and 8.1%, respectively, whereas the samples coated with coconut oil (containing short-chain triglycerides) display an average WRV of 31.8% and 24.1%, respectively. The WRV of the treated samples are summarized in Table 2.

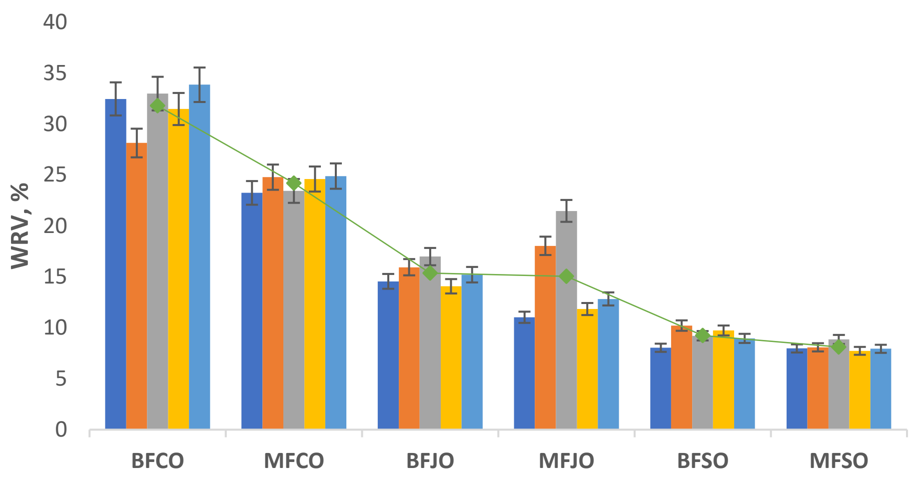

Figure 5. Water Retention Value of Samples with Distilled Water as Swelling Solution.

Table 2. Water Retention Value of Samples with Distilled Water as Swelling Solution.

WRV (%)	A	B	C	D	E	Average
BFCO	32.44	28.11	32.96	31.45	33.83	31.76
MFCO	23.22	24.76	23.42	24.58	24.87	24.17
BFJO	14.54	15.93	16.97	14.06	15.20	15.34
MFJO	11.02	18.03	21.46	11.83	12.82	15.03
BFSO	8.03	10.21	9.21	9.72	8.95	9.23
MFSO	7.98	8.08	8.85	7.73	7.93	8.11

3.4.
3.5. HUMIDITY CONTENT TEST

The oven-dry method, a gravimetric test, was implemented to determine the humidity content that is able to be absorb by each respective sample prepared. It should be noted that oven-dried moisture content is what most meters are trying to estimate, indicating that the oven-dry test is a useful tool in verifying the readings as well as to understanding the absorbency of each sample with moisture. The sample were treated to a conditioned environment of relative humidity 70% to introduce moisture to the samples. The vapour moisture would seep into the fibres through the fibre pores. The test is to investigate on the breathability of the material where surface modification should not cause any changes to occur on the fibre pores.

Following the oven-dry test, the moisture content of each sample was measured indicating that there are no major deviations as all samples indicated a relatively similar percentage. The soybean coating of samples, treated and modified, does have a slightly lower moisture content value of 151.79% in comparison with the other two vegetable oils. All vegetable oils do not disturb the inner workings of the fibre which is ideal. There remains the breathability of the fibre samples.

Figure 6 expresses the reaction of each sample with exposure to moisture for 5 repetitions. The trend of this test indicated that the moisture absorbency is levelled from one sample to another. This indicated that although the surface has been modified, the fibres are still able to absorb moisture through their fibrous pores. The humidity content values are tabulated in Table 3.

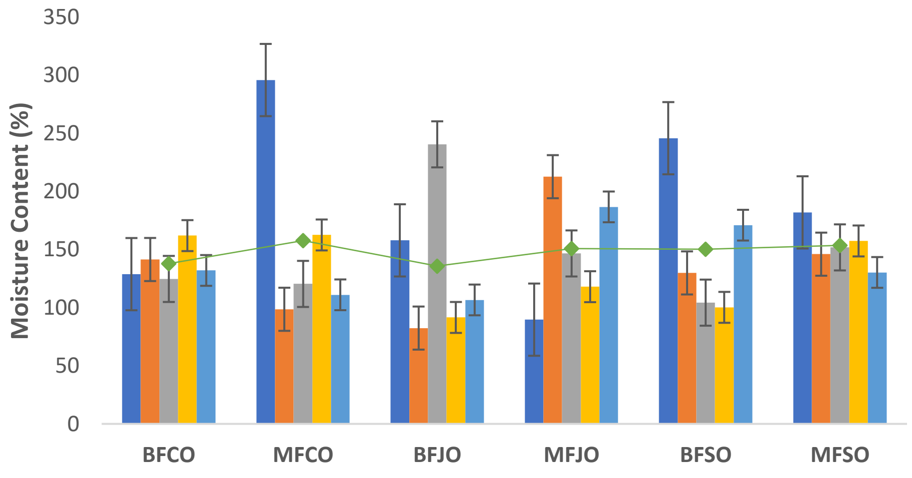

Figure 6. Humidity Content Value of Samples with Distilled Water as Swelling Solution.

Table 3. Humidity Content Value of Samples with Distilled Water as Swelling Solution.

HC (%)	A	B	C	D	E	Average
BFCO	128.76	141.35	124.64	161.90	131.95	137.72
MFCO	295.70	98.56	120.37	162.47	110.99	157.62
BFJO	157.80	82.38	240.38	91.53	106.58	135.74
MFJO	89.63	212.57	146.57	117.97	186.61	150.67
BFSO	245.66	129.82	104.26	100.20	70.88	150.16
MFSO	181.87	145.93	151.76	157.31	130.23	153.42

3.6. WETTING CONTACT ANGLE

With the usage of an optical tensiometer, the surface of each sample was tested by introducing water droplets. The shape of the surface droplets is highly dependable on the interaction among the solvent and interacted surface. Hydrophobic surfaces are generally indicated to obtain a WCA of more than 90°. Water interacts more strongly with itself than with any hydrophobic surfaces, which would render the higher WCA when interacted with the following surfaces. The WCA of the treated fibre without of any oil application was determined to be 17°. This will set as the benchmark for the further testing of WCA.

Table 4 shows the summarized WCA obtained from the optical tensiometer as testing was conducted for 3 repetitions. With the surface modification of vegetable oils increased the WCA of each respective fibre sample. Samples applied with coconut oil in ethanol mixtures shows promising results in the increase in WCA. All vegetable oils show an increase of WCA from 17° with soybean oil being with the highest WCA. Therefore, triglycerides from vegetable oils were used for their potential in forming bonded structures on the surfaces of the cellulose via crosslinking reactions.

Table 4. Wetting Contact Angle of Samples with Distilled Water as Swelling Solution.

WCA (°)	A	B	C	Average
BFCO	44.6	47.3	48.4	46.8
MFCO	47.9	48.9	45.1	47.3
BFJO	56.2	53.1	60.8	56.7
MFJO	58.8	57.4	57.1	57.8
BFSO	71.8	71.5	72.0	71.8
MFSO	73.4	71.4	72.5	72.4

4. CONCLUSION

Surface modification of OPEFB has been proven to be a green approach in producing hydrophobic and superhydrophobic materials for coating applications. Triglycerides of vegetable oils from coconut, *jatropha curcas*, and soybean oils has been investigated for their ability in rendering the fibres hydrophobic. The oils were delivered in homogenous solutions in ethanol with concentration of 20% (v/v). Followed by heating of 105 °C for 60 mins showed to be the most optimal condition in rendering the most hydrophobic OPEFB fibres. The application of soybean oil rendered to being the most hydrophobic properties to the tested samples in comparison to the other 2 oils. This study showed that the analysis of long-chain triglycerides solution achieves a superior increase in hydrophobicity in comparison to the other vegetable oils used. Modified cellulose with the application of soybean oil produces the highest wetting contact angle of 72.4° with the lowest water retention value of 8.11%. Indicating that the soybean oil was able to develop the material with the most hydrophobic properties.

All vegetable oils display a promise of increasing the hydrophobic properties of materials. The more hydrophobic surfaces were achieved with triglycerides that contains the higher unsaturated fatty acyl chains. This supports the role of inducing crosslinking reactions among the long acyl chains which enhanced the coverage with covalent bonded network. The homogenous application of oil on cellulose shows promises for the generation of further green chemistry and bio-based techniques in achieving cellulose with hydrophobic and water-repellent properties as green additives for coating of buildings.

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IDENTIFICATION OF BARRIERS AND CHALLENGES FACED BY CONTRACTORS IN ENERGY EFFICIENT BUILDING FOR AFFORDABLE HIGH-RISE HOUSING IN MALAYSIA TOWARDS GREEN SUSTAINABLE CONSTRUCTION IN MALAYSIA

Ainarull Assikin Abdul Hadi[1], Tuti Haryati Jasimin[1], Syuhaida Ismail[2], and Nur Izzati AbRani[3]

[1]Razak Faculty of Technology and Informatics, Universiti Teknologi Malaysia, Kuala Lumpur, Jalan Sultan Yahya Petra, Kuala Lumpur 54100, Malaysia.
[2]Director of Research, Maritime Institute of Malaysia, B-06-08, Megan Avenue II, Jalan Yap Kwan Seng, 50450 Kuala Lumpur.
[3] School of Civil Engineering, College of Engineering, Universiti Teknologi Mara, Shah Alam Selangor, 40450 Malaysia.
ainahadii@gmail.com

Abstract

Compared to other countries, Malaysia trails behind in the implementation of energy efficient building which is also the green sustainable constructions for affordable high-rise housing projects. The government has taken proactive steps to encourage contractors to adopt the energy efficient building development initiatives, including investment tax credits, free training, and income tax exemptions for the use of eco-friendly construction materials. The objective of these initiatives is to improve the livability of communities through urban transformation. However, despite these government initiatives, contractors continue to encounter significant obstacles when implementing energy efficient building especially in the affordable high-rise housing sector. This paper seeks to identify and investigate the barriers and challenges contractors face when implementing energy efficient building for affordable high-rise housing in Malaysia. Through a comprehensive literature review, this paper sheds light on the current state of affairs. Time, cost, and quality can be used to broadly categorise the identified obstacles and challenges. The high cost of energy efficient building materials, the limited tax exemptions, the scarcity of qualified workers, and regulatory issues are key obstacles. This paper proposes various strategies and approaches to promote the concept of green sustainable construction in Malaysia, in accordance with United Nations Sustainable Development Goal (SDG) 11: Sustainable Ci ties and Communities and the overarching objective of fostering a greener environment.

Keywords: energy efficient building, contractors, barriers and challenges, green sustainable construction,affordable high-rise housing.

1. Introduction

In this context, affordable high-rise housing projects offer a special opportunity as well as a difficulty. The increasing number of people living in urban areas is driving up demand for affordable housing, which is why high-rise buildings that can house many people in constrained metropolitan areas are being built. If these structures are planned and built with energy efficiency in mind, they can make a major contribution to the country's efforts to reduce carbon emissions and support sustainable urban growth. Most people think that fulfilling the Sustainable Development Goals (SDGs) outlined in Agendas 11 and 15 depends in large part on the building sector. Both developed and developing economies have made significant progress towards these objectives. Despite the industry's commitment to these objectives, numerous obstacles continue to impede the advancement of environmental sustainability in building projects [1]. Research has also shown that energy poverty has a detrimental effect on the energy efficiency of the building sector [2]. As stated earlier, an area's ability to transition to a more efficient and sustainable framework for energy use will be hindered if there is a higher degree of energy poverty in that area. As a result, this barrier will cause the construction industry's energy efficiency to decline [3,4]

Energy-efficient practises have been slow to catch on in affordable high-rise housing projects, even with the government of Malaysia actively promoting green, sustainable construction and its obvious advantages. A number of obstacles prevent contractors, who are essential to the realisation of these projects, from easily incorporating energy-efficient practises and technologies into their building operations. Improving building energy efficiency is one of the major challenges—an area that is shockingly underemphasized. Despite having a significant impact on both financial costs and environmental concerns, buildings have not gotten the attention they merit. The building industry is responsible for a significant quarter of the world's energy consumption and greenhouse gas emissions [5]. Recent study underlined the significance of researching building occupants' attitudes and behaviours about energy efficiency in order to create a more effective energy management system for Malaysian buildings [6]. A coordinated and careful strategy is therefore desperately needed to increase the energy consumption efficiency of the building infrastructure. Moreover, have noted that construction operations use enormous amounts of resources and produce a significant amount of waste [7,8,9,10,11,12,13,14]. Making the switch to more ecologically friendly building techniques and materials is essential to reducing these environmental issues [15,16]. This change is good for business since it gives building companies an opportunity to use creative, eco-friendly methods while also helping the environment.

The management of contractors is a crucial obstacle to attaining sustainability in the construction sector, alongside energy efficiency. Despite being comparatively less studied, this topic is crucial. Contractors are important participants in building projects and are essential to the adoption of energy-saving techniques. But Malaysian contractors still have a lot of obstacles and difficulties when it comes to putting energy-efficient building practises into practise, especially when it comes to the affordable high-rise housing market. Construction projects may have delays, higher expenses, and lower quality as a result of these challenges. It is vital to comprehend these obstacles in order to create efficacious tactics and regulations that can promote the extensive implementation of energy-efficient constructions. This study aims to determine and explore the obstacles and difficulties contractors have when putting energy-efficient building practises into practise for affordable high-rise housing developments in Malaysia. Through a thorough literature analysis, the study intends to shed light on these difficulties and offer useful insights for policy formulation and practise. It also hopes to add to the discourse on sustainable urban development.

2. Materials and Methods

This study exclusively employed a literature review approach to explore the challenges faced by contractors in implementing energy-efficient buildings for affordable high-rise housing in Malaysia. A systematic search of relevant databases and academic platforms was undertaken using targeted keywords. The focus was on peer-reviewed articles, reports, and case studies from the last decade. After extracting critical information, a thematic analysis was performed to discern recurring themes, categorizing challenges into areas of time, cost, and quality. This comprehensive review not only synthesized the current state of affairs but also informed the study's conclusions and recommendations, providing a detailed insight into the complexities of green sustainable construction in the Malaysian context.

3. Enhancing Building Energy Efficiency For Sustainability

In the construction industry, energy-efficient buildings are painstakingly constructed to use less energy while improving sustainability, performance, and comfort. The aforementioned structures utilise a range of techniques, including but not limited to efficient insulation, sophisticated window design, energy-efficient HVAC systems, integration of renewable energy sources, adherence to passive design principles, intelligent technology application, water efficiency measures, and the utilisation of sustainable materials. Photovoltaic systems have a number of benefits, including lower energy expenses, a smaller environmental impact, better indoor comfort, and a rise in property value [17]. Furthermore, by drastically lowering greenhouse gas emissions associated with energy use, energy-efficient buildings are essential in the fight against climate change[18].

In order to solve the world's environmental problems, energy-efficient building construction—both new green building construction and retrofitting of existing structures—is essential. While there is no guarantee that this approach will lead to fast utility cost savings or energy self-sufficiency, it is an important area of concentration in the worldwide effort to adapt to climate change. Enhancing building energy efficiency involves more than just turning off lights and adjusting thermostats; it involves using less resources to accomplish more effective goals. Significant advancements in energy efficiency are anticipated during the next ten years, enabling millions more people to live and work in more pleasant and environmentally friendly settings.Due to its waste production, pollution emissions, natural resource consumption, and deforestation, the construction industry has a significant negative influence on the environment. Throughout a structure's existence, energy is required in the production of building components like steel, cement, and bricks as well as during construction, continuing activities, and final demolition. The manufacture of materials, the burning of fuel inside structures, and the creation of electricity—the main energy source for contemporary building operations—all result in CO_2 emissions that worsen the environmental effect [19].

Contemporary home design and construction issues have the ability to impact future generations' environmental circumstances and global energy usage in addition to immediate operational costs. Contrary to popular assumption, a number of chances for energy reductions can be realised at little or no cost, according to substantial industry talks and research. This can be accomplished by operators and tenants managing buildings with diligence and developers designing buildings with care. This strategy encourages firms to pursue increased building energy efficiency by offering them financial incentives that are both attractive and in line with environmental aims. By making optimal use of resources like energy, water, and materials, sustainable development aims to lessen the negative consequences that buildings have on the environment and human health throughout the course of their lives. However, low- and middle-class populations might not be able to purchase sustainable housing. Urban and long-term economic growth may be impacted by insufficient efforts to increase housing affordability and sustainability [20].

In order to attain increased energy efficiency, constructors should prioritise the use of high-efficiency materials and systems along with intelligent design ideas. Building managers and residents also contribute significantly by making energy management a top priority. Furthermore, an increasing tendency in construction projects is to use cost evaluation throughout a building's life cycle to guide decision-making for all parties involved. These practises, which prioritise energy efficiency and long-term sustainability, have the power to revolutionise how we design, develop, and operate buildings in order to address the pressing issues of the modern era.

4. Contractor Challenges

The construction industry plays a pivotal role in the economic and social advancement of nations. It encompasses all stakeholders involved in planning, development, production, design, construction, alteration, and maintenance of the built environment, including energy-efficient building practices. This inclusive spectrum includes manufacturers, suppliers of construction materials, clients, contractors, consultants, and end users of facilities. Nevertheless, the industry has wielded a substantial influence on the environment, and this impact extends to energy-efficient building construction. Historically, the industry's approach has been grounded in the belief that innovations and investments spur economic growth while meeting consumers' needs and desires. However, it is imperative to acknowledge that the industry's products and processes exact a profound toll on the environment.

Construction activities, including those related to energy-efficient building design and construction, heavily rely on natural resources, various forms of energy, and water. According to the Worldwatch Institute, the construction of buildings alone consumes a staggering 40 percent of the world's annual raw stone, gravel, and sand, as well as 25 percent of virgin wood. Additionally, buildings account for 40 percent of global energy consumption and 16 percent of annual water usage worldwide. The detrimental consequences of these practices are unmistakable. The extraction, transportation, and manufacturing of raw materials have frequently led to resource depletion and the loss of biological diversity, affecting both fauna and flora [21] Energy consumption, even within energy-efficient building projects, results in emissions that contribute to global warming and acid rain. Moreover, construction-related waste often contaminates air and water, posing serious health and safety hazards. Furthermore, construction activities can disrupt comfort and compromise overall health conditions. In = of these concerns, the construction industry, including energy-efficient building initiatives, must take proactive measures to mitigate its environmental impact.

Although they confront a number of obstacles that prevent the adoption of sustainable practises, contractors are essential to the advancement of energy-efficient construction practises. Sustainable growth requires the use of energy-efficient building techniques, especially when it comes to Malaysia's low-cost high-rise housing projects. However, when attempting to implement these practises, contractors frequently run across a number of obstacles and difficulties. Lack of awareness and information about the newest materials, technology, and construction techniques for energy-efficient buildings is one of the most frequent barriers. This ignorance may cause them to pass up chances to successfully integrate sustainability into their efforts.

Since the initial expenses of energy-efficient technology and materials frequently exceed their long-term advantages, financial limitations become a significant barrier. The adoption of energy-efficient construction techniques might be impeded by cost concerns, particularly for smaller enterprises with constrained resources. Additionally, there is often a skills gap in the construction industry because energy-efficient building often requires specialised training and abilities that not all contractors have. Contractors face extra challenges due to regulatory complications, such as differing energy efficiency norms and standards, which need them to manage complex compliance procedures. In addition to opposition to straying from conventional construction procedures, client needs and expectations can also impede the adoption of energy-efficient practises. Issues with the supply chain, like more expensive and scarce sustainable building materials, can negatively affect project budgets and schedules. Furthermore, there are obstacles due to technology restrictions, particularly when integrating renewable energy systems. These obstacles are made worse by the lack of explicit incentives and the increased difficulty of putting energy-efficient ideas into practise.

The results highlight how these obstacles are related to one another and how they affect the more general objectives of sustainable building. To overcome these obstacles, government organisations, business organisations, academic institutions, and other interested parties must work together to give contractors support, incentives, and training. Legislators may want to take into account certain financing sources and incentives in order to lessen the financial strain on contractors. To increase knowledge and competence, industry players should give priority to capacity building programmes. Regulatory agencies have the power to expedite and streamline the energy-efficient feature approval process. To foster innovation and tackle supply chain issues, cooperation among developers, suppliers, and researchers is advised. In order to encourage ecologically conscious and sustainable building practises going forward, it is imperative that these issues be resolved. The significance of tackling obstacles unique to cheap housing is emphasised, considering its pertinence to Malaysia's urban development path. Contractors may effectively embrace and execute energy-efficient construction practises by putting tactics like financial incentives, industry-wide training and education programmes, streamlined regulatory processes, and increased stakeholder collaboration into practise.

4. Discussion

Since construction is a major source of energy consumption and greenhouse gas emissions, there is an urgent need to reduce the environmental effects of the industry. This has led to a global change in the building sector towards sustainable practises and energy efficiency. This study explores the difficulties faced by Malaysian contractors, a nation that is at a turning point in implementing energy-efficient building practises, particularly for reasonably priced high-rise housing.

Global Framework and Local Significance: The need for energy-efficient buildings has increased globally due to the demands of sustainable development and climate change. Due to its rapid urbanisation and the resulting need for reasonably priced high-rise housing, Malaysia is a unique case study. However, Malaysia falls behind in adopting energy-efficient practises despite the urgency on a global and local level.

Government Projects and Ongoing Issues: To encourage green building, the Malaysian government has aggressively implemented policies including tax breaks and free training. On the ground, there are significant obstacles to these measures' implementation, nevertheless. As essential participants in the creation of energy-efficient buildings, contractors face a variety of challenges, from lack of funding to limitations in technology and expertise.

Affordable High-Rise Housing as an Opportunity: There are two advantages and one disadvantage to affordable high-rise housing. Even though it serves the growing urban population, making sure these buildings are energy-efficient can have a big impact on efforts to reduce carbon emissions. The report emphasises how the building industry can help achieve the Sustainable Development Goals (SDGs), especially Agendas 11 and 15.

Energy Efficiency Obstacles: The study finds a number of obstacles preventing the development of energy-efficient building practises. These consist of lack of awareness, initial costs, energy poverty, and technology limitations. According to research, regions experiencing greater levels of energy poverty are less likely to make the switch to sustainable and efficient energy consumption, which may have an impact on the building industry's overall energy efficiency.

Contractors' Role: Although they confront many obstacles, contractors are essential to the implementation of energy-efficient practises. Regulatory complexity, supply chain problems, lack of knowledge about sustainable materials and technology, and budgetary constraints are a few of these. These difficulties may cause building projects to be delayed, cost more, and have worse quality standards.

Requirement for a Coordinated Approach: The study highlights the necessity of a coordinated strategy to improve building infrastructure's energy consumption efficiency. It highlights the possibility for implementing ecologically friendly building practises as well as the substantial amount of resources used in construction activities.

Contractor Management: In the building industry, managing contractors becomes essential to attaining sustainability. Even though it's a less studied topic, adopting energy-saving solutions depends on a grasp of the difficulties contractors confront.

The study intends to shed light on these issues and add to the conversation on sustainable urban development through a survey of the literature. The results of the thematic analysis shed light on the difficulties associated with green building in Malaysia by highlighting recurrent themes pertaining to time, money, and quality. To summarise, the conversation highlights the pressing necessity of tackling the obstacles encountered by contractors when including energy-efficient measures into reasonably priced high-rise residential developments in Malaysia. To address these obstacles and speed the shift to sustainable construction, the report recommends a multifaceted strategy that includes stakeholder participation, reduced legislation, financial incentives, and capacity building.

4. Conclusion

To sum up, the shift to sustainable and energy-efficient building practises is not only necessary for the environment, but it also presents a huge chance for innovation and economic growth. In this transformation, Malaysia, like many other countries, finds itself at a crossroads. The government has taken proactive steps and acknowledged the need for cheap, energy-efficient high-rise housing; yet, the implementation of these practises is still sluggish and full with obstacles.
Contractors are essential to the implementation of energy-efficient construction techniques, but they confront numerous challenges, including limited funding, a lack of knowledge, and technological restrictions. A multifaceted strategy including financial incentives, capacity-building initiatives, streamlined laws, and encouraging cooperation across all stakeholders is needed to address these issues.

The aforementioned study emphasises the necessity of a methodical and coordinated endeavour to enable contractors to embrace and execute energy-efficient methodologies in their projects. Through this action, Malaysia has the potential to make noteworthy progress in accomplishing the Sustainable Development Goals and promoting a sustainable urban future. The academic community, industry stakeholders, and politicians must work together to remove these obstacles and enable the widespread adoption of energy-efficient construction techniques. In the end, increasing building energy efficiency involves more than just cutting energy use—it also entails promoting resilient urban areas, sustainable development, and better living standards. Through a comprehensive comprehension and resolution of the obstacles encountered by contractors, Malaysia may guarantee that its construction sector serves as a catalyst for economic expansion and an exemplar of ecological sustainability.

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Green-IoT: The Environmental Game-Changer for Energy Efficient Building

Abstract

Worldwide one clear trend is urbanization. By 2050, it is predicted that city population will make up two thirds of the world's growing population. There will be more demand for and pressure on a variety of resources around the world such as water, energy, transportation and sewerage management. Internet of Things (IoT) technology is playing an important role and becoming increasingly adaptable. It connects consumers and smart devices to interactive real-time networks through diverse industries such as smart building, smart healthcare, smart cities, and so on. Furthermore, it is predicted that the number of intelligent electronic devices will soon outnumber the total number of humans in the world. However, we must not disregard the reality that IoT devices use energy, contribute to harmful pollution, and produce electrical waste. These devices mostly are operated using batteries. The more frequently batteries need to be replaced, the more batteries end up in landfills. These have accelerated difficulties relating to environmental sustainability and challenges to utilise resources more responsibly and organise operations in ways that minimise waste. This paper studies the development of green technologies such as green RFID and green Wireless Sensor Networks that are making IoT more intuitive and user-friendly. Furthermore, the paper also explores the source of energy losses in IoT nodes and the life cycle of green internet of things. In conclusion, the study has also identified some of the emerging challenges that need to be addressed in the future to enable the development of a sustainable and environmentally friendly IoT.

Keywords: Internet of Things (IoT), green Internet of Things, radio-frequency identification (RFID), wireless sensor networks (WSN), cloud computing

1. INTRODUCTION.

The IoT has been used to define a paradigm of any and all possible devices or things that can be connected and communicated to the Internet for data transfer and collection, knowledge formation and automation. As per a projection by the U.S. National Intelligence Council (NIC) in 2008, it was anticipated that by 2020, internet sensors would find their way into virtually everything, including items like food packaging, animals, vehicles, plants, forests, and furniture. This prediction envisioned a scenario where there would be 25 billion devices interconnected with the Internet, equivalent to an average of 3.47 connected devices for every person, within the global population of 7.3 billion by 2015. (Netw, 2012)

Furthermore, it was projected that approximately 50 billion connected devices would be in use globally by the year 2020, equating to an average of 6.41 connected devices for each person within a world population of 7.8 billion in 2020. Another study indicated that the count of smart objects is expected to rise to 80 billion by 2025, with an average of 9.8 connected devices for each person. (Moore, 2020). In addition, current battery technologies of devices is another major concern which leads to a green technology.

The advent of the Internet of Things (IoT) has brought forth several environmental challenges, notably including a rise in electronic waste (e-waste), heightened energy consumption, and increased CO2 emissions as the most prominent among them. It is imperative to address and efficiently manage the risks and difficulties posed by IoT. These challenges primarily involve the escalation in energy consumption, the generation of electronic waste, the emission of greenhouse gases, especially CO2, the utilization of non-biodegradable materials in IoT devices, and the dependence on non-renewable natural resources. This circumstance has emphasized the importance of embracing Green Internet of Things (Green-IoT), which represents a forthcoming technological advancement within IoT closely linked to eco-friendly technology and sustainable economics. Neglecting the eco-friendly aspect of IoT could lead to insatiable energy demands that cannot be met.

The man objectives of this paper is to give an overview of Green-IoT and the obstacles arising from the extensive deployment of energy-intensive IoT devices. Subsequently, detail study of strategies aimed at reducing energy consumption in IoT. For the remaining part of this paper, Section 2 highlight the overview of IoT and utilization of IoT introduces in Section 2.1. A concise overview of green IoT provided in Section 3.0. Various sources of energy wastage and different solutions have been mentioned in Section 4.0. The challenges and issue are discussed in Section 5.0 and the paper is concluded in Section 6.0.

2. INTERNET OF THINGS

The internet of things (IoT) brings together various emerging and enabling technologies and is changing drastically what can be achieved from the Internet. Kevin Ashton was the first to introduce the term "Internet of Things" as the title of his PowerPoint presentation. Kevin conceived the notion of employing "RFID (Radio Frequency Identification)" chips on consumer products to automatically monitor stock levels in warehouses. Subsequently, the Internet of Things (IoT) emerged as a groundbreaking concept, connecting billions of IoT devices and transforming the world. (Shancang Li, 2014; Shancang Li, 2014)

Over the past decade, the Internet of Things (IoT) has emerged as a captivating technology. It enables connectivity between individuals and objects, regardless of location, time, communication channel, or service provider. IoT serves as a foundation for the seamless interconnection of sensors and devices within smart environments, aiming to deliver sophisticated and intelligent services for the benefit of humanity.

The IoT applications normally take the form of one of the following connections such as in Fig. 1

a) Peer-to-Peer (P2P) connection" refers to the exchange or sharing of data directly between users. This includes activities like making telephone calls, engaging in video calls, and participating in social interactions. This type of connection is commonly referred to as a collaborative link. (Stallings, 2015)

b) Machine to People (M2P) connection" involves the transmission of data from devices like sensor nodes, smart gadgets, computing devices, or similar sources to users for analysis purposes. For example, in weather forecasting, smart sensors collect data from their sensing environments and then transmit it to a remote control center for in-depth analysis. (Gheth, Adebisi, Ijaz, Farhan, & Harris, 2019)

c) Machine to Machine (M2M) connection" refers to the exchange of data between devices without any human involvement. For instance, it involves one car connecting and communicating with another car regarding various aspects like lane changes, traffic congestion, accidents, distance between vehicles, speed, braking intentions, and more. (Thota & Kim, 2016)

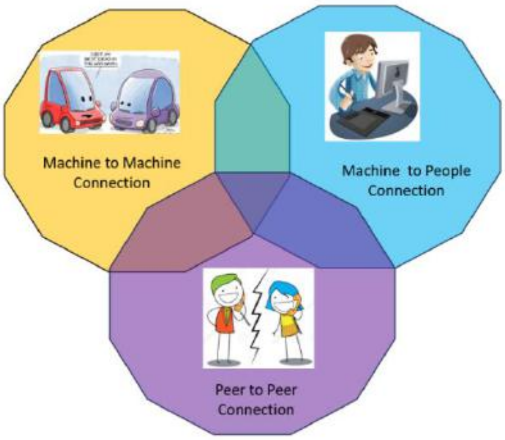

Fig. 1. IoT Connection Network

Generally, an IoT system contains three layers: (1) a perception layer that observes external environments, (2) a network layer that transforms and processes the observed environmental data, and (3) an application layer that provides extensive context-orientated intelligence services. (Abujubbeh, 2019) The three layers of IoT architecture is shown in Fig. 2

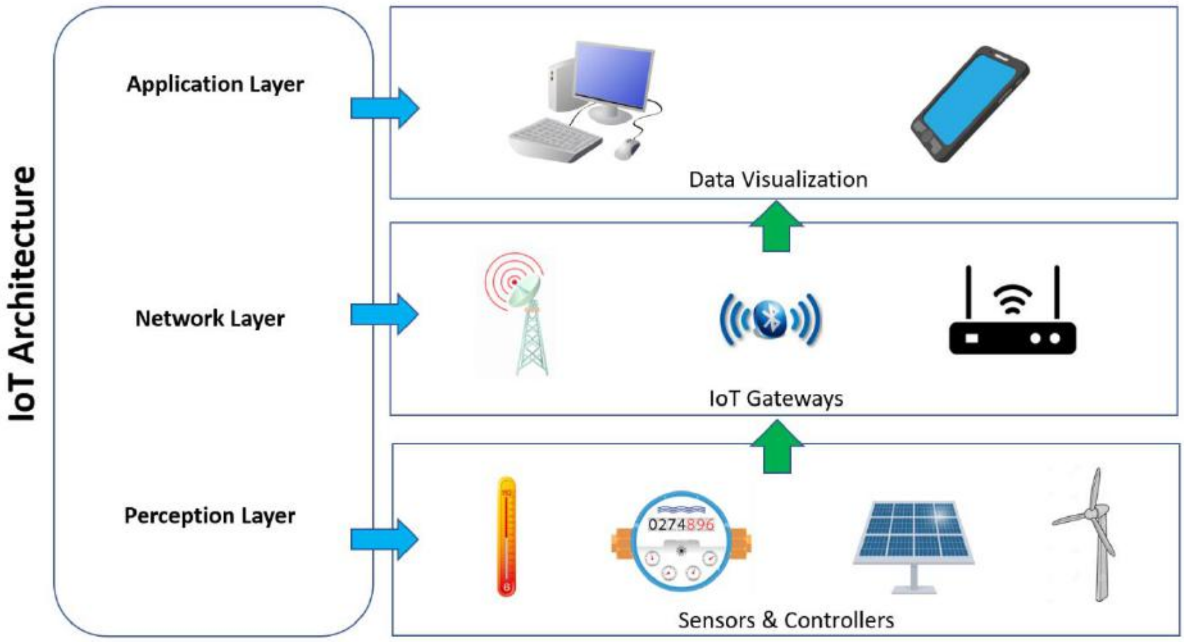

Fig. 2. The three layers of IoT architecture

IoT technology has recently attained substantial development in smart buildings. By incorporating IoT smart devices into smart buildings, dynamic environmental information can be measured and assessed to improve building efficiency (Ejaz, 2017). With IoT technologies, other devices could also be digitally manipulated and managed, such as smart grids and smart meters or smart plugs, to assess electricity consumption (Depuru, 2011).

Since 2010, cloud computing and IoT have efficiently outlined the intelligent management of energy distribution and consumption. Although the IoT nodes typically involved in such processes denote sensing, processing, and networking capacities, the required resources remain limited. Thus, computing activities could be adequately derived from the cloud for complex and comprehensive decision-making. For example, edge computing is a computational paradigm involving data processing at the network edge (Olaniyan, 2018). Moreover, edge computing and deep learning have proven useful in addressing issues on response time prerequisites, bandwidth cost savings, and computational load balancing (Wang, 2020).

For instance, within the realm of transportation, the utilization of a global positioning system (GPS) prevents individuals from getting stuck in traffic by consistently transmitting their current location to a server, which in turn suggests the most efficient route. In the field of e-healthcare, an audio sensor affixed to a person's smartphone can autonomously detect voice irregularities and transmit this data to a server. The server then correlates these abnormalities with a database of voice samples to determine if the person is potentially suffering from an illness.

All IoT nodes consumes power and it’s important to make them environment friendly as they consume energy though very small but when they will be in billion then huge amount of energy will be required.

2.1 Utilization of IoT

IoT is transforming our daily activities by monitoring various scenarios and making intelligent decisions to enhance our quality of life and safeguard the environment. There exists a multitude of IoT applications in our everyday lives. We explore several of them below;

- Smart Homes: By integrating IoT technologies such as RFIDs into our homes or offices, we can monitor the activities of occupants within the building and make informed decisions that not only conserve energy and money but also benefit the environment. For instance, a smart refrigerator equipped with RFIDs on each item inside can help us determine when to go shopping and what items are needed, based on the information provided by the sensors attached to those items
- Smart Agriculture: In agricultural practices, the utilization of contemporary tools and technology is essential to enhance crop production and quality. Smart agriculture entails optimizing input utilization, including water, pesticides, and fertilizers, as well as efficiently

managing pre- and post-harvest operations while monitoring environmental effects. Several effective methods, such as advanced irrigation systems and intelligent subterranean sensors along with smart insect detection, have been developed to automate tasks in smart agriculture. These same approaches can be extended to forest monitoring, with a primary emphasis on forest fire surveillance, as fires frequently lead to substantial environmental damage.

- Smart Underwater Sensor Networks: Underwater sensor networks (UWSNs) find applications in oceanographic data collection, pollution monitoring, offshore exploration, disaster prevention, assisted navigation, and tactical surveillance. UWSNs are comprised of a dynamic array of sensors deployed beneath the water's surface, working collectively to execute tasks through the use of acoustic signals.
- Smart Buildings: The endeavor to create smarter buildings primarily centers on minimizing energy usage by reimagining building functions like air conditioning, heating, and lighting. Building automation has the potential to lower the annual operational expenses of buildings, contributing to a more environmentally friendly setting.
- Smart Street Lights: Typically, streetlight monitoring operates by controlling the streetlights at the transformer station level. Traditional street lighting systems remain illuminated until the morning hours (and sometimes even longer), relying on human intervention to switch them off. In regions with limited nighttime pedestrian activity, streetlights often remain lit unnecessarily throughout the night, leading to substantial energy wastage. The adoption of energy-efficient Wireless Sensor Networks (WSNs) monitoring systems offers a viable solution to these issues, leading to substantial energy conservation.
- Smart Cities: One of the most exciting and burgeoning applications of IoT is the concept of Smart Cities, which has garnered significant attention in recent years. A smart city encompasses various intelligent domains, including Smart Transportation, Smart Energy Conservation Mechanisms, Smart Security, and more, all of which offer users the latest technological amenities within a unified framework

Experts anticipate the arrival of the fifth generation (5G) of wireless communications in 2020, with the capability to handle approximately 1000 times more mobile data compared to current cellular systems (M. Albreem, 2015). 5G is poised to become a cornerstone of IoT technology, facilitating connectivity between both stationary and mobile devices and playing a pivotal role in a new era of industrial and economic transformation. These elements are united to reshape our future through the interconnection of everything. Nevertheless, numerous emerging challenges are on the horizon when it comes to designing IoT-based systems that can seamlessly integrate with 5G wireless communications

(M. Palattella, 2016). Security stands out as one of the foremost challenges encountered by IoT within the realm of 5G.

3.0 GREEN INTERNET OF THINGS

Green Internet of Things (Green-IoT) can be described as the implementation of energy-efficient practices within IoT, aimed at either mitigating the greenhouse gas emissions generated by existing applications and services or minimizing the environmental footprint of IoT itself. The complete life cycle of Green-IoT should prioritize eco-friendly design, sustainable production, environmentally conscious usage, and ultimately, responsible disposal/recycling, in order to minimize or eliminate its impact on the environment (Murugesan, 2008). Refer to Fig. 3.

Green-IoT primarily consists of two key areas of emphasis. The first aspect pertains to the creation of IoT computing devices (hardware), example of green devices which minimizes the amount of heat produced from electronic devices and communication protocols (software) that prioritize energy optimization. The second aspect is dedicated to utilizing Green-IoT technologies as a means to mitigate the emission rates of greenhouse gases, radiation, and pollution. (Mohammed H. Alsharif, 2013).

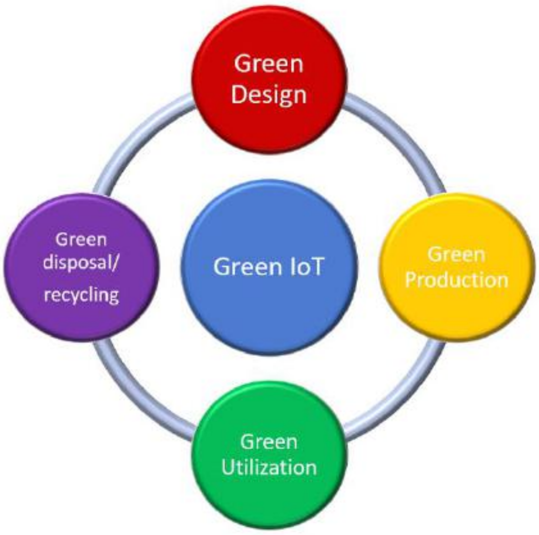

Fig. 3. Life cycle of green-IoT

The primary objective of Green-IoT is to diminish the CO2 emission rates and waste production, promote environmental preservation, and address the significant expenses associated with operating equipment and power consumption. Lowering the energy consumption of IoT devices is essential to foster a healthier and more environmentally sustainable world. To establish an energy efficient building, Green-IoT systems should prioritize energy efficiency as a means to decrease greenhouse gas emissions and carbon dioxide (CO2) emissions from sensors, devices, applications, and services.

IoT is poised to significantly transform how we address everyday challenges, offering the promise of enhanced convenience and improved quality of life. However, along with these benefits come formidable challenges, notably the substantial energy consumption associated with IoT. The sooner we address this issue, the more effectively we can enhance the efficiency of IoT.

3.2 Green-IoT Technologies

In the pursuit of Green-IoT, it's essential to incorporate various sustainable technologies like environmentally-friendly RFID tags, eco-conscious sensing WSN, and environmentally responsible cloud computing networks. Radio Frequency Identification (RFID) is a compact electronic system comprising multiple RFID tags and a tiny tag reader. These RFID tags can store data related to the items they are associated with. Typically, RFID systems have a transmission range of a few meters. There are two categories of RFID tags known as active tags and passive tags. Active tags are equipped with batteries that enable them to consistently transmit their own signals, whereas passive tags do not possess their own batteries. Instead of an onboard battery, passive tags rely on harvesting energy from the reader's signal (Shaikh, 2017). For example, scavenge ambient energy from Wi-Fi, cellular networks, satellite broadcast stations, and radio masts.

Furthermore, a green wireless sensor network (G-WSN) stands as a pivotal technology in facilitating environmentally responsible Green-IoT. A wireless sensor network (WSN) comprises a vast array of sensor nodes characterized by limited power and storage capabilities. To realize a G-WSN, various approaches and strategies has been taken into account to minimise energy usage at the IoT node, as depicted in Table 1.

Table 1: Research approach minimizing energy at IoT node

Reference	Service domains	Objectives	Energy type	Purpose of prediction
Mocnej et al.,	Smart building	Edge computing improved battery life of constrained devices	Battery energy	To increase battery life
Kaur and Sood	Healthcare	Predict and control sleep sensors battery level	Battery energy	To increase battery life
Desai and Nene	Smart building	Proposed self-organizing algorithm	Battery energy	To increase battery life
Yao and Muqing	Access Point	Harvest renewable energy to power IoT nodes	Solar energy	Lossless transfer in IoT nodes
Chu and Liao et al.	Smart building	Increase network life time using renewable energy source	Battery energy	User equipment battery state
Chu and Li et al.	Smart building	Solve user access control and battery prediction problems in a multi-user EH based communication system.	Battery energy	Access control an minimise battery prediction loss
Ashraf et al.,	Smart cities	Regulate transmission to guide battery energy level	Battery energy	Access control an minimise battery prediction loss
Zou et al.,	Smart building	Predict harvest renewable energy	Battery energy	Minimise usage of battery energy

Wireless sensor networks (WSN) are an essential element in IoT deployment. Fig. 4 presents a comprehensive classification of methods for harvesting energy in WSNs from various environmental sources. Nonetheless, exploring alternative energy storage mediums rather than relying solely on batteries has the potential to enhance energy efficiency. Therefore, there is a need for thorough research in this domain.

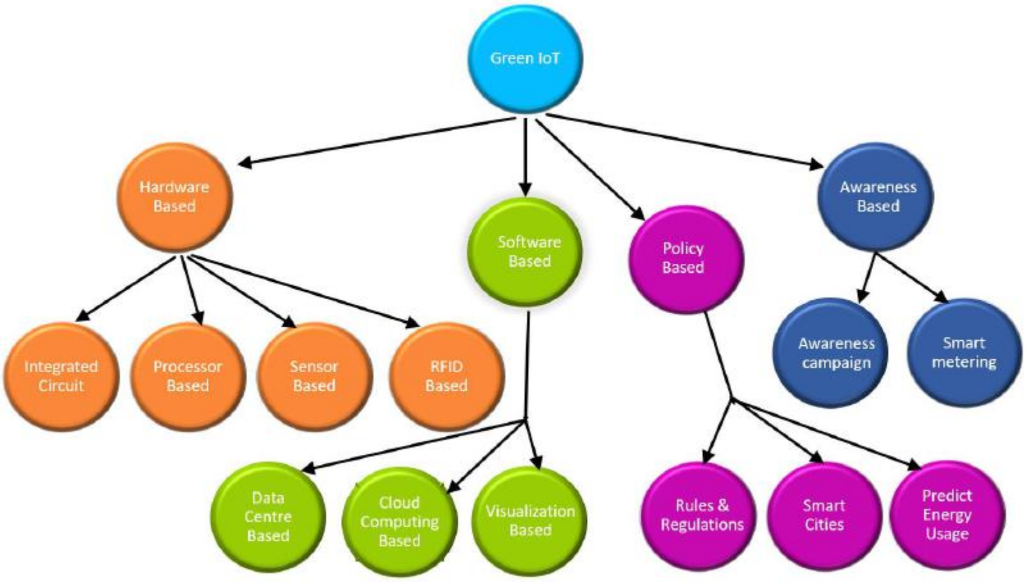

Fig. 4. Taxonomy of green IoT techniques

3.21 Software based

Various data centres hold the potential to support an energy-efficient IoT. Nevertheless, it is imperative to deliberate energy efficiency specifically within the context of these data centres to render them practical. Sensors tend to consume excessive and unneeded energy during idle periods, yet they can be powered on and off as needed. To curtail this avoidable energy expenditure, as suggested by the energy-efficient scheduling algorithm (S. F. Abedin, 2015). This changes the states of sensors to on-duty, pre-off-duty and off-duty according to the requirements in order to prevent unnecessary energy usage. Various algorithms have been developed with the aim of reducing energy consumption and optimizing resource utilization in both Wireless Sensor Networks (WSN) and the Internet of Things (IoT). The software solutions offer efficient designs that consume less energy by minimum utilization of the resources.

3.22 Hardware based

The importance of energy conservation in an IoT network is underscored by the crucial role played by the design of an Integrated Circuit (IC). The introduction of Green Sensors on Chip (SoC) (D. Boll et al., 2013) has revolutionized and improved IoT network design significantly, as it integrates sensors and processing power onto a single chip. This integration serves to minimize network traffic, reduce electronic waste, decrease the carbon footprint, and lower overall energy consumption in the architecture or infrastructure. This will yield a remarkable outcome in terms of conserving energy within the IoT. As a result, network traffic and communication overheads are significantly minimized, leading to a reduction in overall energy consumption.

3.23 Policy based

Real-time data from IoT serves as the foundation for crafting specific policies aimed at achieving the desired energy efficiency levels. The process of developing these policies involves several stages, including monitoring, soliciting user feedback, and offering various services. To illustrate, data can be gathered from different areas within a building, where occupant behavior and energy consumption differ. These policies then inform the creation of tailored strategies for optimizing energy usage in different sections of the same building.

3.24 Awareness based

A crucial element in curbing energy consumption is the implementation of various awareness campaigns. One approach involves employing smart meters to provide homeowners with real-time feedback on their energy usage. Similarly, in office and workplace settings, distributing brochures serves as a means to raise awareness among all individuals, helping them comprehend the factors contributing to energy consumption. As cited in reference (Torriti, 2013), these efforts not only enhance understanding but also contribute to energy conservation

4.0 SOURCE OF ENERGY LOSSES

Numerous investigations have indicated that the communication component consumes a significant amount of energy (Chang & Shen, 2016). In wireless sensor networks (WSNs), a substantial portion of energy is expended during data processing, reception, or transmission to meet application demands (Khriji, et al., 2018). It is evident that minimizing data transmissions can lead to energy conservation in these intelligent devices (Minet, 2009). Concerning communication, multiple research studies have identified that a significant quantity of energy is expended in manners that do not contribute meaningfully to the application such as;

4.1 Overhearing

Which occurs when a node unnecessarily receives packets not intended for it, represents a notable energy inefficiency, particularly in scenarios with high node density and heavy traffic. When a node transmits a packet, all sensor nodes within its transmission range receive the packet, even if they are not the intended recipients. Refer to Figure 5 for a visual representation. Node A intends to transmit its data to Node B, but numerous neighboring nodes fall within the radio range of Node A. As a result, all these nodes will receive the data sent by Node A. Energy is expended when a sensor node sends or receives data that are actually destined for other nodes (Pal & Nasipuri, 2017). It's important to note that Node A will also receive data from its neighboring nodes when they transmit their own data.

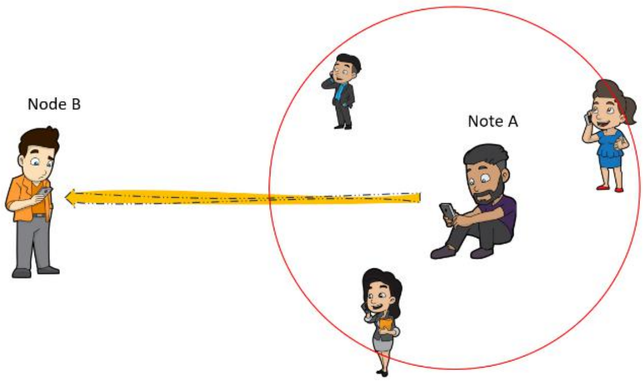

Fig 5. A source node sends data to its intended destination, and neighboring nodes inadvertently intercept the communication

4.2 Idle listening

Occurs when a sensor node must remain active on an idle communication channel, awaiting potential traffic. Consequently, in a densely populated sensor network, nodes often remain active for extended periods. This is primarily a result of overhearing transmissions, the discovery of neighboring nodes, or the utilization of multiple paths to transmit data to neighboring nodes. It's evident that nodes with less idle listening time exhibit superior energy efficiency compared to others (Margolies, Grebla, Chen, Rubenstein, & Zussman, 2016).

Sensors tend to consume excessive and unwarranted energy while in an idle state, yet they can be activated. Therefore, to mitigate the needless energy consumption, as suggested by the energy-efficient scheduling algorithm (Swan, 2012). This results in the sensors transitioning to active, pre-inactive, and inactive states in accordance with specific needs, aiming to prevent unnecessary energy usage.

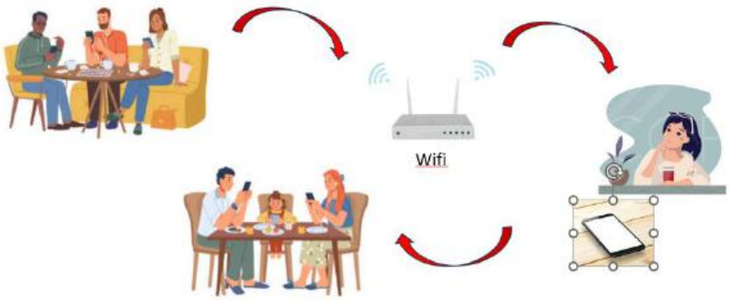

Fig 6. Idle communication channel

4.3 Redundant Data

Nodes are typically deployed in a random manner, leading to certain regions being monitored simultaneously by two or more sensors. Nonetheless, such deployment patterns contribute to the reporting of redundant data within the network. Consequently, energy is squandered on tasks like data aggregation, processing, and transmission. To mitigate energy consumption, it's advisable to prevent unnecessary node operation (Shabna, Jamshid, & Manoj Kumar, 2014).

Advancement in mobile applications can address the need for higher data rates, but increased data rates result in higher energy consumption per bit, given a certain bit error rate. This subsequently elevates the system's overall energy consumption and contributes to the threat of global warming. Hence, it is imperative to minimize unnecessary data transfers or redundant data to mitigate energy consumption in IoT nodes. Numerous studies have explored feature selection techniques to gather data that align with system requirements. For example, when dealing with temperature sensors in a given area that provide similar temperature readings, rather than collecting and transmitting data from all temperature sensors to the network system, only pertinent information is transmitted, and redundant data is filtered out. This approach effectively reduces energy consumption in IoT nodes.

5.0 CHALLENGES AND PROSPECTS IN GREEN IOT

Green technologies are set to assume a crucial role in facilitating the energy-efficient IoT. Several complex challenges must be tackled, and in the following, summary of these challenges, emphasizing the pivotal areas requiring deeper exploration.

- Both the devices and communication protocols employed should prioritize energy efficiency and minimize power consumption.
- The integration of efficient energy mechanisms, such as wind, solar, vibration, and thermal power sources, holds the potential to make IoT more promising and sustainable.
- Security and privacy are major concerns for IoT deployment. The potential of energy efficient, secure mechanisms, which are still in their infancy, should encourage more research and development in this area.
- It is important to understand how to integrate energy efficiency across the whole IoT architecture. Both the devices and communication protocols should prioritize energy efficiency, and applications must also be designed with energy efficiency in mind to minimize their environmental footprint.
- Creating an energy-efficient IoT infrastructure can be realized by adopting a clean-slate redesign approach. Nevertheless, given the intricacies involved in implementing a fundamentally new infrastructure, or even gradually adapting an existing one, this research domain has received relatively less attention and warrants further investigation.

6.0 CONCLUSION

This paper explored into the realm of Green-IoT technologies. It discusses the motivations driving the adoption of green-IoT, outlines the challenges it presents, and highlights its potential benefits. Additionally, the paper has identified a list of IoT applications and green-IoT life cycle, examining the essential technologies needed to realize a sustainable green-IoT system. The role of IoT in 5G networks and its implications for smart cities are also presented within the paper's scope. Furthermore, the paper offers insights into future research directions and addresses the challenges that lie ahead in this domain.

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WHY ARE GREEN BUILDING AS ENERGY EFFICIENT BUILDING IS A MUST? REVIEWING INDONESIA'S RESPONSE

Ngakan Ketut Acwin Dwijendra[1*], Kadek Diana Harmayani[2], I Dewa Gede Agung Diasana Putra[3], Ida Bagus Putu Adnyana[4], Desak Ayu Krystina Winastri K[5]

[12345] Faculty of Engineering, Udayana University, Badung, Bali, 80361, Indonesia
*Corresponding: acwin@unud.ac.id

Abstract

Climate change is a problem that must be addressed immediately because of its harmful effects on living things. WHO estimates that by 2030 to 2050 climate change could trigger approximately 250,000 deaths annually from malnutrition, malaria, diarrhoea, and heat stress. Climate change is caused by global warming that is due to the effect of changing natural conditions, one of the sectors that contribute is the building construction sector. This article discusses why is green building as energy efficient building is a must regarding to climate change and how does Indonesia respond to this concept? The method used is by investigating data and facts that occur, conducting a review of Indonesian policies, and presenting descriptive analysis to draw a conclusion and recommendations. The results of the study show that construction projects significantly contribute to global warming and climate change. About 70 percent of energy use, buildings, and construction account for 39 percent of carbon dioxide emissions. In dealing with this problem, Indonesia made a policy by planning low-carbon development through the application of the green building concept. The study also shows that the implementation of green buildings as energy efficient building in Indonesia is difficulty in implementing. There are many challenges and obstacles in its implementation, starting from the lack of public awareness of the importance of sustainability, to the absence of finance to implement this green building concept. This study recommends that green building is a must. Green building is one of the efforts in overcoming the issue of climate change. This concept is a translation of the concept of sustainable construction which refers to environmentally responsible structures and processes, from the pre-construction stage to the demolition stage. Although the application of the green building concept still has obstacles and challenges in Indonesia, this is a real step in dealing with climate change issues, especially in the building and construction sector.

Keywords: energy efficient building, green building, climate change, sustainability, green construction.

1. Introduction

Climate change and global warming are serious threats to the sustainability of life on Earth. Based on WHO estimates, climate change is expected to cause around 250,000 deaths annually between 2030 and 2050 [1][2]. In facing this problem, green building is important, especially in Indonesia, as a step in reducing the impact of climate change. Through this article, we will explore the contribution of the building construction sector to climate change and how green buildings can be a solution in reducing these adverse impacts.

Climate change is a scourge that continues to haunt the sustainability of life. The impact of climate change is increasingly felt, with the frequency of natural disasters getting higher and global temperatures getting warmer [11]. Indonesia, as an archipelagic country, is very vulnerable to the impacts of climate change, making this country must be proactive in finding solutions.

The building and construction sector is a major contributor to global warming, accounting for 39% of carbon dioxide emissions and 70% of energy use. With the number of buildings constantly increasing, the level of energy consumption and greenhouse gas emissions is also increasing, which contributes directly to climate change.

In the current era of sustainable development, Green Building or green building has become an urgent need throughout the world, including in Indonesia. Green buildings are buildings that are designed, constructed, and operated to reduce negative impacts on the environment and human health. This concept includes energy efficiency, reduction of greenhouse gas emissions, use of sustainable materials, and well-being of building occupants.

Figure 1. Human Activities Responsible for Golbal Warming

Previous studies have shown a link between the construction sector and climate change. According to the Intergovernmental Panel on Climate Change [5][6] the building sector contributes about 39% to CO2 emissions.[3][4] Various literature also mentions the concept of green building and sustainability as part of the solution to reduce greenhouse gas emissions [2][8].

Indonesia, as one of the countries with a high level of urbanization and population, faces significant challenges in responding to the need for environmentally friendly infrastructure and settlements. With rapid economic growth and increasing energy demand, sustainable development solutions such as green building are becoming imperatives to reduce environmental burdens and promote sustainability.

This article discusses (1) why is green building important for Indonesia in the context of energy efficiency and environmental sustainability? and (2) What are the responses and initiatives that have been carried out by Indonesia in implementing the concept of green building? While the objectives of this study are to (1) Analyze the Importance of Green Building, to understand why green buildings are important as energy efficiency and environmental sustainability solutions in Indonesia; (2) evaluate Indonesia's response; and Assess the extent to which Indonesia has responded and implemented the concept of green building, as well as the effectiveness of the response.

Taking into account the background, problem formulation, and objectives, this article is expected to make a significant contribution to the discourse on sustainable development and green building in Indonesia and encourage further implementation of these concepts.

2. Research Methods

The method used in this study is to collect the latest data and facts, review Indonesian government policies, and apply descriptive analysis to draw conclusions and recommendations. The focus of this study is to examine the role of green buildings in tackling climate change and the challenges faced by Indonesia in implementing the concept.

3. Results and Discussion

Construction Sector's Contribution to Climate Change

It found that the construction sector has a significant contribution to global warming and climate change, with 39% of CO2 emissions and 70% of energy use. The construction sector plays a crucial role in contributing to global warming. From the process of extracting raw materials, transporting, to operating and demolishing buildings, every stage has an impact on the environment.

Figure 2. Building Consume and Results Towards Global Warming

Here are some aspects where the construction sector contributes to global warming:

1. Energy Use and Carbon Emissions. The construction sector is one of the largest energy consumers, accounting for about 36% of global energy use and 39% of energy-related carbon dioxide emissions [7][9]. These emissions come from the production of building materials, such as cement and steel, which require a lot of energy in their production, as well as from the operation of buildings through the use of energy for heating, cooling, and lighting.
2. Extraction and Use of Natural Resources. The extraction of raw materials for construction, such as sand, gravel, and stone, has significant environmental impacts, damaging ecosystems and reducing biodiversity. The process of processing and producing building materials is also often energy-intensive and produces air and water pollution.
3. Waste Management. Waste from construction sites, including excess material and demolition residue, also contributes to environmental problems. According to the World Bank [14] the construction sector generates more than 2 billion tons of construction waste annually.
4. Land Use Change. Infrastructure and building development often lead to land-use changes, such as deforestation and conversion of agricultural land, that damage ecosystems, reduce carbon stocks, and release carbon dioxide into the atmosphere.
5. Water Use. The construction sector is also a significant consumer of water, and inefficient use of water in construction can add pressure to already limited water sources.
6. Transportation. The transportation of construction materials from the production site to the project site using motor vehicles also produces greenhouse gas emissions.

Meanwhile, there are mitigation efforts to reduce the impact of the construction sector on global warming, such as the development of green buildings, the use of sustainable materials and environmentally friendly construction technologies, efficient energy management, and increased recycling and reduction of construction waste.

Green Buildings: Solutions to Climate Change

Green building or "green building" refers to the concept and practice of designing, construction, operating, maintaining, and demolition of buildings with a sustainable and environmentally friendly approach. The application of green buildings is a must in order to mitigate climate change for the following reasons:

1. Energy Saving. Green buildings are designed to reduce energy use, both through energy efficiency and through the use of renewable energy sources. This decrease in energy consumption has a direct impact on reducing greenhouse gas emissions, which are a major factor in climate change.
2. Sustainable Water Management. Green buildings also implement sustainable water management systems, reduce water use and maximize the use of rainwater and recycled water, thus helping the conservation of water resources.
3. Reduce environmental impact. Through the use of sustainable materials and environmentally friendly construction practices, green buildings can reduce negative impacts on the environment, such as air and water pollution, as well as degradation of land and natural habitats.
4. Occupant Health and Well-being. Green buildings provide a healthier and more comfortable living and working environment for their residents, through the management of indoor air quality, natural lighting, and temperature control, which directly and indirectly supports the well-being of residents.
5. Resilience to Climate Change. Green building design includes increased resilience to the impacts of climate change, such as floods, droughts, and temperature changes, through features such as green roofs, sustainable drainage systems, and the use of materials that are resistant to extreme conditions.

6. Waste and Waste Reduction. The principles of green building design involve the reduction of waste and waste production, as well as the reuse and recycling of materials, which contributes to the reduction of the waste load on the environment.

Green building is recognized as one of the most effective approaches in addressing the challenges of climate change and environmental sustainability. According to the World Green Building Council [15][16][17], green buildings are important because they can reduce or eliminate negative impacts on the climate and environment, such as reduced energy consumption, reduced greenhouse gas emissions, and improved quality of life through the use of sustainable materials and renewable energy technologies.

Figure 3. Green Building Councli Indonesia (GBCI)

Green building is a must because the impact of climate change and environmental degradation has reached a critical stage. In addition, with increasing population density in urban areas, the need for more environmentally friendly and energy-efficient buildings is becoming increasingly urgent [8][12].

Green buildings can be a solution in reducing the impact of climate change. Green buildings are buildings that are designed, constructed, operated, and demolished with an environmental approach, referring to structures and processes that are environmentally responsible. The building aims to reduce energy, water use, and minimize environmental impact.

The study recommends that the implementation of the concept of green building as a concrete step in tackling climate change. This concept emphasizes environmentally friendly structures and processes, from pre-construction to demolition, as part of efforts to mitigate the impacts of climate change.

Indonesia's Response and Policy on Green Building

Indonesia, as one of the countries with a high urban growth rate, has begun to apply the concept of green building in its infrastructure development. Several buildings in big cities such as Jakarta and Surabaya have begun to be designed and built with the principles of sustainability. The aim is to reduce the environmental impact of the energy-intensive building sector and produce significant carbon emissions [13][16].

Indonesia has responded by developing policies that support low-carbon development through the concept of green buildings. However, the implementation of this concept encountered many obstacles such as lack of public awareness about sustainability and financing challenges. Nevertheless, the application of this concept is a proactive step in dealing with climate change.

The Government of Indonesia through the Ministry of Public Works and Public Housing (PUPR) [10] has launched policies and technical guidelines related to the development of green buildings in Indonesia. One of them is through PUPR Minister Regulation No. 02 / PRT / M / 2015 concerning Green Building which aims to realize buildings that are environmentally friendly, efficient in the use of energy, water, and materials, as well as comfortable and healthy for its residents.

Figure 4. Permen No. 21/PRT/M/2021 regading Green Building Performance Assessment

The implementation of green buildings in Indonesia is in line with global efforts to mitigate climate change. However, challenges such as lack of public understanding and awareness, financial constraints, and regulatory barriers make the implementation of this concept still need to be pushed further. Proactive policies and regulations, fiscal incentives, public education, and multisectoral cooperation will accelerate the implementation of green building in Indonesia.

In an effort to address this issue, the Indonesian government has responded by developing policies that support low-carbon development through the concept of green buildings. This policy encourages the implementation of green buildings in various construction projects both large and small scale in Indonesia. However, the implementation of this policy still faces various obstacles such as lack of public awareness, lack of technical understanding of green buildings, and limited financing [10].

4. Conclusion

The implementation of green buildings in Indonesia still faces obstacles, especially in the aspects of awareness and financing. However, green buildings are an effective solution in reducing greenhouse gas emissions and mitigating climate change, particularly from the building construction sector. Therefore, increasing public awareness and full support from the government in the form of policies and financing are needed to ensure the successful implementation of green buildings in Indonesia.

The implementation of green buildings in Indonesia still faces many challenges, but this implementation is important as an effort to reduce the negative impacts of climate change. Green building can be one of the solutions to maintain the sustainability of the environment and life in Indonesia. Therefore, it is necessary to increase public awareness about the importance of green buildings and also full support from the government in the form of policies and financing to ensure the successful implementation of green buildings.

Some points that can be recommended related to the implementation of green buildings in Indonesia are: (1) Public education about the importance of sustainability and the concept of green building; (2) Development of policies that support the implementation of green buildings; (3) Financing and incentives for property industry players who apply the concept of green building; and (4) Development of research and innovation in green building technology.

In the context of climate change, green buildings are not just an option, but a necessity, as part of a comprehensive solution to reduce greenhouse gas emissions, conserve natural resources, and create a sustainable, healthy, and resilient built environment.

Although green buildings are still in the early stages of development in Indonesia, their sustainability is key in combating climate change, particularly in the construction and building sectors. Initiatives and commitments from all parties, including the government, the community, and industry players are needed to overcome implementation challenges and achieve true environmental and social sustainability.

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Engineering Properties of Sustainable Green Asphalt incorporating Crumb Rubber using Dry Process: Sabah, Malaysia Experience

Nurul Ariqah Ispal[1,2], Lillian Gungat[3], Jeffrey Koh[2], Mohd Ishaq Selamat[4]

1. Young Engineer Section (YES), Institution of Engineers Malaysia (IEM) Sabah Branch, 88100 Kota Kinabalu, Sabah, Malaysia.
2. Astenpave Sdn Bhd, 88400 Kota Kinabalu, Sabah, Malaysia.
3. Civil Engineering Program, Faculty of Engineering, Universiti Malaysia Sabah, 88450 Kota Kinabalu, Sabah, Malaysia.
4. Integrated Asset Planning Branch, Public Work Department, 05582 Kota Setar, Kedah, Malaysia.

Email: nurulariqahispal@gmail.com

Abstract

A substantial rise in waste tyre vehicles is another significant cause of pollution. Improper waste disposal can lead to increased disposal costs, illegal dumping, and environmental damage. Tyre waste in the form of crumbs has been extensively examined internationally in order to help the issue, besides to improve the performance of asphalt pavements that commonly noted having poor performance, and this was found to inspire green technology. In Sabah, it has ample source of sandstone aggregate, that is not used in West Malaysia. Thus, the purpose of this research is to assess the dry process interaction of locally sandstone aggregate with various sources of crumb rubber applied at 0-3% in Stone Mastic Asphalt. The research comprised substantial laboratory work, assessed using the established standard as a baseline for its physical, mechanical, and chemical properties. The results showed the decline in average of stiffness by 30%, creep by 12%, and rutting by 32%, but it improved bitumen drain down by 10%, that is explained by the chemical components of the aggregate with high acidity level that affects the bonding. In general, addition of crumb rubber to a local sandstone aggregate requires additional refinement to maximise the benefits for usage in real industry.

Keywords: asphalt, crumb rubber, dry process, sandstone aggregate, stone mastic asphalt

1. Introduction

Tyres is expected to rise at a compound annual growth rate of 4.4 percent from 2.1 trillion units in 2022 to 2.5 trillion units in 2026 [1]. To address these concerns, several initiatives have been made in waste management systems to develop a market for scrap tyres [2]. As a result, using tyres in civil engineering appears to be more cost-effective and environmentally advantageous, with significant expansion potential [3]. The idea of using ground tyres in asphalt for surface treatment was initially proposed in the mid 1960s, and crumb rubber modified's use as an asphalt modifier in the hot mix asphalt industry grew in the 1970s [4]. Asphalt can be amended in two ways: dry and wet. The dry procedure involves adding crumb rubber to aggregate before adding bitumen, whereas the wet process involves pre-blending bitumen with crumb rubber before adding it to aggregate [5]. However, other researchers are interested in the dry technique because of its capacity to use more crumb rubber in the asphalt mixture [6].

In terms of the quality of the asphalt pavement, the degree of its performance is highly depending on the raw materials used in the mixture [7]. Aggregate is the main constituent of asphalt that may up to 96% of the mixture, and which has the main role to ensure the quality [8]. The physical and mineralogical properties of the aggregate itself primarily are the benefactor of the quality of the asphalt mixture as it affects the adhesion between aggregate and bitumen [9]. In terms of aggregate mineralogy, the presence of minerals such as silicone dioxide (SiO_2) and calcium carbonate ($CaCO_3$) can have a significant influence on the hydrophilic and hydrophobic characteristics of aggregates [10], where high SiO_2 proven to have lower adhesion within the asphalt mixture [10]. Many types of aggregate that can be used for asphalt, including granite, basalt, diorite, sandstone and others [8]. In Sabah, Malaysia, where this study was done, the type of aggregate available for asphalt industry works are dominated by sandstone type of aggregate, as this is the main source available [11].

In general, as the asphalt is mainly composed of aggregate, the aggregate gradation is also a vital to determine the strength of the asphalt to sustain the load. This gradation that made up the mixture can be in different type of gradations, including dense graded, gap graded, and open graded. It is widely known that Stone Mastic Asphalt (SMA) is a popular gap-graded asphalt mixture used across the world. The Germans developed SMA in the 1960s to reduce tire-caused rutting to a minimum [12] Since SMA mixtures often contain a fair amount of bitumen, it is important to stop the bitumen from leaching out. Incorporating fibre or a polymer modifier can satisfy these requirements, but commercial polymer is too expensive to be practical in terms of use [13]. Mashaan (2012) found that using recovered polymer like crumb rubber into asphalt reduced costs and improved environmental outcomes [14]. The gradation of SMA, on the other hand, was introduced to Malaysian road authorities in the 1990s [15]. Malaysia Public Work Department (PWD) has included the SMA design in their standard specification in 2008 and were revised for rubberised SMA in 2019 [16]. In the last 30 years, SMA has become a global mix, so it can be found almost anywhere that mineral-asphalt layers are used. As a result, several studies and initiatives have been launched with the goal of researching the longevity and stability of SMA until today.

However, based on the past research that employed the crumb rubber through dry process in the SMA mixtures, which includes the researches that have been done in Malaysia, the mixtures produced were not made up of the sandstone aggregate. The exploration on the performance incorporating this mixture was not been done thoroughly, which includes the chemical and mechanical analysis on the mixture. There were also limited literatures that can referred to on the basis of the crumb rubber types that performed well in asphalt production. Thus, this study is expected to pertain the query about adopting crumb rubber is suitable for use through dry process method with sandstone aggregate in SMA grading.

2. Methodology

Materials and Sample Preparation. The materials used in this study were sandstone aggregate, bitumen, quarry dust as filler, and crumb rubber (CR) sourced from truck tyres, nylon truck and car passenger. The asphalt gradation followed the Malaysia Standard Specification of Public Work Department (PWD) 2019 crumb rubber stone mastic asphalt (CR-SMA). Sandstone aggregate and quarry dust were supplied by one of Sabah's top blasting quarries, with physical composition specifications as shown in Tables 1. Penetration grade 60/70 bituminous binder was used, with physical qualities as shown in Table 2, and ASTM Mesh 40 (0.425 mm) crumb rubber derived from truck steel (TS), truck nylon (TN) and car passenger (CP) with the properties shown in Table 3.

Table 1. Physical properties of sandstone aggregate

Properties	Standard	Value (%)	ASTM Requirement	PWD Specification
Crushing Value	ASTM D5821	23.47	<25%	<25%
Impact Value	ASTM C125	10.59	-	-
Flakiness Index	ASTM D4791	13.78	<15%	<25%
Elongation Index	ASTM D4791	0.0	-	-
Los Angeles Abrasion	ASTM C131	23.30	<30%	<25%
Water Absorption (Coarse)	ASTM C127	1.35	<3%	<2%
Bulk Specific Gravity (Coarse)	ASTM C127	2.56	-	-
Water Absorption (Fine)	ASTM C128	1.56	<3%	<2%
Bulk Specific Gravity (Fine)	ASTM C128	2.53	-	-
Soundness	ASTM C88	0.94	-	<12%

Table 2. Properties of bitumen

Properties	Standard Specification	Value	Standard Requirement
Softening point	ASTM D 36-06	51	49 – 56
Penetration @ 25°C	ASTM D 5	64	60 – 70
Ductility @ 25°C	ASTM D 113-99	129.5	> 100

Table 3. Crumb rubber properties

Content	Composition (%)		
	Truck steel	Truck nylon	Car passenger
Fibre content	0.01	0.01	0
Moisture content	0	0	0
Mineral contaminants	0.01	0.01	0.01
Metal contaminants	Non-metal	Non-metal	Non-metal

During mixing, all aggregates and crumb rubber were well covered with bitumen, and no grey surface of aggregate was evident. Crumb rubber from three distinct varieties, namely TS, TN, and CP, was added at 0 - 3% of the total aggregate weight. The percentages of crumb rubber applied in this dry process were based on previous research by Abdul Hassan (2014) [12]. Bitumen was added in the range of 5 - 7% of the total aggregate weight. Sandstone aggregate was utilised in the combination and was warmed at mixing temperature for 3 hours, while bitumen was preheated at mixing temperature. The mixture was mixed at 160°C and compacted at 150°C to use both the premix plant production and site compaction temperature modes, with a 10°C difference indicating temperature loss during the transporting period from the premix plant to the construction site, and these temperatures were also used in the Farouk *et al*., (2017) study [17]. The mixing and compaction temperatures were determined using the local industry approach, which proved to be appropriate for application by utilising the same raw ingredients as in this study. Using the dry process method, crumb rubber was mixed for around 20 seconds with the sandstone aggregate and was assured to be equally dispersed with no clumping when mixing. After attaining the correct consistency, bitumen was added to the mixture and stirred for around 30 seconds. Prior to compaction, the mixture was short-term aged for 2 hours at compaction temperature to show the travel duration from premix facility to construction site. The Marshall technique was used to condense the samples in a 101 mm mould to a height of 64.5 mm, using 75 blows per face using an impact hammer. Following 24 hours, the specimens were extruded from the moulds and tested. In the investigation, three examples of each type of combination were made, and average readings from the tests were collected. During the test, irregular values were removed before averaging, and if two readings were rejected, the combination preparation and testing were redone until the reading was constant.

Experimental Procedure. This study was using Marshall mix design method to identify the optimum bitumen content (OBC). The criteria identified were the Marshall stability, Marshall flow and volumetric properties including voids filled with bitumen (VFB), voids in mineral aggregate (VMA) and voids in mix (VIM) according to the specification as in Table 4. After obtaining the OBC, more samples were prepared for performance test to test the stiffness, creep, rutting and binder drain down, by using resilient modulus test, dynamic creep test, wheel tracking test and binder drain down test. Towards the end, mineralogy properties of the aggregate were identified by conducting few analyses including x-ray fluorescence (XRF) and x-ray diffraction (XRD) to explain the findings.

Table 4. Determination Method of OBC for CR-SMA

Test	Requirement	Determination Method
Stability	Min. 6000 N	Peak of graph
Flow	2.0 – 5.0 mm	Equals to 3.5 mm from graph
Bulk Density	-	Peak of graph
VIM	3 – 6 %	Equals to 4.5% from graph

3. Results & Discussion

Optimum Bitumen Content (OBC). To determine the OBC, samples were tested for it volumetric and strength properties. Table 5 shows the summarised result of adopting different sources of crumb rubber in CR-SMA by using local sandstone aggregate.

Table 5. OBC of CR-SMA

Crumb Rubber	Content (%)	Stability (kN)	Flow (mm)	G_{mb} (Mg/m^3)	VIM (%)	OBC (%)
	0	17.20	3.015	2.256	5.28	5.30
TS	1	12.50	3.185	2.273	6.00	5.80
	2	13.85	3.605	2.261	4.41	5.90
	3	15.60	3.230	2.272	3.95	5.90

TN	1	16.90	3.250	2.277	4.22	5.50
	2	13.40	3.020	2.259	4.88	5.70
	3	13.00	3.410	2.276	3.72	5.70
CP	1	14.90	3.390	2.241	5.92	5.80
	2	13.90	3.370	2.238	5.49	6.00
	3	15.30	3.720	2.200	6.95	6.10

Based on the result in Table 6, the specifications to obtain OBC of CR-SMA in accordance to the Malaysia Standard Specification of PWD 2019 as in Table 4, the requisite Marshall stability, Marshall flow, volumetric analysis and binder drain down analysis is adequate to determine the OBC of CR-SMA. The OBC was found at increases from 0% to 3% of crumb rubber inclusion for all crumb rubber types, after taking the average of the OBC result for every parameter. As the crumb rubber content increases, more bitumen is absorbed, increasing the optimal binder level of the mixture. It was found that CP type of crumb rubber has the highest OBC value as the amount of crumb rubber added increased. Studies in Peninsular Malaysia discovered that the addition of crumb rubber in asphalt improves the Marshall stability and quotient [2][18]. However, this study has come out with the result for all sources of crumb rubbers, where it shows the stability values by differing crumb rubber content in tandem with bitumen content, the value is lower comparably with the control sample without any addition of crumb rubber. One possible factor, the aggregate chemistry has previously been shown to be the most major contributing component in the adhesion phenomena within asphalt-aggregate systems [19]. Though past studies stated that crumb rubber has good adhesion to aggregate surface [2][20][21], and dry process could increase the stiffness [22], the previous researches were using different aggregate sources like granite and basalt with different mineralogy content.

Performance Test. The stiffness of the asphalt mixture was determined using resilience modulus following the standard of ASTM D 4123. Figure 1 demonstrate the resilient modulus (Mr) versus the mixture types reinforced with various crumb rubber types and contents at their OBC. The result indicates the resilient modulus varies significantly between reinforced and non-reinforced materials. From the result, all mixtures with crumb rubber added have a lower resilient modulus value compare with the control mixture without the additional of crumb rubber. The decline in resilient modulus after adding crumb rubber can be attributed to high OBC content and, in particular, the continual air void required. The crumb rubber component absorbs a portion of the bitumen in modified asphalt mixes, resulting in the OBC increasing [23]. As the crumb rubber component increases, more bitumen is absorbed, increasing the mix's OBC. The drop of resilient modulus value for TS-CR, TN-CR and CP-CR has a coefficient of variance of 0.38, 0.23 and 0.34 respectively. The findings may be explained by the fact that the strong matrix was generated by homogeneously virgin SMA and only slight rubber particles in the mixes and that this maintained an adhesion between the bitumen and the aggregate. It is possible to draw the conclusion that the rubber particle had a detrimental impact on the cohesiveness [24]. Apart from the nature of crumb rubber that affects the property of mastic in CR-SMA, this study is also using the sandstone type of aggregate, which is different from most of the previous study. This could be possible due to the sandstone high silicon dioxide, SiO2 content of the aggregate used in this study. With high SiO2 content, aggregate will produce poor adhesion of aggregate-bitumen relation [19].

For quantifying permanent deformation of the asphalt mix, the dynamic creep test was utilised. Figure 2 shows the results of the dynamic creep test for OBC mixes with varying crumb rubber types and contents at 50˚C. It was found that the strain value increased as more crumb rubber increased. This is corresponding to the resilient modulus data, where higher stiffness will result higher permanent strain or deformation, and vice versa. On the basis of the dynamic creep data, it appears that adding more crumb rubber has no improvement on permanent deformation resistance at optimal conditions. The decline in permanent deformation after adding crumb rubber can be attributed to the nature of crumb rubber that affects the property of mastic in CR-SMA that produces poor bonding within the mixture [24]. Other possible factor might be due to the type of raw material using the virgin bitumen with penetration grade of 60/70, as well as the sandstone type of aggregate, which is different from some of the previous study. Undeniably, the mineralogy of aggregate to affect the mixture.

Rutting describes longitudinal depressions in the wheel path. To resemble elevated temperatures and pressures of those seen on the road, the wheel tracking test assesses a mixture's sensitivity to plastic deformation. The rutting of an asphalt mixture is determined by rolling a steel wheel across the surface of a 60°C asphalt [25]. Based on the Malaysia PWD standard specification, for CR-SMA, the maximum rutting shall be at 12.5mm. The rut depth for mixtures with varying CR types and contents at their OBC is displayed in Figure 3, and it indicates increasing the asphalt component of a typical asphalt mixture without crumb rubber enhances cracking resistance but reduces rutting resistance. However, it is correlated with the creep analysis that defining cracking, where the inclusion of crumb rubber increases the creep which influence cracking. Thus, this causes the rutting in this study is developed with the addition of all crumb rubber types.

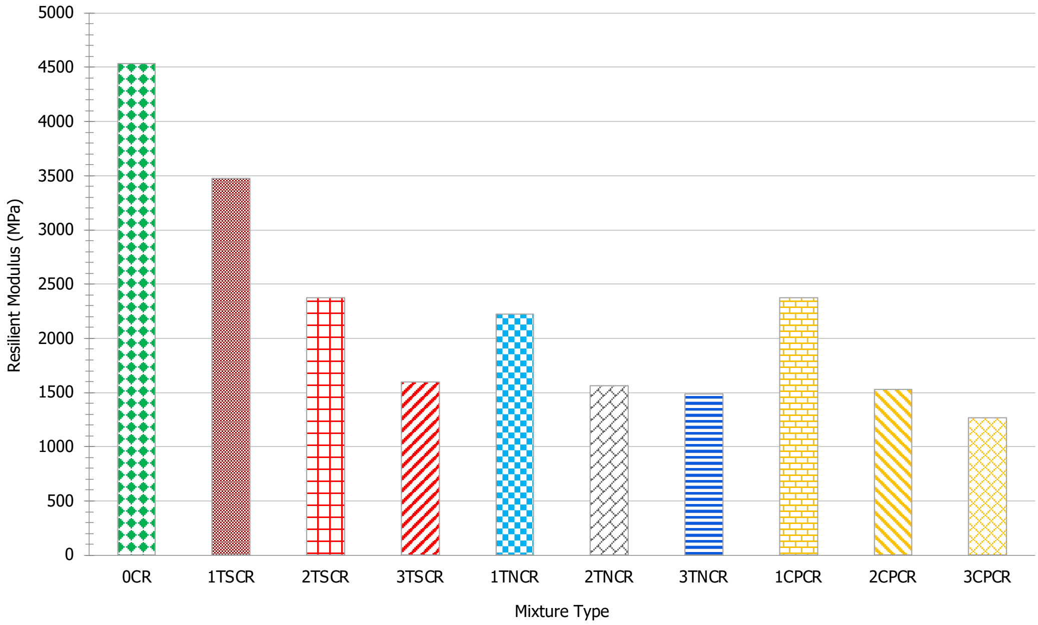

Figure 1. Resilient modulus result

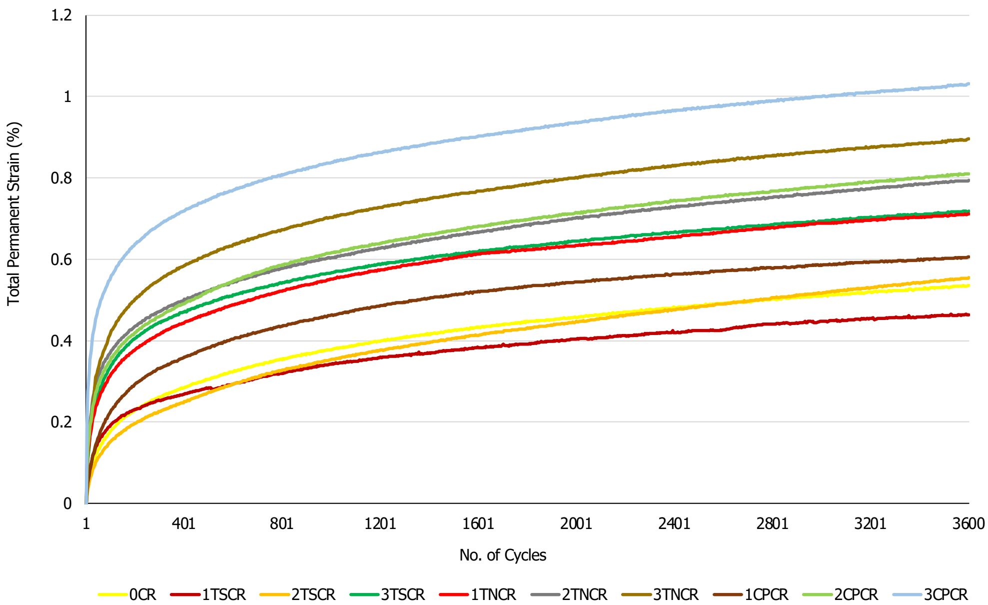

Figure 2. Dynamic creep result

Binder drains down analysis was done to indicates the existence of crumb rubber will enhance the bonding between the binder and aggregates, which is very crucial during production, storage, transport and placement in real site [26]. Figure 4 compares the drain down of TS, TN and CP in asphalt at 1% to the control mix by visual observation, whereas Table 6 shows the drain down value of the mixtures. Based on the visual observation, it shows for all types of crumb rubber, left the paper with lesser stains. Numerically, all types of mixtures pass the standard requirement. This proves the crumb rubber absorbs the component of the bitumen and reducing the draining of bitumen, and concluded that crumb rubber improved the draining properties.

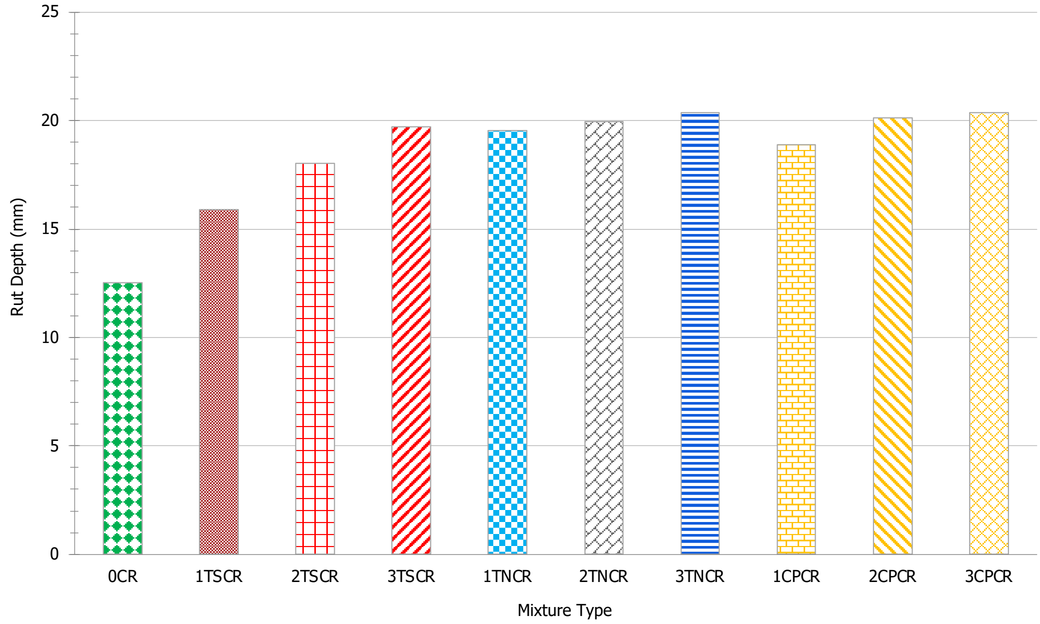

Figure 3. Rut depth of wheel tracking result

(a) 0% CR

(b) 1% of TS CR

(c) 1% of TN CR

(d) 1% of CP CR

Figure 4. Visual observation of drain down test

Table 6. Drain down of CR-SMA

Mixture type	Drain down (%)
0CR	0.014
1TSCR	0.009
2TSCR	0.003
3TSCR	0.013
1TNCR	0.013
2TNCR	0.008
3TNCR	0.018
1CPCR	0.013
2CPCR	0.017
3CPCR	0.016

Mineralogy of Sandstone Aggregate. Throughout the investigation in this study, it was found out the stiffness, creep and rutting reduction in performance were influenced by the aggregate type used in the study. This section includes x-ray fluorescence (XRF) and x-ray diffraction (XRD) analysis to identify the mineralogy of the aggregate. XRF analysis was done to obtain the mineral composition and oxide constituents of the sandstone aggregate used in this study for all types of the mixtures. Table 7 shows the compound exist in the aggregate with the oxide concentration. Based on the result, silicon dioxide (SiO_2) is often used to categorise the aggregate as acidic or basic, where more than 65% concentration is classified as acidic [8]. Quartz can be quantified by SiO_2, Al_2O_3, and TiO_2, whereas alkali can be quantified by potassium and sodium elements. It was mentioned by AboQudais and Al-Shweily (2007) that the chemistry of the aggregate influences the degree of water sensitivity of the bitumen-aggregate connection, and that silica generally reduces bond strength between bitumen and aggregate [27]. In this study, sandstone aggregate has a high SiO_2 concentration, thus it produces lower bonding strength between bitumen and aggregate, and also prone to water damage.

XRD analysis was done for the chemical characterisation of the sandstone aggregate used that proposed to answer the poor performance of the mixture in this study. Figure 5 shows the refined XRD result which the refinement was done using a Rietveld analysis program which is Material Analysis Using Diffraction (MAUD) software to filter the lattice parameters for use in the characterisation of crystalline materials, whereas Figure 6 displays the 3D structure of the main mineral in sandstone aggregate showing the geometry or shape of molecules using XRD. Based on the result, sandstone aggregate is presented to be dominantly with peaks of quartz minerals (SiO_2) and also feldspar group (SiO_2) with peaks of lower intensity. The standard diffraction peaks and the refined diffraction gives the χ^2 value of 1.4, which indicates good agreement, and the main constituents of the sandstone aggregate was found to be SiO2. It was studied by Yin et al. (2017), aggregate with higher SiO_2 does not exhibit strong adhesion property with asphalt, compare to aggregate with higher $CaCO_3$ content [28]. The mineralogy of the aggregates has been shown to influence the durability of asphalt mixtures, where the presence of mica reduces the mechanical resistance of the mixture, while high levels of quartz and alkali feldspars reduce the adhesion between the binder and the aggregate [29][30][31].

Table 7. Chemical properties of sandstone aggregate

Compound	SiO_2	Al_2O_3	MgO	CaO	K_2O	Fe_2O_3	TiO_2	P_2O_5
Conc unit (%)	71.97	12.90	2.66	2.30	4.24	3.62	0.51	0.61

Note: SiO_2 = silicon dioxide, Al_2O_3 = aluminium oxide, MgO = magnesium oxide, CaO = calcium oxide, K_2O = potassium oxide, Fe_2O_3 = iron oxide, TiO_2 = titanium oxide, P_2O_5 = phosphorus pentoxide

The majority of the aggregates used in asphalt mixes were acquired mechanically from natural rocks. When exposed to external stresses, aggregate minerals break along surfaces where the bonding strength between interlayers is insufficient. Researchers in the past discovered that typically exposed surfaces are directly connected to interlayer spacing, bonding characteristics, surface electrical properties, and surface free energy [32][33]. The bonding strength between interlayers and surface free energy tends to diminish as interlayer separation rises, and the mineral surface becomes more exposed in nature. The electron density is equally distributed throughout the Si-O bonds in the quartz crystal, showing that the Si-O links are rather stable covalent bonds [32]. When the bonds are stable, lower possibility for it to form stronger contact with other constituent from different materials, which consequently forming poor adhesion between aggregate and the asphalt. Resilient modulus characterises asphalt's elasticity and evaluates its quality when subjected to axial force over time. This study found out that the resilient modulus decreases as inclusion of crumb rubber increases. Apart from the poor adhesion exhibited by the aggregate and asphalt, utilisation of crumb rubber using dry process would reduce the mixture's cohesiveness. This is due to a lack of contact and adhesion between the bitumen and the crumb rubber [34]. As a result, utilising this approach to apply crumb rubber combined with sandstone aggregate in asphalt mixes results in poor strength against cyclic load and moisture failures.

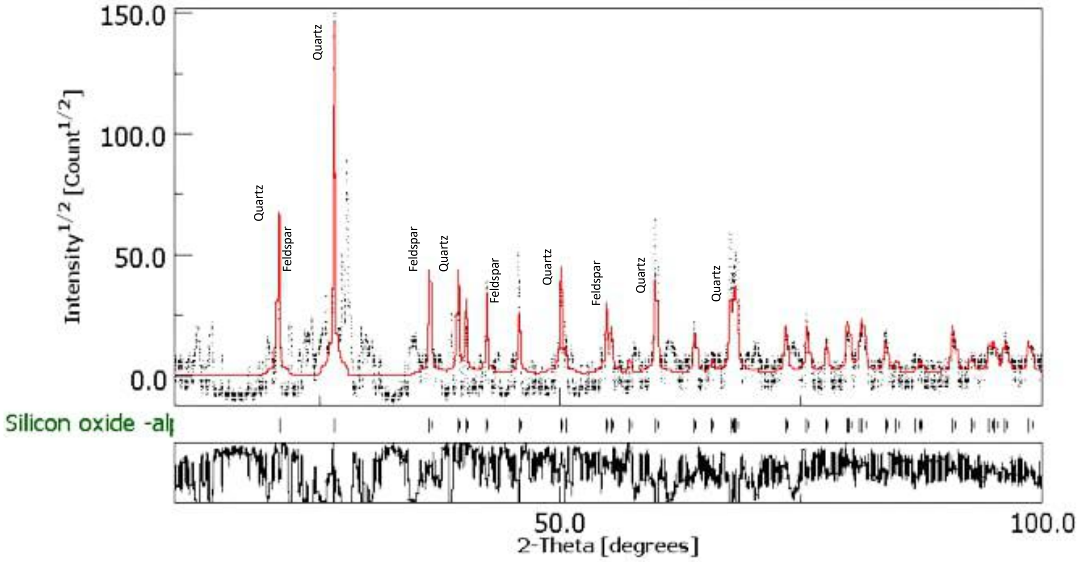

Figure 5. Refined XRD result of sandstone aggregate

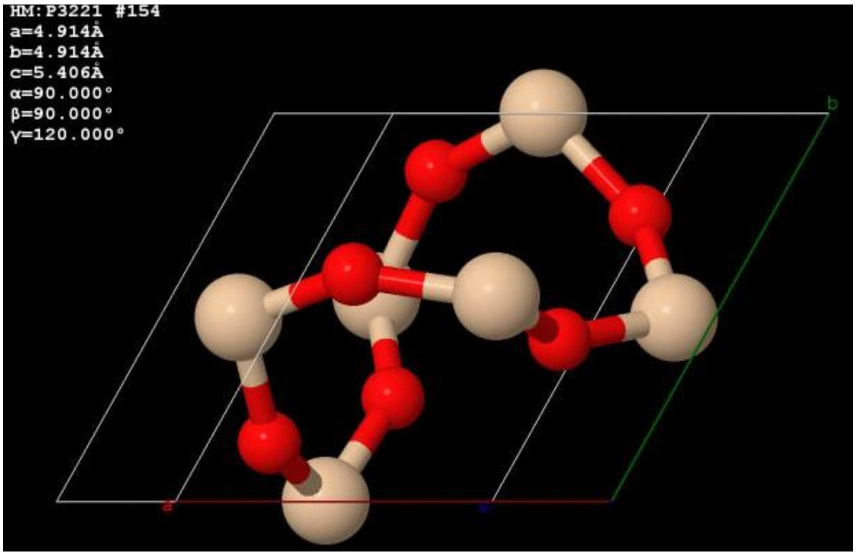

Figure 6. 3D structure of SiO_2 in sandstone aggregate

4. Conclusion

As a conclusion, The OBC of sandstone SMA containing different sources of crumb rubber increases as the crumb rubber content increased. Marshall stability, stiffness, creep and rutting showed decline of results by adding crumb rubber of all types to the SMA mixture with sandstone aggregate. All types of crumb rubber addition also do not improve the life of reinforced samples, except on the binder drain down, where it was found to be improved. When compared to the control mixture, the mechanical performance of modified mixture is most likely influenced by the adhesion produced within the mixture due to the chemical content of the sandstone aggregate and the feature of crumb rubber to absorb the bitumen. Precisely, after the execution of laboratory works and analysis, it can be concluded that the inclusion of crumb rubber in sandstone aggregate asphalt should be further studied.

Acknowledgement
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MARITIME TRANSPORTATION IN THE CITY OF MANADO

Theo Kurniawan Sendow[2], Oktovian B. A. Sompie[1], Lucia I.R. Lefrandt[2], Audie L. E. Rumayar[2]

[1]The Rector Of Sam Ratulangi University, Manado 95115, Indonesia.
[2] Civil Engineering Department, Engineering Faculty, Sam Ratulangi University, Manado 95115, Indonesia.
theosendow@unsrat.ac.id

Abstract

Based on the maritime transportation needs in the city of Manado, it produces a large movement of 1446 people/day, so with a boat capacity of 20 people/boat, and the number of trips per day is 10 trips, the number of boats required is 8 boats. The capacity that can be transported in river transport is measured by the number of vessels available to accommodate movements that may occur, this is something that is sometimes difficult to predict. Determination of the capacity of river transport is different from road transport.

There are special things that determine the capacity of river transport, namely capacity is not only determined by the volume that can be accommodated in one ship but must also pay attention to the ability of water bodies to push the ship to the maximum limit, to avoid the possibility of the ship sinking. In the sense that the capacity of the river is endeavored to be full and press the ship downwards (full and down). In this operation the planned capacity of the ship is 22 people including the crew. The number of people who answered that they really needed a water bus was 10.67%, those who answered that they really needed a water bus were 51.47%. The total who answered that they needed and really needed it was 62.14%, thus in general the people of Manado City answered that they needed this water bus. The number of people who answered that they really needed the Water Bus only for transportation was 10.40%, those who answered for transportation and tourism were 46.47%, those who answered for tourism only were 13.44%. Thus, in general, the people of Manado City are of the opinion that the use of the Air Bus is apparently for transportation and tourism.

Finally, the study of the provision of transportation infrastructure including water buses is essentially related to decisions based on supply and demand for transportation services. There needs to be responsibility and awareness with the people of the city of Manado, especially on the banks of the Tondano river and the coast of Manado Bay in keeping the Tondano river and Manado beach clean so that they are feasible and comfortable to use as a water bus shipping medium.

Keywords: Maritime Transportation, Water Bus, Movement Modeling.

1. Introduction

Based on survey data, it shows that the most dominant distribution of community trips in Manado City is to Wenang sub-district, namely 38.48%, then the second largest is to Wanea sub-district with a percentage of 18.66%, then the third largest is to the sub-district. Malalayang with a percentage of 14.33%, the fourth largest, namely heading to the Sario sub-district of 9.46% of the total movement of households in the city of Manado.

People in the city of Manado have a fairly high level of activity resulting in significant movement every day. This resulted in a concentration of origin of traffic generation at the same time and an imposition on the road lanes leading to activity centers (Kec. Wenang, Sario and Malalayang), so that it can be concluded that the existing public transport vehicles (Mikrolet) are not sufficient to accommodate the movement the people of the city of Manado. There are 17,980.13 movements that have not been carried by city/microbus transportation. This opportunity was captured by the Manado City Water Bus. Based on this background, the research entitled Maritime transportation in the city of Manado aims to provide an assessment/recommendation regarding whether or not maritime transportation development in the city of Manado is feasible.

2. Materials and Methods

with the highest percentage of travel destinations for respondents to carry out activities. Because this sub-district is a Central Business District (CBD), commercial and entertainment center with a total of 870 movements (36.62%).

The second sub-district with the largest percentage of movement destinations is Wanea sub-district with 423 movements (17.80%) and the third largest percentage is Malalayang sub-district with 326 movements (13.72%) that shown in fig. 1.

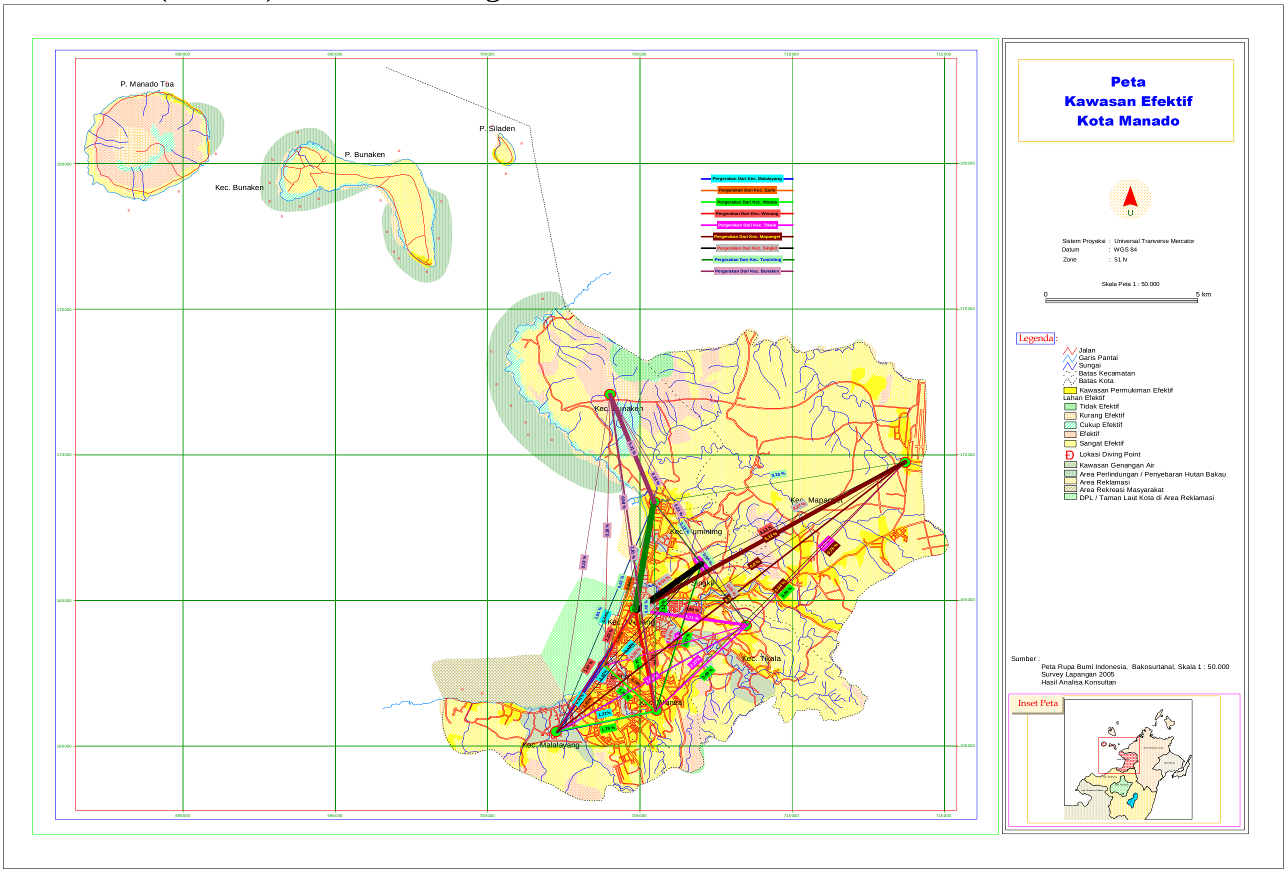

Figure 1. Manado City Desire Line 2023 (with Map).

Table 1. Travel Destination Origin Matrix in Manado City 2023 (in percentage units)

Zon	1	2	3	4	5	6	7	8	9	10	11	12	13	oi
1	4,06%	0,31	1,21%	4,46%	0,63	0,22	0,13	0,04	0,00	0,04	0,00	0,04	0,00	11,16%
2	1,61%	2,10	3,79%	2,99%	0,54	0,00	0,00	0,04	0,04	0,00	0,00	0,00	0,00	11,12%
3	1,79%	1,88	3,97%	2,54%	0,49	0,09	0,27	0,13	0,00	0,00	0,00	0,00	0,00	11,16%
4	1,07%	1,83	3,57%	2,95%	0,94	0,13	0,13	0,54	0,00	0,00	0,00	0,00	0,00	11,16%
5	1,65%	1,16	2,37%	3,71%	1,79	0,22	0,00	0,09	0,04	0,04	0,00	0,09	0,00	11,16%
6	2,32%	0,80	0,94%	6,12%	0,76	0,18	0,00	0,00	0,00	0,04	0,00	0,00	0,00	11,16%
7	0,63%	0,58	0,40%	8,04%	0,04	0,27	1,12	0,63	0,00	0,00	0,00	0,00	0,00	11,70%
8	1,03%	0,63	0,40%	7,10%	0,58	0,18	0,18	1,07	0,00	0,00	0,00	0,04	0,00	11,21%
9	0,18%	0,18	2,01%	0,58%	0,31	0,00	0,18	5,31	1,34	0,04	0,00	0,04	0,00	10,18%
10	0,00%	0,00	0,00%	0,00%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00%
11	0,00%	0,00	0,00%	0,00%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00%
12	0,00%	0,00	0,00%	0,00%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00%
13	0,00%	0,00	0,00%	0,00%	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00%
dd	14,33	9,46	18,66	38,48	6,07	1,29	2,01	7,86	1,43	0,18	0,00	0,22	0,00	100,00

Zone Description : 1 Malalayang, 2 Sario, 3 Wanea, 4 Wenang, 5 Tikala, 6 Mapanget, 7 Singkil, 8 Tuminting, 9 Bunaken, 10 Bitung, Minut, 11 Sitaro, Satal, 12 Tomohon, Tondano, Mitra, 13 Minsel, Kotamobagu, Bolmong, Gorontalo.

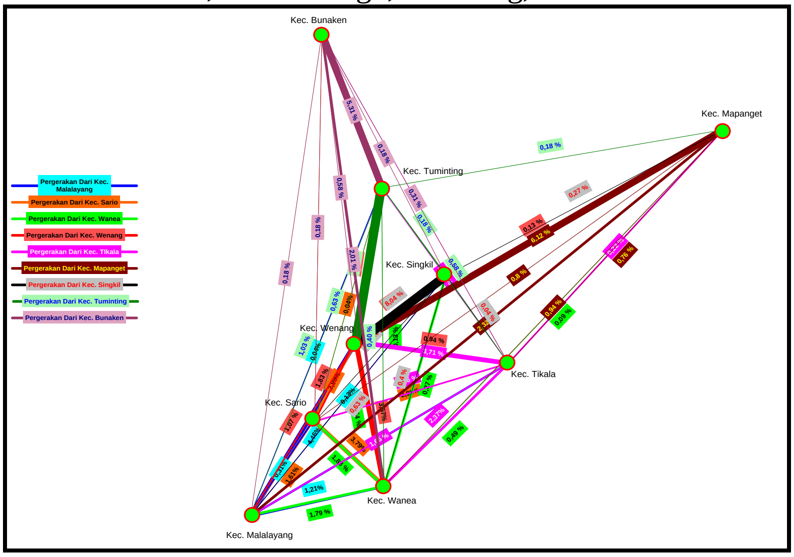

Figure 2. Manado City Desire Line 2023 (without Map).

Figure 2. Water Bus Routes at Manado Beach.

Table 2. Movement Influences the Need for Water Bus Transportation in 2023 - 2043 with i = 8% (Optimistic), Person Movement Unit/Day.

Tahun	1) Pergerakan zona Tikala – zona Singkil (dan sebaliknya)	2) Pergerakan zona Tikala – zona Wenang (dan sebaliknya)	3) Pergerakan zona Singkil – zona Wenang (dan sebaliknya)	1) Pergerakan zona Bunaken – Tuminting (dan sebaliknya)	2) Pergerakan zona Bunaken – Singkil (dan sebaliknya)	3) Pergerakan zona Bunaken – Wenang (dan sebaliknya)	4) Pergerakan zona Bunaken – Sario (dan sebaliknya)	5) Pergerakan zona Bunaken – Malalayang (dan sebaliknya)	6) Pergerakan zona Tuminting – Singkil (dan sebaliknya)	7) Pergerakan zona Tuminting – Wenang (dan sebaliknya)	8) Pergerakan zona Tuminting – Sario (dan sebaliknya)	9) Pergerakan zona Tuminting – Malalayang (dan sebaliknya)	10) Pergerakan zona Singkil – Wenang (dan sebaliknya)	11) Pergerakan zona Singkil – Sario (dan sebaliknya)	12) Pergerakan zona Singkil – Malalayang (dan sebaliknya)	13) Pergerakan zona Wenang – Sario (dan sebaliknya)	14) Pergerakan zona Wenang – Malalayang (dan sebaliknya)	15) Pergerakan zona Sario – Malalayang (dan sebaliknya)
2023	23	667	1446	955	32	104	32	32	113	1277	113	185	1446	104	113	681	802	289
2024	25	720	1561	1031	35	113	35	35	122	1379	122	200	1561	113	122	736	866	313
2025	27	778	1686	1114	38	122	38	38	132	1489	132	216	1686	122	132	795	935	338
2026	29	840	1821	1203	41	131	41	41	143	1608	143	233	1821	131	143	858	1010	365
2027	32	908	1967	1299	44	142	44	44	154	1737	154	252	1967	142	154	927	1091	394
2028	34	980	2124	1403	48	153	48	48	166	1876	166	272	2124	153	166	1001	1178	425
2029	37	1059	2294	1515	51	165	51	51	180	2026	180	294	2294	165	180	1081	1273	459
2030	40	1143	2478	1636	55	179	55	55	194	2188	194	317	2478	179	194	1168	1374	496
2031	43	1235	2676	1767	60	193	60	60	210	2363	210	343	2676	193	210	1261	1484	536
2032	47	1333	2890	1909	65	208	65	65	226	2552	226	370	2890	208	226	1362	1603	579
2033	50	1440	3121	2061	70	225	70	70	245	2756	245	400	3121	225	245	1471	1731	625
2034	55	1555	3371	2226	75	243	75	75	264	2977	264	432	3371	243	264	1589	1870	675
2035	59	1680	3640	2404	81	263	81	81	285	3215	285	466	3640	263	285	1716	2019	729
2036	64	1814	3931	2597	88	284	88	88	308	3472	308	504	3931	284	308	1853	2181	787
2037	69	1959	4246	2804	95	306	95	95	333	3750	333	544	4246	306	333	2002	2355	850
2038	74	2116	4586	3029	103	331	103	103	359	4050	359	587	4586	331	359	2162	2544	918
2039	80	2285	4953	3271	111	357	111	111	388	4374	388	634	4953	357	388	2335	2747	992
2040	86	2468	5349	3533	120	386	120	120	419	4723	419	685	5349	386	419	2521	2967	1071
2041	92	2651	5745	3795	129	415	129	129	450	5072	450	736	5745	415	450	2707	3187	1150
2042	98	2834	6141	4057	138	444	138	138	481	5421	481	787	6141	444	481	2893	3407	1229
2043	104	3017	6537	4319	147	473	147	147	512	5770	512	838	6537	473	512	3079	3627	1308

3. Results and Discussion

For Water Buses on the Manado River Coast, the movements that affect this route are:

1) The movement of the Bunaken – Tuminting zone (and vice versa) is 5.31% and 0%
2) The movement of the Bunaken – Singkil zone (and vice versa) is 0.18% and 0%
3) The movement of the Bunaken – Wenang zone (and vice versa) is 0.58% and 0%
4) The movement of the Bunaken – Sario zone (and vice versa) is 0.18% and 0.04%
5) The movement of the Bunaken – Malalayang zone (and vice versa) is 0.18% and 0%
6) The movement of the Tuminting – Singkil zone (and vice versa) is 0.18% and 0.63%
7) The movement of the Tuminting – Wenang zone (and vice versa) is 7.10% and 0.54%
8) The movement of the Tuminting – Sario zone (and vice versa) is 0.63% and 0.04%
9) The movement of the Tuminting – Malalayang zone (and vice versa) is 1.03% and 0.04%

10) The movement of the Singkil – Wenang zone (and vice versa) is 8.04% and 0.13%
11) The movement of the Singkil – Sario zone (and vice versa) is 0.58% and 0%
12) The movement of the Singkil – Malalayang zone (and vice versa) is 0.63% and 0.13%
13) The movement of the Wenang – Sario zone (and vice versa) is 1.83% and 3.79%
14) The movement of the Wenang – Malalayang zone (and vice versa) is 1.07% and 4.46%
15) The movement of the Sario – Malalayang zone (and vice versa) is 1.61% and 0.31%

Table 3. Sea Stop Locations Based on Zone Division

No	Nama Lokasi	Sta	Jarak	Sta	Jarak	Zona
1	Halte Laut Tongkaina Kec. Bunaken	0		0,00		Bunaken
			4,81		8910,47	
2	Halte Laut Seputaran MDC Kec. Bunaken	4,81		8910,47		Bunaken
			0,8		1481,99	
3	Halte Laut Tuminting Kec. Tuminting	5,61		10392,46		Tuminting
			1,66		3075,13	
4	Halte Laut Kali Mas Pasar Bersehati	7,27		13467,59		Singkil
			0,38		703,95	
5	Halte Laut Marina Plasa	7,65		14171,54		Wenang
			1,14		2111,84	
6	Halte Laut Megamas	8,79		16283,38		Wenang
			1,38		2556,43	
7	Halte Laut Bahu (Kantor Pariwisata)	10,17		18839,81		Sario
			0,83		1537,57	
8	Halte Laut RSU Malalayang (Blkg Akper)	11		20377,38		Malalayang
			1,05		1945,11	
9	Halte Laut Seputaran Terminal Malalayang	12,05		22322,49		Malalayang
			12,05		**22322,49**	

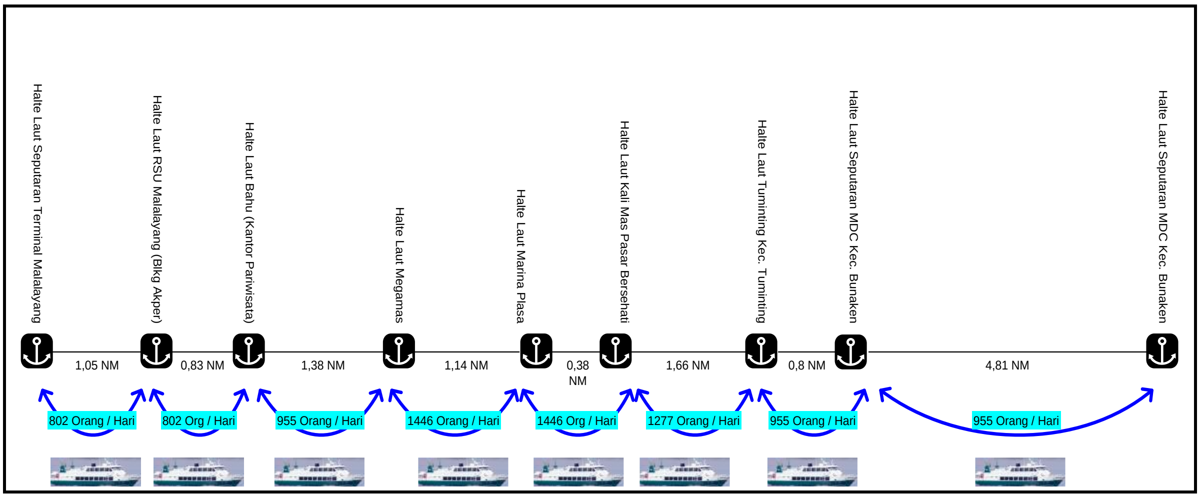

Figure 3. Scheme of Water Bus Transport Routes on Manado City Beach.

Based on the natural and environmental conditions on the Tondano River, what will influence the suitability of the size/type of boat is the condition of the waters along the planned Tondano river crossing, based on the comfort of service users without ignoring the demands of shipping safety and security which are the main prerequisites for providing various types of river and sea transportation. . In this case the considerations are:
1) maximum tidal drift,
2) wind velocity,
3) waves and depth of river water and Manado coastal waters
4) high vertical clearance under the bridge (Especially for the Tondano river)

From the data and analysis that has been collected, the following parameters are obtained:
1) Sailing distance = 4077.36 m for rivers
2) Sailing distance = 12.05 NM for coast
3) Travel time on the river = 60 minutes per trip
4) Travel time to the beach = 60 minutes per trip
5) Tidal Range at the beach = 2.6 m

6) Maximum (Extreme) Wave Height at the beach = 3.0 m (West season)
7) Dominant Wave Period at the beach = 5 seconds
8) Dominant Wave Direction = North, South, West
9) Most wave height = 0.5 m.
10) Pier depth = - 2.0 m
11) Maximum current speed = 0.4 m/sec
12) Dominant current direction = 0 o
13) Dominant wind direction = North, South
14) Most wind speed = 1 – 4 knots.
15) Maximum wind speed (Extreme) = 36 knots.

Based on these parameters, especially the short distance and short travel time, the 20 seat catamaran boat as mentioned above is suitable for operation.

However, please note that sailing activities on the coast and on the Tondano river are temporarily stopped if the waves in the waters reach 1 m, and the Tondano river experiences flooding with the highest water level resulting in vertical clearance under the bridge making it impossible to traverse by catamaran boat.

Table 4. Passenger Ship / Boat Parameters.

	Main Dimension (Lx B x H)	Passenger	Power	Tonnage	Velocity
18,3 m double deck Traffic Boat	18,3 x 3,90 x 1,5 0 m	60	278 x 2	-	38 – 40 kmh
21,8 m traffic boat	21,8 x 5,60 x 2,00 m	96	300 - 900	-	18 – 48 kmh
Jet Express	27 x 8,5 x 1,22 m	149	1100	60 GT	35 mph
Sifka Viking	40 x 10,1 x 1,6 m	168	-	-	-
M/S Holmen	18,9 x 4,55 x 2,05			50 GT	-
Coastal Psg Ship	29 x 6,4 x 1,8 m	130		48 GT	25 mph
Katamaran	8 x 1,5 x 1,5 m	20	-	-	-

Table 5 Types of Sea Stop Piers Based on Water Conditions

No	Nama Lokasi	Kondisi Perairan	Tipe Dermaga/Halte
1	Halte Laut Tongkaina Kec. Bunaken	pantainya landai	Dermaga Jetty, Movable Platform
2	Halte Laut Seputaran MDC Kec. Bunaken	pantainya landai	Dermaga Jetty, Movable Platform
3	Halte Laut Tuminting Kec. Tuminting	pantainya landai	Dermaga Jetty, Movable Platform
4	Halte Laut Kali Mas Pasar Bersehati	pantainya landai	Dermaga Jetty, Movable Platform
5	Halte Laut Marina Plasa	pantainya curam	Movable Platform
6	Halte Laut Megamas	pantainya curam	Movable Platform
7	Halte Laut Bahu (Kantor Pariwisata)	pantainya curam	Movable Platform
8	Halte Laut RSU Malalayang (Blkg Akper)	pantainya landai	Movable Platform
9	Halte Laut Seputaran Terminal Malalayang	pantainya landai	Movable Platform

In determining ship specifications, consider the following things: Ship speed is calculated in units of knots, one knot is defined as one mile per hour. Ship speed can be determined by various factors, namely:

The push force of a body of water

a) The force of the wind
b) Design criteria for the ship itself
c) The water surface affects the smooth running of the ship.
d) Vibration and sound levels can also affect passenger comfort.

The characteristics of the proposed ship can be seen in the table below.

Table 6. Characteristics of the proposed ship.

Uraian	Spesfisikasi
LOA (m)	8 meter
Lebar, B (m)	1,5 meter
Draft (m)	0,5 – 1 meter
Tonnage	1 Ton
Kapasitas Penumpang	20 Seat
Crew	2
Speed	10 Knot
Engine Power	Menyesuaikan

The capacity that can be carried in river transportation is measured by the number of ships available to accommodate possible movements, this is something that is sometimes difficult to predict. Determining the capacity of river transportation is different from road transportation. There are special things that determine river transport capacity, namely capacity is not only determined from the volume that can be accommodated in one ship but must also take into account the ability of the water body to pressurize the ship to the maximum limit, to avoid the possibility of the ship sinking. In other words, efforts are made to ensure that the river capacity is full and presses the ship towards the bottom (full and down). In this operation, the planned capacity of the ship is 22 people including the crew.

Table 7. Water Bus Travel Time at Manado Beach.

No	Nama Lokasi	Sta (Nautical Miles)	Jarak Antara (NM)	Sta (Meter)	Jarak Antara (Meter)	Tracel Time (Jam)	Tracel Time (Menit)	Waktu Load/Unload (Menit)
1	Halte Laut Tongkaina Kec. Bunaken	0		0,00				15
			4,81		8259,32	0,351460481	21,08762885	
2	Halte Laut Seputaran MDC Kec. Bunaken	4,81		8259,32				15
			0,8		1373,69	0,058454966	3,507297938	
3	Halte Laut Tuminting Kec. Tuminting	5,61		9633,01				15
			1,66		2850,41	0,121294054	7,277643221	
4	Halte Laut Kali Mas Seputaran Pasar Bersehati	7,27		12483,42				15
			0,38		652,50	0,027766109	1,66596652	
5	Halte Laut Marina Plasa	7,65		13135,93				15
			1,14		1957,51	0,083298326	4,997899561	
6	Halte Laut Megamas	8,79		15093,44				15
			1,38		2369,62	0,100834816	6,050088943	
7	Halte Laut Bahu (Kantor Pariwisata)	10,17		17463,06				15
			0,83		1425,21	0,060647027	3,63882161	
8	Halte Laut RSU Malalayang (Belakang Akper)	11		18888,26				15
			1,05		1802,97	0,076722142	4,603328543	
9	Halte Laut Seputaran Terminal Malalayang	12,05		20691,23				
			12,05		20691,23			172,8286752

The capacity that can be carried in river transportation is measured by the number of ships available to accommodate possible movements, this is something that is sometimes difficult to predict. Determining the capacity of river transportation is different from road transportation. There are special things that determine river transport capacity, namely capacity is not only determined from the volume that can be accommodated in one ship but must also take into account the ability of the water body to pressurize the ship to the maximum limit, to avoid the possibility of the ship sinking. In other words, efforts are made to ensure that the river capacity is full and presses the ship towards the bottom (full and down). In this operation, the planned capacity of the ship is 22 people including the crew.

Figure 4. Passenger Ship (Catamaran)

Based on the results of the questionnaire data, data was obtained regarding the opinions of the people of Manado City regarding the existence of Water Buses. This data can be seen as in the image below.

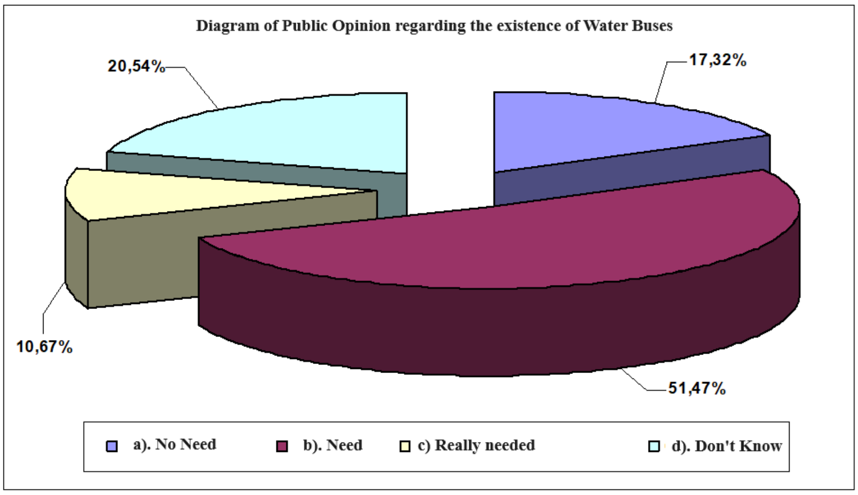

Figure 6.23 Diagram of Public Opinion regarding the existence of Water Buses

The number of people who answered that they really needed a water bus was 10.67%, and those who answered that they really needed a water bus was 51.47%. The total number of people who answered that they needed and really needed was 62.14%, so in general the people of Manado City answered that they needed this water bus.

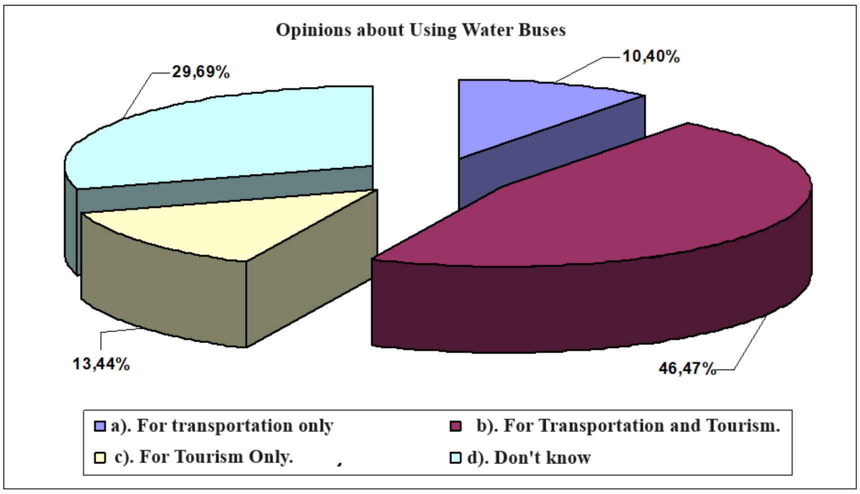

Figure 6.24 Community Opinion Diagram regarding the use of Water Buses

The number of people who answered that they really needed Air Buses only for transportation was 10.40%, those who answered for transportation and tourism were 46.47%, and those who answered for tourism only were 13.44%. Thus, in general, the people of Manado City are of the opinion that the use of Water Buses is for transportation and tourism.

4. Conclusion

Based on the results of the analysis discussed previously, the following conclusions can be drawn:

1) Based on survey data, it shows that the most dominant distribution of people's trips in Manado City is to Wenang sub-district, namely 38.48%, then the second largest is to Wanea sub-district with a percentage of 18.66%, then the third largest is to to Malalayang sub-district with a percentage of 14.33%, the fourth largest is to Sario sub-district with 9.46% of total household movements in the city of Manado.
2) People in the city of Manado have a fairly high level of activity, resulting in significant movement every day. This results in a concentration of traffic generation at the same time and an overload on road routes leading to activity centers (Wenang, Sario and Malalayang subdistricts), so it can be concluded that the existing public transport vehicles (Microbuses) are not sufficient to accommodate movement. the people of Manado city. There are 17980.13 movements that have not been transported by city transportation / Mikrobus. This opportunity was captured by the Manado City Water Bus transport well.
3) Based on the analysis of forecasting transportation needs, it is assumed that the number of trips is 10 trips per day.
4) Based on the calculations, the total length of travel time and recapitulation of stopping times for river stops (9 river stops), namely from the Tongkaina Sea Stop, Kec. Bunaken to the Sea Stop around Malalayang Terminal takes 132,067 minutes or around 2 hours 12 minutes. The stops in question are as follows: Tongkaina Sea Stop Kec. Bunaken; Sea stops around MDC Kec. Bunaken; Tuminting Sea Stop Kec. Tuminting; Kali Mas Pasar Bersehati Sea Stop;Marina Plaza Sea Stop; Megamas Sea Stop; Bahu Sea Stop (Tourism Office);Malalayang RSU Sea Stop (Behind Akper);Sea stops around Malalayang Terminal
5) Based on the transportation needs for the coast route which produces a movement of 1446 people/day, with a boat capacity of 20 people/boat, and a number of trips per day of 10 trips, 8 boats are needed.
6) The capacity that can be carried in river transportation is measured by the number of vessels available to accommodate possible movements, this is sometimes difficult to predict. Determining the capacity of river transportation is different from road transportation. There are special things that determine river transport capacity, namely capacity is not only determined from the volume

that can be accommodated in one ship but must also take into account the ability of the water body to pressurize the ship to the maximum limit, to avoid the possibility of the ship sinking. In other words, efforts are made to ensure that the river capacity is full and presses the ship towards the bottom (full and down). In this operation, the planned capacity of the ship is 22 people including the crew.

7) The number of people who answered that they really needed a water bus was 10.67%, and those who answered that they really needed a water bus was 51.47%. The total number of people who answered that they needed and really needed was 62.14%, so in general the people of Manado City answered that they needed this water bus.
8) The number of people who answered that they really needed Air Buses only for transportation was 10.40%, those who answered for transportation and tourism were 46.47%, and those who answered for tourism only were 13.44%. Thus, in general, the people of Manado City are of the opinion that the use of Water Buses is for transportation and tourism.

Acknowledgement

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CAFEO 41

Theme: "Igniting ASEAN Blue Economy and Green Energy"

Subtopic: Low-carbon transport

Title: Feasibility Study of Solar-Powered Electric Vehicle Charging Infrastructure at Selected Petrol Stations in Malaysia

Authors: Siow Chun Lim* and Adeesarn Chindamanee

Corresponding author*: chunlim87@gmail.com

Abstract

The transition from the conventional internal combustion engine (ICE) to electric vehicles (EV) are expected to result in higher total electricity demand in the country. With the introduction of more EVs into the market, the need for charging stations will grow, subsequently increasing power consumption. This research study aims to assess the potential of solar energy production at petrol stations in central region of Peninsular Malaysia and assess the feasibility of solar-powered petrol stations in meeting the energy demands of electric vehicles. 10 samples of existing petrol stations are selected to install a solar-powered DC charging station as a case study. To study their energy consumption, 90kW DC charger was evaluated. The design of the PV systems for the petrol stations was done by using the PVsyst simulation software. As a result, it is found that 90% of the designed PV systems are able to generate enough energy to meet the estimated annual energy consumption of the 90kW DC charging system. The results also showed that the cost to install the solar-powered charging system for both power ratings can be recouped in less than 2 years. Overall, this research study offers valuable insights for addressing the rising energy consumption resulting from the increased penetration of electric vehicles in the future. Additionally, the implementation of solar-powered charging infrastructure aligns with the country's renewable energy objectives and efforts to reduce greenhouse gas emissions. However, the assessment of EV penetration and the adoption of charging infrastructure was conducted based on government targets rather than relying on current data regarding the actual numbers and trends of EVs and chargers in Malaysia. The availability of accurate and up-to-date data on the number of EVs, their battery characteristics, chargers, and user charging behaviors in Malaysia would contribute to further enhancing this research work.

Keywords: Electric vehicle, fast charger, solar energy, PVsyst

I. Introduction

The transportation sector is one of the major contributors to greenhouse gas emissions globally. To address this issue, the adoption of electric vehicles (EVs) has been considered as an alternative to conventional internal combustion engine (ICE) vehicles. Malaysia, as a developing country, has set a target to have 100,000 EVs on the road by 2030 [1]. However, the widespread adoption of EVs requires a reliable and efficient charging infrastructure [2]. As more EVs are introduced into the market, the demand for charging stations will increase, leading to an increase in power consumption. Therefore, it is essential to evaluate the impact of EV chargers on power consumption to ensure the stability of the grid.

As more electric vehicles penetrated the Malaysian market, the demand for the EV charging infrastructures will increases. To solve this problem, build more EV charging infrastructures has to be built, especially along the existing expressway. However, there are few challenges that have to be encountered, where most of the existing EV chargers are powered by unclean electricity from conventional thermal power plants [3]. These power plants rely on non-renewable resources such as coal and natural gas [3]. As more EV charging stations are to be installed in the future, the electricity demand to power up these stations will be high, therefore requiring more fossil fuels to generate the power. To overcome this problem and avoid future power shortages, a study has to be done to support the power consumption of the EV charging stations from the grid to more green and eco-friendly energy resources such as solar energy. Hence, this paper aims to assess the feasibility of solar-powered petrol stations at selected locations in meeting the energy demands of electric vehicles in Malaysia.

In this research work, it is important to consider the various types of EV chargers available. However, for the purpose of this case study, the focus will be solely on Direct-Current (DC) chargers as the research variable. Additionally, while there are numerous petrol stations across Malaysia, this project research study is specifically limited to 10 petrol stations located along the North-South Expressway in the Central region of Peninsular Malaysia. Furthermore, there are different types of electric vehicles currently available in the market, including battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and hybrid electric vehicles (HEVs). However, this research project will concentrate solely on studying BEVs. Lastly, this research will only focus the grid connected PV system, without any additional battery energy storage system.

II. Material and Method

At the initial stage of the project, the number of petrol stations as well as their locations along the North-South Expressway will be obtained from the official PLUS Expressway website [4]. As of 26 July 2022, there are up to 100 existing petrol stations along the North-South Expressway [4]. The petrol stations include Shell, Caltex, Petron, BHP, and Petronas.

Once the number and locations for each petrol stations have been obtained, Google Earth application will be used to capture the rooftops of every petrol station along the expressway [5]. A sample of 10 petrol stations located in the central region will be calculated and analysed. Fig. 1

shows a sample of a rooftop image of a petrol station at the coordinate of 3.2246017,101.57682758 decimal degrees, which was captured by Google Earth to estimate the net area of the rooftop [5]. The next step is to use the calculated rooftop area as a parameter to design and size the solar PV system for the selected petrol stations.

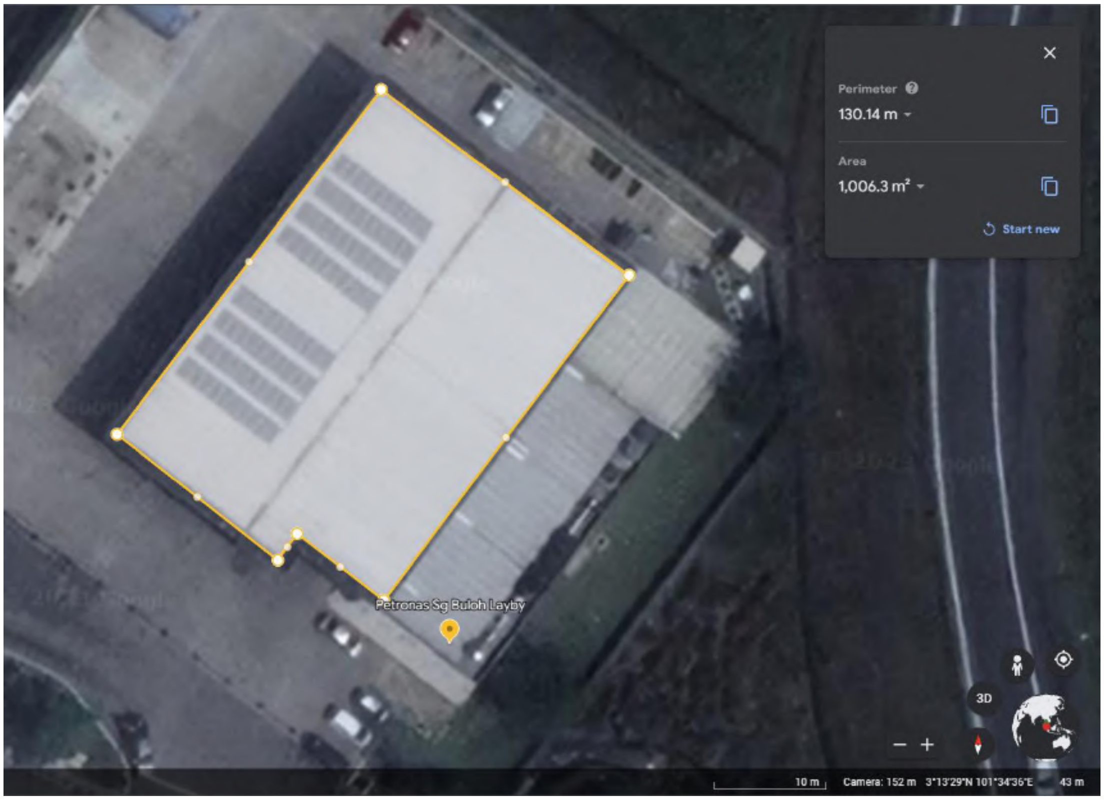

Figure 1. Sample of a Rooftop of a Petrol Station Captured by Google Earth [5].

The selection of PV modules for the system design was done by taking the modules' efficiency into consideration. The efficiency of the PV modules determines how effectively they can convert sunlight into electrical energy. The higher the efficiency of the PV modules, the more energy from the sunlight can be converted into electrical energy. Therefore, a model of monocrystalline PV modules was selected for the design as it has higher efficiency than polycrystalline modules. The specification of the selected module is shown in Table 1 [6]. As for the inverter, it was selected by considering the size of the designed PV system and its expected total power output. According to a previous study, the optimal DC-to-AC ratio should be closer to 1.2 in order to maximize the specific yield [7]. Table 2 shows the specifications of the selected inverter [8].

Table 1: Electrical Parameters of the Monocrystalline PV Module

Rated Maximum Power (Pmax) [W]	545
Open Circuit Voltage (Voc) [V]	49.75
Maximum Power Voltage (Vmp) [V]	41.8
Short Circuit Current (Isc) [A]	13.93
Maximum Power Current (Imp) [A]	13.04
Module Efficiency [%]	21.1
Power Tolerance	0~+5W
Temperature Coefficient of Isc(α_Isc)	+0.045%/°C
Temperature Coefficient of Voc (β_Voc)	-0.275%/°C
Temperature Coefficient of Pmax (γ_Pmp)	-0.350%/°C
STC	Irradiance 1000W/m², cell temperature 25°C, AM1.5G

Table 2: Technical Specification of the Inverter

Max. Input Voltage	1100 V
Max. Current per MPPT	26 A
Max. Short Circuit Current per MPPT	40 A
Start Voltage	200 V
MPPT Operating Voltage Range	200 V - 1000 V
Rated Input Voltage	600 V
Number of Inputs	8
Rated AC Active Power	30000 W
Max. AC Apparent Power	33000 VA
Rated Output Voltage	230 Vac / 400 Vac / 480 Vac, 3W/N+PE
Rated AC Grid Frequency	50 / 60 Hz
Rated Output Current	43.3 A
Max. Output Current	47.9 A
Max. Total Harmonic Distortion	< 3%

Once the rooftops' area has been obtained and the types of solar module and inverter have been selected, the next step is to design and simulate the PV systems based on the design parameters using PVsyst software [9]. The design parameters that were obtained will be used to size the PV system, which the PVsyst software will prompt the user to enter the rooftop area, types of solar modules, and types of solar inverters.

The power ratings of DC chargers for electric vehicles can vary depending on the specifications of the charger model. However, there are several common power ratings for DC chargers that are currently being installed in Malaysia. Based on official websites of TNB Electron, Shell and Petronas [10]-[12], DC chargers with power ratings of 90kW and 180kW are quite commonly being installed in petrol stations along the expressway. It is important to note that the power ratings of the DC chargers can vary further based on the technological advancements and individual charger manufacturer. Nevertheless, the research was focused more on the 90kW power ratings as it is more common along the expressway compared to other power ratings.

The next step in this research work is to calculate the estimated energy consumption of those 90kW DC chargers' power ratings. The equation to calculate the estimated daily energy consumption of the DC chargers is shown in Equation 1 below:

$$Daily\ energy\ consumption = P \times t \times N \qquad (1)$$

where,
P = Power rating of DC charger (kW), t = charging time (hours), N = Number of EVs charged per day

The parameter N in Equation (1) was obtained by determining the number of EVs and charging points available in Malaysia. The Malaysian government has set a target to have 100,000 EVs on the road by 2030 [1]. As for the charging points, the Ministry of Natural Resources, Environment, and Climate Change (KASA) aims to set up 10,000 EV charging points in Malaysia by 2025 under the Low Carbon Development Plan 2021-2030 [13]. Since there are no well-established data regarding the number EVs and the charging points that are currently available in Malaysia, this information was used to estimate the number of EVs per charging point. Therefore, based on the government targets, the estimated ratio of EV-to-charging points approximates 10 EVs per charging points.

The total cost of the entire system for each petrol station was calculated based on the number of units of PV modules, solar inverters, and DC chargers installed. The market prices for each component unit are shown in Table 3 [14] – [16]. Note that the installation costs are excluded from this study as the rate may vary significantly.

Table 3: Market Price for Each Component Unit

Item	Price per unit
PV module	RM883.00
Solar inverter	RM9,200.66
90kW DC charger	RM71,495.00

The return on investment (ROI) and payback period for the whole system on each petrol station was calculated using the Equation 2 and Equation 3, respectively. The annual profit in the Equation 2 refers to the profit generated from the whole investment. The profit for each petrol station was calculated based on the charging rates of the DC chargers. According to TNB Electron, the charging rate for the 90kW DC charger is RM2.20/min [10].

$$ROI = \frac{Annual\ Profit}{Total\ Cost\ of\ the\ System} \times 100\% \qquad (2)$$

$$Payback\ Period = \frac{Total\ Cost\ of\ the\ System}{Annual\ Profit} \tag{3}$$

III. Results and Discussions

Table 4 shows the simulated solar energy production from each of the 10 selected petrol stations in this study. The average irradiance level received by the Central region is 1778 kWh/m^2. Higher irradiance levels result in a greater amount of energy generation. However, the net area of the rooftops also plays an important role in maximizing the energy harvest from the solar PV system. Based on the obtained results, it can be observed that a larger rooftop area at a petrol station allows for the installation of more PV modules, resulting in higher power generation.

Table 4: Designed PV System Simulation Results in Central Region

Stations	Area (m^2)	Annual Average Irradiation (kWh/m^2)	Performance Ratio	Annual Energy Produced (kWh)
Shell Tapah NB	894.84	1757.3	0.848	275808
Petron Behrang Layby SB	936.69	1754.7	0.847	288995
Petronas Ulu Bernam SB	817.63	1758.3	0.846	247892
Petronas Rawang NB	683.51	1772.4	0.846	208150
Petronas Sg Buloh Layby SB	1006.46	1775.2	0.847	311367
Petron NKVE	995.8	1783.1	0.846	307303
Caltex Elite USJ	603.02	1794.1	0.845	185057
Petron Dengkil Elite SB	495.79	1800.8	0.847	155394
Shell Dengkil Elite SB	713.37	1801.1	0.846	225736
Petronas Damansara NKVE	1381.85	1783	0.842	435328
Average	**852.896**	**1778**	**0.846**	**264103**

The energy consumption of the 90kWDC chargers' power ratings was calculated using Equation 1. It is important to note that the charging time for an electric vehicle (EV) depends on the EV's specifications and its built-in battery capacity. Based on the assumption of 10 EVs per charging point, as discussed in previous section, if each EV is charged for 30 minutes regardless of the state-of-charge, the estimated daily energy consumption for both chargers is as follows:
90kW:

$$Energy\ consumption = P \times t \times N$$
$$Energy\ consumption = 90kW \times 0.5hrs \times 10 = 450kWh$$

The annual energy consumption of the DC charger was obtained by multiplying the daily energy consumption by 365 days. Thus, the annual energy consumption for the 90kW DC chargers is 164,250 kW.

As observed in the Table 5, 9 out of 10 samples (90%) of the designed systems are able to meet the annual energy demand of the 90kW DC charger. The petrol stations with rooftop areas below 510 m^2 could not generate enough energy to support the annual energy demand of the charger. Specifically, Petron Dengkil which has rooftop areas lesser than 510 m^2, resulting in insufficient energy generation to meet the energy demand of the 90kW charger.

Table 5: Estimated Annual Energy Consumption of the Chargers and the Annual Energy Produced by the Systems

Stations	Area (m^2)	Annual Energy Produced (kWh)	Can support the energy demand of 90kW?
Shell Tapah NB	894.84	275808	164250 (Yes)
Petron Behrang Layby SB	936.69	288995	164250 (Yes)
Petronas Ulu Bernam SB	817.63	247892	164250 (Yes)
Petronas Rawang NB	683.51	208150	164250 (Yes)
Petronas Sg Buloh Layby SB	1006.46	311367	164250 (Yes)
Petron NKVE	995.8	307303	164250 (Yes)
Caltex Elite USJ	603.02	185057	164250 (Yes)
Petron Dengkil Elite SB	495.79	155394	164250 (No)
Shell Dengkil Elite SB	713.37	225736	164250 (Yes)
Petronas Damansara NKVE	1381.85	435328	164250 (Yes)

The number of EVs that can be charged per year for each charger was determined by dividing the annual energy generation by the energy consumption of each EV. Table 6 presents the number of EVs that can be charged per year for each type of charger. Note that the analysis was made on the basis of 30 minutes of charging time, regardless of the state-of-charge of the EVs.

Table 6: Comparison on the Annual Charging Capacity of the Systems

Stations	Annual Energy Produced (kWh)	90kW Power Consumption (kWh)	No. of EVs can be charged by 90kW
Shell Tapah NB	275808	45	6129
Petron Behrang Layby SB	288995	45	6422
Petronas Ulu Bernam SB	247892	45	5509
Petronas Rawang NB	208150	45	4626
Petronas Sg Buloh Layby SB	311367	45	6919
Petron NKVE	307303	45	6829
Caltex Elite USJ	185057	45	4112
Petron Dengkil Elite SB	155394	45	3453
Shell Dengkil Elite SB	225736	45	5016
Petronas Damansara NKVE	435328	45	9674

The total cost for the whole system for each petrol station was calculated by considering the amount of unit of PV modules, inverter, and chargers used to design the system and is as per Table 7.

Table 7: Total Cost of the Whole System for Petrol Stations

Stations	Units of PV Module	Units of Inverter	Total Cost of 90kW System (RM)
Shell Tapah NB	340	5	417718.30
Petron Behrang Layby SB	357	6	441929.96
Petronas Ulu Bernam SB	306	5	387696.30
Petronas Rawang NB	255	4	333462.64
Petronas Sg Buloh Layby SB	380	5	453038.30
Petron NKVE	374	6	456940.96
Caltex Elite USJ	224	4	306089.64
Petron Dengkil Elite SB	187	3	264217.98
Shell Dengkil Elite SB	272	4	348473.64
Petronas Damansara NKVE	532	8	614856.28

The annual profit for each system was obtained by calculating the profit gained from the number of EVs that can be charged with the annual energy generated. With the charging rates for the 90kW chargers being RM2.20/minute and with the assumption of 30 minutes charging time for each EV as per discussed previously, the annual profit for all petrol stations can be found in the Table 8.

Table 8: Annual Profit for Petrol Stations

Stations	No. of EVs Charged per Year (90kW)	Charging Duration (min)	Annual Profit for 90kW (RM)
Shell Tapah NB	6129	30	404518.40
Petron Behrang Layby SB	6422	30	423859.33
Petronas Ulu Bernam SB	5509	30	363574.93
Petronas Rawang NB	4626	30	305286.67
Petronas Sg Buloh Layby SB	6919	30	456671.60
Petron NKVE	6829	30	450711.07
Caltex Elite USJ	4112	30	271416.93
Petron Dengkil Elite SB	3453	30	227911.20
Shell Dengkil Elite SB	5016	30	331079.47
Petronas Damansara NKVE	9674	30	638481.07

The total cost and annual profit obtained for every designed system previously were used for the calculation of return on investment (ROI) and their payback period. The ROI and payback period for each system were calculated using the Equation 2 and Equation 3. The results for all the systems are displayed in Table 9. Again, it is to be noted that the ROI and payback period are estimated without considering the cost of installation.

While this study seems to strongly suggest that solar powered 90 kW EV chargers is highly feasible, do note that there could be practical implementation issues and challenges in ensuring maximisation of solar PV being installed at the available space of the petrol stations. Hence, strategies for beneficial charging such as those outlined in [17] can be considered. Due to the constraints of low wind speed in general, small wind turbine can be considered for additional renewable energy harvesting to supplement the potential drop in solar energy yield during cloudy or stormy days [18].

Table 9: Return on Investment and Payback Period of the Systems

Stations	ROI for 90kW System	Payback Period for 90kW System (Year)
Shell Tapah NB	96.84%	1.03
Petron Behrang Layby SB	95.91%	1.04
Petronas Ulu Bernam SB	93.78%	1.07
Petronas Rawang NB	91.55%	1.09
Petronas Sg Buloh Layby SB	100.80%	0.99
Petron NKVE	98.64%	1.01
Caltex Elite USJ	88.67%	1.13
Petron Dengkil Elite SB	86.26%	1.16
Shell Dengkil Elite SB	95.01%	1.05
Petronas Damansara NKVE	103.84%	0.96

IV. Conclusions

In a nutshell, 90% of the petrol stations considered in this study is able to meet the energy demand of EV charging as per the assumptions made. Moving forward, more petrol stations from the Northern and Southern regions will be studied to provide a more comprehensive overview of the feasibility of solar powered EV charging stations in Malaysia.

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OCEAN THERMAL ENERGY CONVERSION (OTEC); POTENTIAL TECHNOLOGY IMPLEMENTATION FOR GREEN ENERGY IN ASEAN AND EXPLORING PROJECT MANAGEMENT CHALLENGES

Ir Dr Harris Abd Rahman Sabri [1], Dr Sathiabama T. Thirugnana [2]

[1]The Institution of Engineers Malaysia (IEM)
[2]Universiti Teknologi Malaysia Ocean Thermal Energy Centre (UTM OTEC)
Harris.ars@gmail.com; sathiabama@utm.my

Abstract

Ocean Thermal Energy Conversion (OTEC) is an innovative technology that harnesses the temperature difference between warm surface waters and cold deep waters of the ocean to generate clean and sustainable electricity. This one-page abstract provides an overview of OTEC, highlighting its working principles, potential benefits, challenges, and current advancements. The growing concerns over climate change and the finite nature of fossil fuels have led many nations, particularly those in Southeast Asia, to explore and adopt renewable energy sources as a sustainable solution for their energy needs. This paper examines the potential and challenges of introducing renewable energy technologies in Southeast Asia, with a specific focus on Ocean Thermal Energy Conversion (OTEC) and its potential impact on the region's energy landscape. OTEC, a promising yet underexplored technology, utilizes the temperature difference between warm surface waters and cold deep waters to generate electricity. This paper highlights the unique attributes of OTEC and discusses how its integration could revolutionize the energy sector in Southeast Asia. In conclusion, OTEC holds immense potential as a clean and sustainable energy solution. With continued advancements and the right support from government, this technology could play a significant role in diversifying the global energy mix, reducing reliance on fossil fuels, and mitigating the impacts of climate change while providing additional benefits such as freshwater production and ecosystem conservation. The paper will explore potential implementation of OTEC technology in ASEAN countries.

Keywords: Renewable, New Technology, Ocean Thermal, project management, challenges

1. Introduction

Malaysia has an equatorial climate, with temperatures increasing in the range of 0.13-0.24°C per decade since the 1970s. Rainfall distribution is influenced by the topography and monsoon winds, and annual rainfall averages between 2,000 and 4,000 mm. Malaysia is a small open economy with gross domestic product (GDP) and gross national income (GNI) of RM1.79 trillion and RM1.73 trillion, respectively, in 2022. Its population stood at 32.7 million people in 2022 and is expected to reach 40 million by 2050. It has traditionally been a producer of finite quantities of oil and gas, which contributed approximately 13% to GDP in 2021. Indigenous gas resources have ensured secure energy supply at affordable prices.

As the nation evolves and lifestyles change, environmental sustainability has gained more focus in business and policy decisions, and this has implications for people's livelihoods. Rapid urbanisation and climate change require a timely adjustment of the way we live, commute and interact with our surroundings, including the way in which we consume and produce energy. Fossil fuels continue to contribute the largest share of Malaysia's energy supply, and have a significant influence in shaping the country's energy landscape. As of 2020, four energy sources dominated the national energy mix. Natural gas constituted the largest portion of primary energy supply at 42.4% of TPES, followed by crude oil and petroleum products at 27.3% and coal at 26.4%. Renewables, comprising hydropower, solar and bioenergy, constituted just 3.9% of energy.

2. Malaysia Landscape of Green Energy

In March 2023, Malaysia joined the Japan-led Asia Zero Emission Community (AZEC) along with Australia, Brunei, Cambodia, Indonesia, Laos, the Philippines, Singapore, Thailand and Vietnam. AZEC is a regional energy cooperation block that aims to drive the energy transition on the principles of cooperation. Growth in the energy sector drives development in various adjacent industries, creating spin-offs through employment, capital inflows and investments, as well as supporting the energy service companies ecosystem.

In order to enable this, Malaysia government has embarked their own journey by utilizing The National Energy Policy, 2022-2040 which is also known as Dasar Tenaga Negara (DTN) that's lays the groundwork for a transformation in the energy landscape. It defines the energy transition as a structural shift in energy systems, characterised by a transition towards cleaner sources of energy, increased use of Renewable Energy (RE), and a significant reduction in carbon emissions. The energy transition is expected to occur at an accelerated pace, driven by rapid technological advances and robust climate change policies. The DTN's Low Carbon Nation Aspiration 2040 (LCNA 2040) seeks to transform the primary energy supply, moving to cleaner, RE sources. LCNA 2040 emphasises low-carbon policies.

These progressive aspirations will ensure the energy sector is resilient to future challenges and in a good position to seize the opportunities arising from the energy transition. The DTN is supported by four strategic pillars, 12 strategies, 31 action plans and five enablers as described in Figure 1.

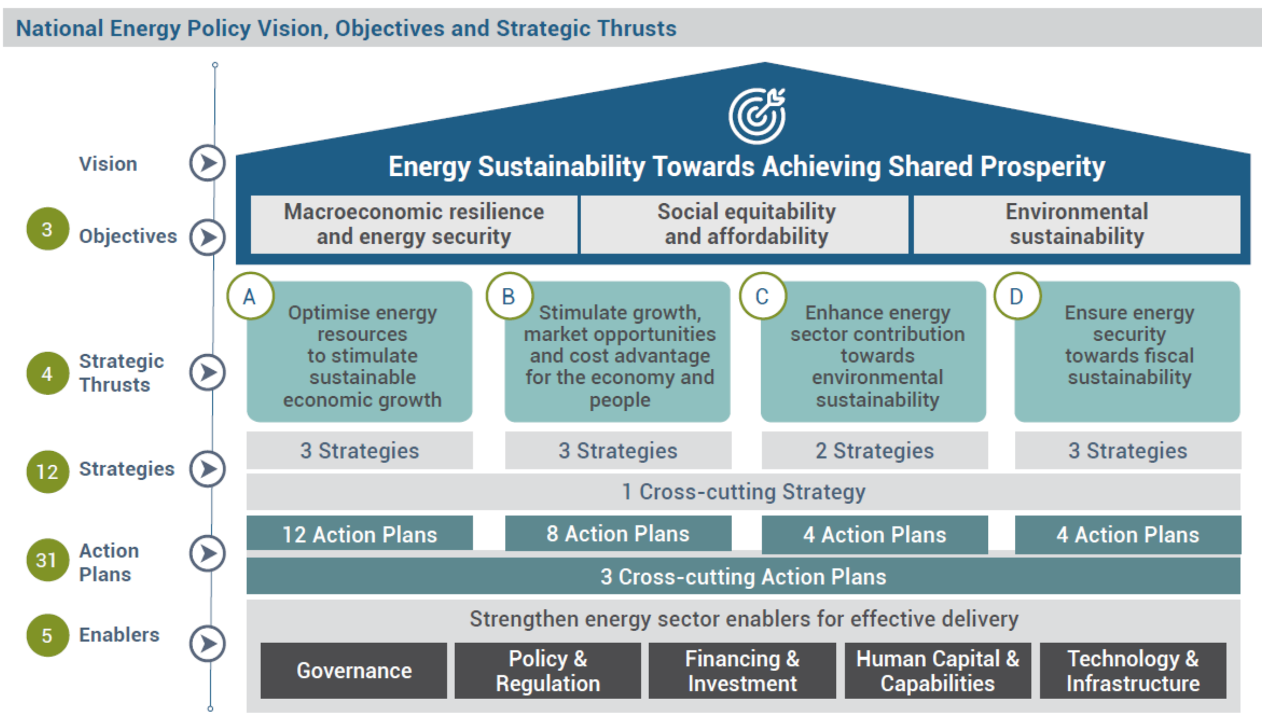

Figure 1: Dasar Tenaga Negara (DTN) Pillars

3. Ocean Thermal Energy Conversion (OTEC)

3.1 Principle of OTEC:

The main principle of OTEC is to harnesses the temperature difference between warm surface waters and cold deep waters to drive a thermodynamic cycle, producing electricity. Warm surface waters vaporize a working fluid, which drives a turbine connected to a generator. Cold deep waters then condense the vapor back into liquid, completing the cycle. Figure 2 shows the simple diagram of how an OTEC looks like for a 1 Megawatt Closed Cycle OTEC System.

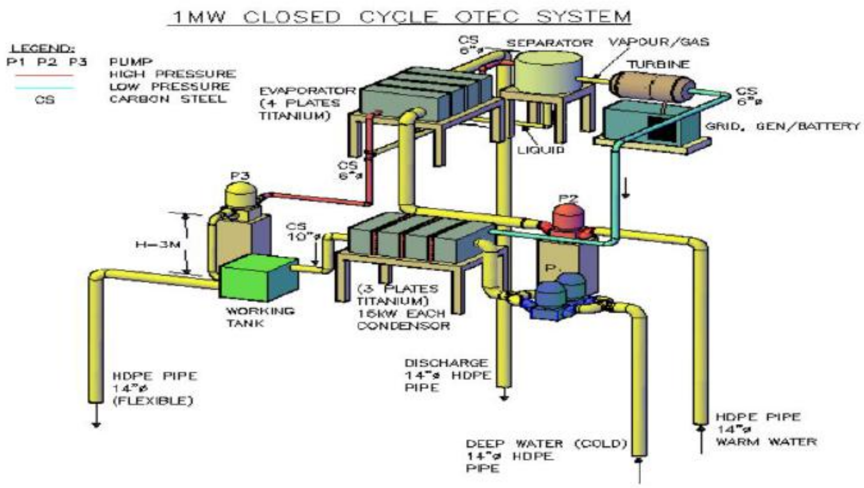

Figure 2 : 1 Megawatt Closed Cycle OTEC System

3.2 Ocean Thermal Energy Conversion (OTEC) Work Principles:

Ocean Thermal Energy Conversion (OTEC) is a renewable energy technology that harnesses the temperature difference between warm surface waters and cold deep waters of the ocean to generate electricity. The fundamental principle of OTEC is based on the heat transfer process and the utilization of a thermodynamic cycle. Here's a breakdown of the key principles behind OTEC:

Temperature Gradient: The primary requirement for OTEC is a significant temperature difference between warm surface waters and cold deep waters. In tropical and subtropical regions, such as those found in Southeast Asia, this temperature gradient is most pronounced, making these areas ideal for OTEC implementation. The difference in temperature helps drive the thermodynamic cycle that generates power. Thermodynamic Cycle: OTEC operates on a thermodynamic cycle known as the Rankine cycle, which involves the phase changes of a working fluid (typically a low boiling point fluid like ammonia) as it is subjected to varying temperatures and pressures. The cycle consists of four main stages: evaporation, expansion, condensation, and compression.

a. Evaporation: Warm surface seawater is used to heat the working fluid, causing it to evaporate and become a vapor.
b. Expansion: The vaporized working fluid expands and drives a turbine connected to a generator. As the fluid expands, its pressure and temperature drop.
c. Condensation: Cold deep seawater is used to condense the vaporized working fluid back into a liquid state. This releases the latent heat of vaporization, which is transferred to the cold water.
d. Compression: The condensed working fluid is pressurized back into a liquid state, and the cycle repeats.

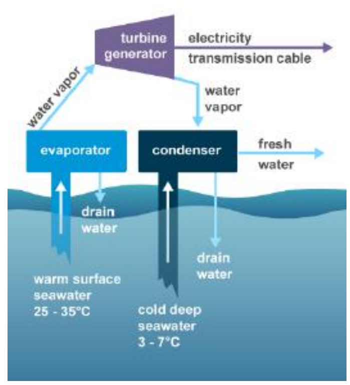

Figure 3: OTEC Diagram

3.3 OTEC Variants:

OTEC systems can be categorized into closed-cycle and open-cycle configurations. Closed-cycle systems use a working fluid with a low boiling point, such as ammonia, while open-cycle systems use seawater as the working fluid. Hybrid systems combining elements of both configurations are also being explored.

Ocean Thermal Energy Conversion (OTEC) systems can be categorized into several types based on their design, operation, and the depth at which they source cold seawater. Each type of OTEC system has its own advantages and considerations. Here are the main types of OTEC systems.

3.4 Closed-Cycle OTEC (CCOTEC):

In closed-cycle OTEC systems, a working fluid with a low boiling point, such as ammonia, is used to transfer heat between warm surface seawater and cold deep seawater. The working fluid undergoes phase changes (vaporization and condensation) within a closed loop to drive a turbine and generate electricity. The major components include a heat exchanger, a turbine, a generator, and a condenser. It provides an efficient heat transfer due to the use of specialized working fluids. It minimizes environmental impact as the working fluid remains enclosed. It can be designed for various scales, from small installations for specific applications to larger power generation systems.

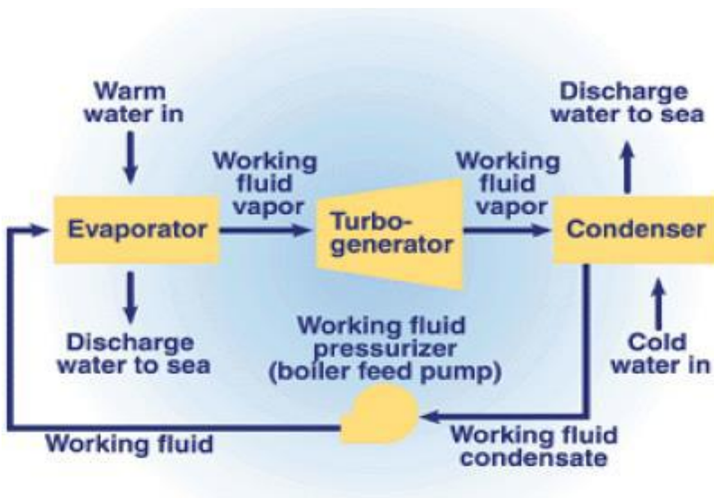

Figure 4: Closed Cycle OTEC System

3.5 Open-Cycle OTEC (OCOTEC):

Open-cycle OTEC systems use warm surface seawater itself as the working fluid. The seawater is vaporized at low pressures in a vacuum chamber, and the vapor drives a turbine connected to a generator. Cold deep seawater is then used to condense the vapor back into liquid form, completing the cycle. The cold seawater is released back into the ocean after the condensation process. It demonstrates a simplicity of design as it eliminates the need for a separate working fluid, lower maintenance requirements compared to closed-cycle systems and less risk of working fluid leaks into the environment. However, it may lead towards a lower efficiency compared to closed-cycle systems due to the absence of specialized working fluids. Furthermore, the direct interaction with seawater can lead to corrosion and fouling concerns. Figure X diagram shows the Open Cycle OTEC system.

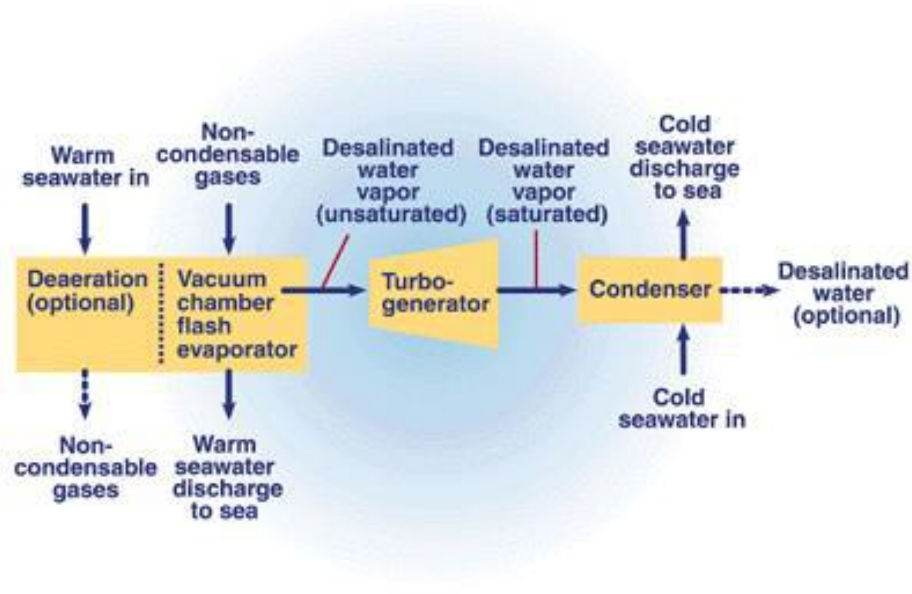

Figure 5: Open Cycle OTEC System

3.6 Advantages of OTEC:

Based on various literature review conducted, OTEC is a promising renewable energy technology with several distinct advantages that set it apart from other energy sources. These advantages make OTEC a potentially valuable contributor to the global energy mix, especially in regions with suitable oceanic conditions. Here are the key advantages of OTEC:

Steady and Predictable Power Generation: OTEC systems provide a consistent and reliable source of power, unlike some other renewable energy sources such as solar and wind, which are subject to fluctuations due to weather conditions. The temperature difference between warm surface waters and cold deep waters remains relatively stable, enabling OTEC to produce electricity continuously, day and night.

Large Energy Potential: Tropical and subtropical regions, which are most suitable for OTEC, experience a significant temperature difference between surface waters and deep waters. This results in a substantial thermal energy gradient that can be harnessed for efficient power generation. As a result, OTEC has the potential to produce a significant amount of electricity, contributing to energy security.

Minimal Environmental Impact: OTEC has a low environmental impact compared to fossil fuel-based power generation. It produces minimal greenhouse gas emissions, helping to mitigate climate change. Unlike fossil fuel combustion, OTEC does not release pollutants or contribute to air pollution, making it a cleaner energy option.

Sustainable Resource: The temperature difference that drives OTEC is a natural and perpetual resource provided by the sun's heating of the Earth's surface and the deep ocean's coldness. This makes OTEC a sustainable and renewable energy source, in contrast to finite fossil fuels.

Potential for Desalination and Cooling: OTEC systems can provide additional benefits beyond electricity generation. The cold water discharged from the deep ocean during the condensation phase of the OTEC cycle can be used for desalination processes, producing fresh water. Furthermore, the cold water can be utilized for cooling purposes in various industries and air conditioning systems, reducing the demand for conventional cooling methods that consume large amounts of energy.

Energy Security and Diversification: OTEC can enhance energy security by diversifying the energy mix of coastal nations. Countries that rely heavily on imported fossil fuels can reduce their dependence on external energy sources by incorporating OTEC into their energy portfolio.

Job Creation and Economic Growth: The development, installation, operation, and maintenance of OTEC systems create job opportunities across various sectors, including engineering, manufacturing, research, and operations. OTEC projects can stimulate local economies and support sustainable economic growth. Long-Term Potential: OTEC technology has the potential for long-term scalability and development. As technology advances and economies of scale are achieved, the efficiency and cost-effectiveness of OTEC systems are likely to improve.

Low Land Footprint: OTEC systems are primarily offshore installations, which means they do not require large amounts of land. This is in contrast to land-based renewable energy sources like solar and wind, which can sometimes face land availability challenges. Climate Resilience: OTEC can contribute to climate resilience by providing a stable source of energy that is less susceptible to climate variability compared to other renewable sources like wind and solar.

While OTEC offers numerous advantages, it's important to acknowledge that there are also challenges and considerations associated with its implementation, including high initial costs, technical feasibility, environmental impact, and site-specific considerations. Balancing these advantages with challenges is essential for realizing the full potential of OTEC as a sustainable energy solution.

4. Challenges in delivering OTEC

While OTEC holds promise as a sustainable energy source, it also has several disadvantages. The obvious challenges would be high initial costs: The construction and deployment of OTEC facilities can be extremely expensive. The technology requires complex infrastructure, including pipes to bring cold water from the depths and warm water from the surface, heat exchangers, and power generation equipment. These high upfront costs can make OTEC projects economically challenging, especially when compared to other renewable energy sources.

Next is limited geographical applicability, since OTEC can only be efficiently deployed in regions with a sufficient temperature difference between surface and deep ocean waters, typically in tropical areas as defined in Figure 8. This limits its geographical applicability and availability as a widespread energy solution.

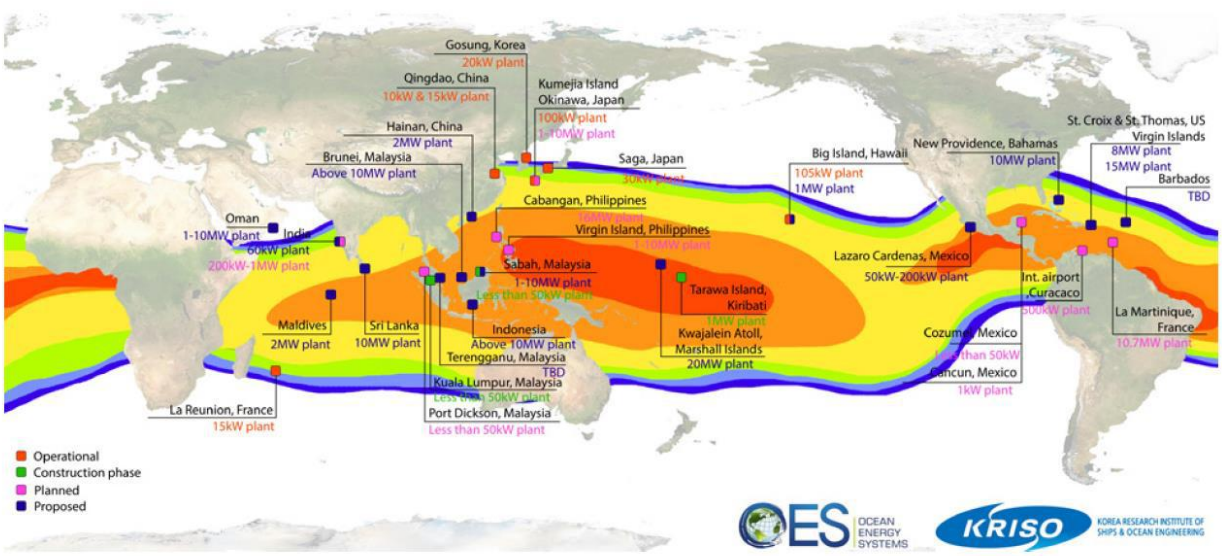

Figure 8: Areas of OTEC Installation in the World

In terms of environmental impact, OTEC systems can have an impact on marine ecosystems. Bringing cold nutrient-rich water from the deep ocean to the surface can lead to changes in local ecosystems and marine life. Additionally, the intake and discharge of large volumes of ocean water can disrupt marine habitats, alter local currents, and harm marine organisms.

OTEC systems are technically complex and require specialized components, such as heat exchangers and turbines, that need regular maintenance and upkeep. Operating in the harsh ocean environment can increase maintenance challenges and costs. Therefore it leads towards technological complexity and maintenance challenges.

OTEC systems tend to have relatively low energy conversion efficiencies compared to some other renewable energy technologies. The efficiency is influenced by factors like the temperature gradient, heat exchange efficiency, and losses in energy transmission. As a result, a significant portion of the energy harvested from the temperature difference may be lost during conversion and transmission, which leads towards lower efficiency compared to existing conventional power generation.

Energy output of OTEC is influenced by the availability of temperature differences between the ocean's surface and depths, which can vary due to weather conditions, seasonal changes, and other factors. This intermittency can make it challenging to provide consistent and reliable power, especially when compared to more predictable energy sources like solar or wind. Therefore it leads towards the concern pertaining intermittency of OTEC power generation, but likely to be resolve with the consistent temperature differential of seawater which may lead towards 24 hours power generation a day.

Scale Limitations: OTEC facilities require access to large volumes of ocean water to function efficiently. Scaling up the technology might lead to concerns about the ecological impact, disruption of marine life, and potential conflicts with other ocean uses such as shipping, fishing, and conservation efforts.

Competition with Other Renewable Sources: OTEC competes with other established and more cost-effective renewable energy sources like solar and wind power. These sources have advanced significantly in terms of efficiency and cost reduction, making it difficult for OTEC to compete on economic grounds.

Long Permitting and Approval Processes: The installation of OTEC facilities can involve long and complex permitting processes due to the potential environmental impact on marine ecosystems. Regulatory hurdles and community concerns can slow down project development and increase overall costs.

Budget Overruns and Funding: OTEC projects often require significant upfront capital investment, and cost overruns can occur due to unexpected technical issues, changes in scope, or delays. Securing funding and managing budgets effectively is essential to ensure the project's financial viability.

Community Engagement and Stakeholder Management: OTEC projects can have an impact on local communities, fisheries, tourism, and other ocean-based industries. Engaging with stakeholders, addressing concerns, and building community support are crucial for successful project delivery.

Skilled Workforce: OTEC projects require a skilled and specialized workforce, including engineers, marine biologists, environmental experts, and construction personnel. Recruiting and managing a diverse team with the necessary expertise can be challenging.

Technology Validation and Scaling: OTEC is still a relatively emerging technology, and scaling up from pilot projects to commercial-scale facilities can involve unanticipated technical challenges. Ensuring that the technology is validated, optimized, and scaled effectively requires careful project management.

Long Project Lifecycles: OTEC projects typically have longer lifecycles from concept to operation due to the complex nature of the technology and the need for thorough testing and validation. Managing long-term project timelines and maintaining stakeholder engagement over extended periods can be demanding.

Knowledge and Expertise Gap: The specialized nature of OTEC technology can lead to a scarcity of experienced professionals and limited industry knowledge. Project managers must bridge the expertise gap through training, collaboration, and knowledge sharing.

Addressing these challenges requires effective project management strategies that encompass technical expertise, stakeholder engagement, risk management, and adaptive planning. Successful OTEC project delivery requires a multidisciplinary approach that accounts for the unique characteristics of the technology and the marine environment.

6. Conclusion

The introduction of renewable energy, particularly OTEC, in Southeast Asia has the potential to reshape the region's energy landscape. OTEC's reliable and consistent power generation, along with its environmental benefits, make it a promising candidate for addressing energy security and sustainability. However, addressing the technical, financial, and environmental challenges associated with OTEC deployment is essential to harness its full potential and contribute to the region's transition to a cleaner and more resilient energy future. The potential implementation of Ocean Thermal Energy Conversion (OTEC) in Southeast Asia presents a mix of opportunities and challenges, which should be carefully evaluated before considering widespread adoption.

Each type of OTEC system has its own set of advantages, challenges, and suitability for different applications and environments. The choice of OTEC type depends on factors such as available resources, technical feasibility, environmental considerations, and the intended scale of operation. In summary, OTEC harnesses the temperature gradient present in tropical and subtropical oceans to drive a thermodynamic cycle, converting the thermal energy difference between warm surface waters and cold deep waters into electricity. This renewable energy technology has the potential to provide a steady and reliable source of power while minimizing environmental impacts and contributing to sustainable energy solutions.

In conclusion, while OTEC holds significant promise as a renewable energy solution for Southeast Asia, its potential implementation should be approached with careful consideration of both its benefits and challenges. By leveraging the region's abundant oceanic resources, addressing technical and environmental concerns, and fostering collaboration, Southeast Asian nations can work towards a sustainable energy future that balances energy needs with environmental preservation. A balanced and holistic approach to OTEC implementation can contribute to the region's energy security, economic growth, and environmental stewardship.

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FIRST GBI GOLD-RATED CONFECTIONERY MANUFACTURING FACILITES IN MALAYSIA

Catherine Siew Ping Sim[1], Zi Xun Ooi[1], Tze Hoong Ooi[1],
Ji Herng Tang[1], Yee En Seah[1]

1. M.E.I. Project Engineers Sdn. Bhd., Level 20, BHL Tower 51, Jalan Sultan Ahmad Shah 10050, Penang, Malaysia
mei@mei.com.my

Abstract

This state-of-art confectionery manufacturing plant was conceived as a statement of sustainability and functionality. Carrying the flagship as Hershey's single largest investment in Asia and being the second largest Hershey's global manufacturing network, the facility garnered first Green Building Index (GBI) Gold rated confectionery manufacturing facility in Malaysia. Only about 5% of total GBI certified building in Malaysia belongs to industrial category and up to July 2023, Hershey stands as the one and only confectionery manufacturing facility in Malaysia that was garnered Gold Rated in green building certification. Green Building Index is Malaysia's first comprehensive rating system for evaluating the environmental design and performance of Malaysian buildings based on the six (6) main criteria of Energy Efficiency, Indoor Environment Quality, Sustainable Site Planning & Management, Materials & Resources, Water Efficiency, and Innovation. Green buildings possess many advantages compare to conventional building such as efficient use of resources, have significant operational savings and increases workplace productivity. Hershey's manufacturing facilities green features include Overall Thermal Transmission Value (OTTV) less than $4W/m^2K$, Energy Use Intensity (EUI) achieved more than 30% power saving, Rain Water Harvesting system combined with production waste water recycling for cooling-tower-make-up achieved approximately 31% potable water reduction.

Keywords: Confectionery-Manufacturing-Facilities, Energy-Efficiency, Green-Building-Index (GBI), Industrial-Category, Water-Efficiency.

1. Introduction

Climate change, water scarcity, natural resource depletion and biodiversity degradation pose increasing threats to our planet, communities, and individuals around the world. With the constant environmental challenges, in order to play a part creating positive change for a brighter future, Hershey is proud to be among the companies committed to Science Based Targets initiative (SBTi), science- based greenhouse gas (GHG) reduction, with emissions reduction targets aligned with the 1.5-degree Celsius temperature pathways. [1]

To meet these ambitious objectives, the implementation asides investing in renewable energy, advancing sustainable packaging solutions and ending deforestation across the value chain in global context; in Malaysia, the design, construction and commission of the Hershey's single largest investment in Asia comes with a facility that garnered the first Green Building Index (GBI) Gold rated confectionery manufacturing facility in Malaysia as shown in Figure 1.

The GBI rating system provides an opportunity for the architects, designers, engineers, and investors to have sustainable facilities with energy savings, water savings, healthier indoor environment, better connectivity to public transport, carbon footprint reduction. GBI emerged as the first step in promoting sustainability in the design and construction environment in Malaysia and raising awareness among professionals of the filed as well as public about environmental issues and our responsibility to the future generations. [2].

Figure 1. Front Ariel View of the 800,000sqft build-up-First GBI Gold Rated confectionery-manufacturing-facilities in Malaysia

2. Materials and Methods

Located between the latitudes of 1° and 7° north and the longitudes of 100° and 119.5° east, Malaysia is a tropical Southeast Asian nation close to the equator. Malaysia is subjected to 400 to 600 Mj/m^2 of radiation each month [3]. Malaysia's average temperature ranges from 24.5 to 28.5 degrees Celsius, above the recommended limit provided by the Ministry of Energy, Telecoms, and Posts [4]. The majority of studies suggested that Malaysia's comfortable air temperature is around 25° C [5].

Numerous studies examine how population growth, climate change, and economic expansion affect energy efficiency. The biggest problem facing the world today is climate change. Over 40% of the carbon dioxide emissions in Malaysia come from the greenhouse effect produced by buildings [6]. Climate change is impacted by the situation, which is harmful to the environment. Consequently, since the turn of the 20th century, a number of sustainable building assessment methodologies have been developed [5,7].

Since 2009, Malaysia has had a comprehensive and well-established green building grading system (the Malaysia Green Building Index, or GBI) [8]. The Green Building Index (GBI) is a green rating system that was created in 2009 by the Malaysian Institute of Architects (Pertubuhan Arkitek Malaysia) and the Association of Consulting Engineers Malaysia (ACEM). The purpose of including this rating system was to promote sustainability, green building, and Building Energy Intensity (BEI) or Energy Use Intensity (EUI) standards in Malaysia. A building required to fulfil a specified set of requirements in order to be certified as a green building under the green rating system. The four-tier award ranking system is shown in Table 1 [9]. This effort, which is being led by the private sector, intends to increase environmental awareness among industry participants and promote sustainability in the built environment. Building will be awarded GBI rating score based on six key criteria; energy efficiency, indoor environment quality, sustainable site planning, material and resources, water efficiency and innovation [8].

Table 1. GBI Award Rating Systems [9]

Points	GBI Rating	Energy Efficient
86+	Platinum	> 60%
76 – 85	Gold	50 – 60%
66 – 75	Silver	40 – 50%
50 – 65	Certified	30 – 40%

According to the US Green Building Council, the goal of green building is to considerably minimise or eliminate a facility's negative effects on the environment and its occupants (LEED, 2004). Golstein (2011) went on to explain that a green building is one that takes into account the local climate and cultural requirements, as well as the demands of its residents in terms of their health, safety, and productivity. The Green Building Index (GBI), a ranking system for green buildings, was introduced in Malaysia in May 2009 in accordance with the country's technological and environmental policy. The Building Research Establishment Environmental Assessment Method (BREEAM) and the United States' LEED (Leadership in Energy and Environmental Design) rating systems served as the foundation for the design of the GBI. According to the GBI, a green building is one that prioritizes both human health and the environment through improved planning, building, operating, maintaining, and removal practices. Table 2 compares the green building rating systems used in various nations [10].

Table 2. Comparison of Different Countries' Green Building Rating Tool [10]

Rating Tools	BREEAM	LEED	Green Star	Green Mark	GBI
Origin	UK, 1990	US, 1993	Australia, 2003	Singapore, 2005	Malaysia, 200
Categories	Energy Use Transportation Water Ecology Land Use Materials Pollution Health and Well Being	Energy and atmosphere Water efficiency Sustainable sites Materials and resources Indoor Environmental Quality (IEQ) Innovation	Energy Transport Waer	Energy efficiency Water efficiency Environmental protection Indoor Environmental Quality (IEQ) Innovation	Energy efficiency Indoor Environmental Quality (IEQ) Sustainable site planning and management Materials and resources Water efficiency Innovation
Developer	Building Research Establishment (BRE)	United States Green Building Council (USGBC)	Green Building Council of Australia (GBCA)	Building and Construction Authority (BCA)	Green Building Index Sdn. Bhd.

3. Results and Discussion

Building Envelope to achieve minimum Energy Efficiency Performance. Passive design of a building is a fundamental prerequisite to achieve green building certification and energy saving. A good passive design would help to reduce energy cost and reduce mechanical active system required for building. Two key concepts for passive design is Roof U-value and Overall Thermal Transfer Value (OTTV). Roof thermal transmittance (U-value) is dependent on the material thickness and thermal conductivity properties. OTTV is the indication of thermal load transmitted through the building envelope excluding the roof, influence by wall-window ratio (WWR), solar absorptivity of opaque wall, thermal transmittance of opaque wall and fenestration system, solar correction factor and shading coefficient of fenestration system. Under Green Building Index (GBI), point is given for achieving OTTV less than 50 W/m^2 and provision of Energy Management System (EMS) for air-conditioned space more than 4,000m^2. The use of pre-painted white gloss Insulated Metal Panel (IMP) contribute to absorptivity, α for heat conduction through walls as shown in Figure 2. The OTTV value of factory building 1 & 2 is shown in Table 3.

Figure 2. Ariel View of the first GBI Gold Rated confectionery manufacturing facilities in Malaysia (angular view) with indication of sun-path

Table 3. Overall Thermal Transfer Value (OTTV)

	OTTV (Excluded non-air-conditioned "attic space")	**OTTV (Included non-air-conditioned "attic space")**
Factory Building 1	3.25 W/m^2	3.89 W/m^2
Factory Building 2	3.96 W/m^2	4.59 W/m^2

The Roof U-value is 0.206 W/m^{2}K, which is less than 0.4 W/m^{2}K required for lightweight roof. The section of roof built up is shown in Figure 3.

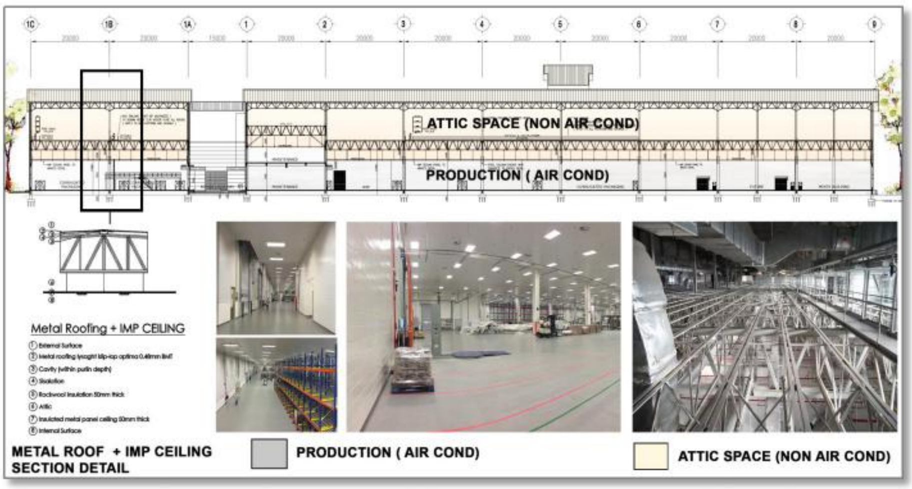

Figure 3. Building and roof section built up

Lighting Zoning. The plant is provided with flexible lighting control where individual or enclosed spaces have separate switches. User can switch off the zone which is not in use without impacting person working in another switch zone. Daylighting strategy is adopted with implantation of photocell sensor at perimeter zone. When the lux level fall below the room's lux level requirement, the lighting will be switched on.

Electrical Sub-Metering. Individual digital power meter is installed at each area's lighting distribution board, power distribution board, industrial process distribution board, mechanical control center and equipment with energy usage more than or equal to 100kVA, refer to Figure 4. For ease of monitoring, the sub-meters are linked to Energy Power Monitoring System (EPMS).

Figure 4. Digital power meter for lighting, power, process, mechanical equipment, and flexible lighting controls to optimize energy savings.

Advanced or Improved Energy Efficiency Performance via Energy Used Intensity (EUI) by comparing baseline data with the current energy consumption. According to the data collected as shown below, energy usage decreased after the plant operated since January 2018, even though production ramped up. This reduction was achieved by comprehensive testing and commissioning of the M&E infrastructure per the design intent as well as in accordance to GBI requirement. With persistent work throughout the project and the implementation of both passive and active green design solutions, the facility proven to be able to achieve as much as 30% reduction in energy usage intensity as shown in Table 4 & 5.

Energy Management System. Building Management System (BMS) and Energy Power Monitoring System (EPMS) are provided. Total of 2270 input and output (I/O) points monitor and control steam condensate & hot water system, air conditioning & mechanical ventilation (ACMV) system, compressed dry air (CDA) system, industrial water system (IW) and electrical system. EPMS records the utility consumption data for energy audit as shown in Figure 5.

Table 4. Actual Energy Data Collected

Month	Production, kg	Total Power, kWh	EUI, kWh/kg
Jan-18	643,125.00	2,261,144.00	3.52
Feb-18	633,584.20	2,030,375.00	3.20
Mar-18	730,512.00	2,370,417.00	3.24
Apr-18	595,764.00	2,317,192.00	3.89
May-18	962,405.00	2,669,988.00	2.77
Jun-18	1,389,549.00	2,725,185.00	1.96
Jul-18	1,434,459.00	2,670,853.00	1.86
Aug-18	1,703,763.00	2,752,433.00	1.62
Sep-18	2,039,501.00	2,728,131.00	1.34

Table 5. Comparison of Energy Use Intensity

SYSTEM & EQUIPMENT	BASE LOAD (Reference to MS 1525)		ACTUAL LOAD (Data Collected in Sept 2018)	
ACMV - Water Side - Factory Building	1,151,550.28	kWh/Month	513,857.98	kWh/Month
ACMV - Water Side - Admin Building	23,384.97	kWh/Month	23,384.97	kWh/Month
ACMV - Air Side	544,083.64	kWh/Month	544,083.64	kWh/Month
Process Utility Infrastructure	590,266.62	kWh/Month	590,266.62	kWh/Month
Lighting and Small Power	714,093.47	kWh/Month	161,745.06	kWh/Month
Other Utility (eg. Lift)	315,581.80	kWh/Month	315,581.80	kWh/Month
Production Equipment	579,210.93	kWh/Month	579,210.93	kWh/Month
Total Utility Usage	3,918,171.71	kWh/Month	2,728,131.00	kWh/Month
Production Output	2,039,501.00	kg	2,039,501.00	kg
Energy Use Intensity (EUI)	1.92	kWh/kg	1.34	kWh/kg
Saving	30.4%			

Figure 5. Building Management System to monitor and analysis of energy consumption

Maximum Demand Limiting Program. Maximum demand limiting program as shown in Table 6 is applied to monitor the building maximum demand. The user can shed load to limit the demand to predetermined limits. Loads which may be shed shall be nominated on a schedule. This shall be arranged on a priority basis. Each load shall also be given an associated reasonable kW value. The system shall provide the facility for the user to select the demand limit and the loads available for shedding. The maximum demand period shall parallel that of the Electricity Supplier half hour cycle for maximum demand.

Good levels of Daylighting for building occupants and plant workers. It is vital that a good level of daylighting is provided for building and plant occupants. The building perimeter design allowing for natural light on both sides and generous window heights of minimum 2200mm. These ensures that and average of 30% of NLA has daylight factor of 1.0% to 3.5%. The blinds operated individually and internal painting of white colour helps in daylighting. The productivity, health and well-being of building users can be improved if access to controlled daylight is maintained.

Table 6. Maximum Demand Limiting Program (MDL) Implementation.

Maximum Demand Baseline (May 2017) kW	**5,720**	**Start Date**
VSD has been provided to Cooling Tower Fans. Cooling Towers' total power has been reduced 58 kW.	-58	Jun-17
Glycol Chillers have been changed from 1,000 RT to 400 RT. The Glycol Chiller's power has been reduced 50 kW during operation.	-50	Jun-17
The AHUs at Reese Building has been switched off. This has made the overall peak load at around 1,200 RT instead of 1,600 RT. This has avoided 2nd chiller to cut-in. Chillers' power has been reduced 350 kW.	-350	Oct-17
When Waste Store's door is opened, the waste odor will flow out from Waste Store. When Waste Store's door is closed, the waste odor will not come out. The ventilation fan is interlocked with door so that the fans only run when door is opened. This has reduced 39 kW of fans power.	-39	Oct-17
The Attic Fresh Air Fans (AFAFs) running hours have been rescheduled. The AFAFs have been grouped into 2 groups. Each group will run half an hour alternately instead of all running together. This has reduced the AFAFs' total power from 400 kW to 200 kW.	-200	Dec-17
The Boiler House has one number of roller shutter previously. Another roller shutter has been added to the Boiler House. The mechanical ventilation fans in Boiler House have been switched off. This has reduced 16 kW of fans power.	-16	Dec-17
Maximum Demand After MDL Programs (Dec 2017) kW	**5,007**	

Daylight Glare Control. Figure 6 shows the section of building with daylighting. The following points address maintenance of internal daylight at an optimum level. When a window is subject to direct sunlight partially closed blinds (or closed perforated blind) can be installed with occupant controls so that occupants can achieve comfortable lighting level throughout the day. Whereas, when the sunlight is not directly penetrating the windows, opening the blinds often help illuminate a room. This can help to reduce the need for indoor artificial lighting which in turn reduces energy costs.

Electric Lighting Levels and High Frequency Ballast. The lighting level are designed in accordance to MS1525:2007 except area which required specific luminance level due to product and operation related. In addition, all the T5 fluorescent fitting installed in the plants are equipped with high frequency electronic ballast.

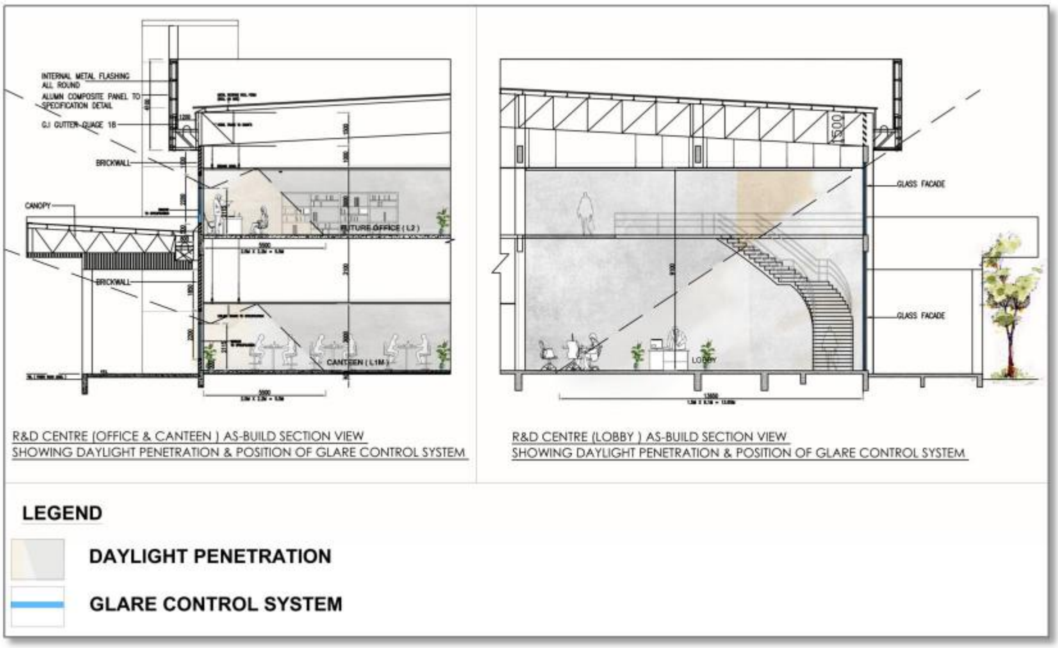

Figure 6. Section of building daylighting

External Views. The provision of external view helps to reduce eyestrain for building occupants by providing long distance views and visual connection to the outdoor. The building internal design is based on an Open-Plan-Concept and windows-within-room. Adoption of low-level workstation partition or use vision panel to maintain line of sight to external. All in-house office services for example, pantry, toilets, photocopying area are located at the AHU/ toilet core area. Adoption of blinds are as and when necessary, only. About 69.11% of the NLA has a direct right of light through vision glazing at a height of 1.2m from floor level. Figure 7 shows the section of building external view.

Figure 7. Typical building section and 3D illustration for external view

Carbon Dioxide Monitoring and Control. The CO2 sensors was provided (either installed in the main return air duct or mounted within the room), connected to the motorized damper at the fresh air intake duct of ACMV system via building management system (BMS), to ensure sufficient fresh air will be intake to the room and control the ventilation rates to maintain CO2 level < 1,000 ppm for indoor air quality control. The fresh air damper will open whenever the CO2 reading exceeds 900ppm and will remain 30% open while the reading is below the set point to maintain a specific level of fresh air amount inside the room. Figure 8 shows the excerpts of Building Management System (BMS).

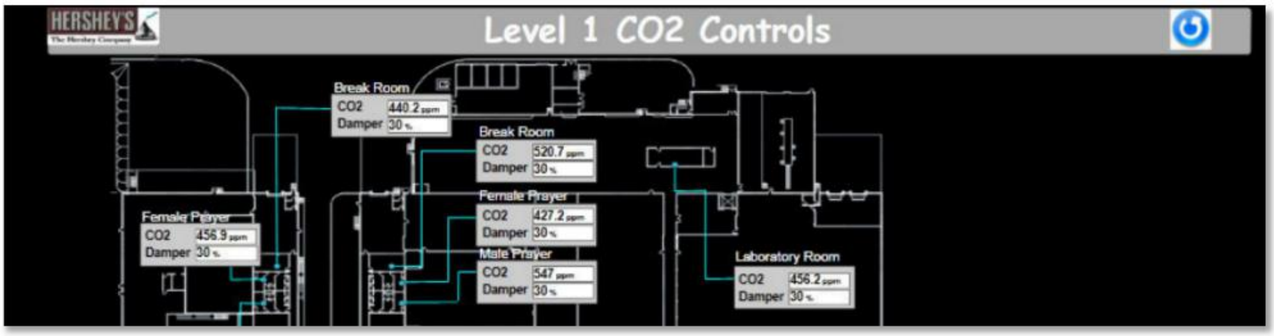

Figure 8. Excerpts of Building Management System (BMS) at Control Room showing CO2 Sensor and Fresh Air Damper Monitoring System for North Side of Manufacturing Building

Internal Noise Levels. The building internal noise level especially the office area was also controlled at appropriate level to ensure the comfortable of occupancy. Insulated Metal Panels (IMP) for the wall and ceiling, which have good sound acoustics across the entire structure, was installed to significantly reduce the amount of internal noise. Aside from that, more than 90% of the significant areas are supplied by either MAU, AHU, RAH, or FCU, which are installed on the AHU platform in the attic space above the IMP ceiling. As a result, the noise level measurement result below demonstrates that we are in compliance with GBI requirements, which state that at least 90% of the general office area's NLA must not exceed 45 dBA for open offices or 40 dBA for closed offices. Refer to Table 7 for noise level record.

Sustainable Site Planning and Management with Greenery and Roof. The purpose of greenery and roof is to reduce heat island effect (thermal gradient difference between developed and undeveloped areas) so as to minimize impact on microclimate and human and wildlife habitat [11]. Roofing material shall be with Solar Reflectance Index (SRI) equal to or greater than the value in the table below for a minimum of 75% of the roof surface. The factory has more than 75% of total roof area with SRI value more than 78.

Table 7. Noise Level Measurement Data Recorded.

ROOM	NLA (m2)	dB Measured	Max dB	Pass NLA	ROOM	NLA (m2)	dB Measured	Max dB	Pass NLA
Cafeteria	318	44.7	50	318	Autoclave Lab 4	33	40.2	50	33
Guard House	28	45.3	60	28	Change Room	4			
Exam 1	11	42.1	45	11	Locker Access	12			
Exam 2	13	45.1	45		M Change Room 1	182	42.1	45	182
Payroll	21	45	40		M Change Room 2	31			
Medical Centre	28	43	45	28	F Change Room 1	224	42	45	224
Office Area	55	42.3	45	55	F Change Room 2	31			
Manager 8	11	42.3	40		Mothers' Lounge	18			
Manager 9	11	45.3	40		Access	38			
Server Room	61	42.1	50	61	AHU Room	89			
Security Manager	16	45.1	40		Board meeting Room	38	38.2	40	38
Micro Lab 1	211	40.3	50	211	Discussion Room 1	50	38.6	40	50
Media Prep Lab2	58	40.5	50	58	Discussion Room 2	53	38.8	40	53
Extraneous Lab3	45	40.6	50	45	**Total**	**1808**			**1713**
								Percent	**95%**

Materials Reuse and Selection. During construction stage, the building materials and products are reused to reduce the demand for virgin materials and creation of waste. Material with recycled material such as metal roofing, steel structure, reinforcement bar and BRC were used.

Regional Material. Regional materials were used with sourcing distance between 500km radius with the aim to minimize carbon omission from transportation of goods from source to the construction site. During construction, contractor has been provided different skips in order to sort and segregate different construction waste. This is also to facilitate recycling and re-use of materials as many as possible before resorting to disposal or dumb to landfill. During occupancy, a dedicated areas for each floor of the building are installed with 3R bins. The construction waste management had been implemented by the contractor for this project. Waste on-site was sent to recycle center in order to reduce construction waste being sent to landfill area. The construction waste was first sorted on-site into the following bins, i.e. wood, metal and concrete. All the bins were weighed individually before sent to one of the certified recycling-landfill waste treatment stations. The strategies to achieve the target are as 75% of recycled and salvaged waste will be the established goals for diversion from disposal in landfills and incinerators and adopt a construction waste management plan to achieve these goals; consider recycling cardboard, metal, brick, acoustical tile, concrete, plastic, clean wood, glass, gypsum wall board, carpet and insulation; Designate a specific area/s on the construction site for segregated or co-mingled collection of recyclable materials; track recycling efforts throughout the construction process by construction waste management form, photos and receipts; Construction haulers and recyclers be identified to handle the designate material and donation of materials to charitable organizations and salvage of materials on-site.

Water Efficiency in Rainwater Harvesting. This confectionery manufacturing facilities maximise rainwater collection from rooftop or runoff rainwater systems for building consumption and/or irrigation. The rainwater harvesting lead to 21.25% in potable water consumption. Key system of rainwater harvesting is syfonic system, whereby vortex and air are restricted from entering the pipe system through the incorporation of syfonic square inlets located in the gutter as shown in Figure 9. With the absence of air and vortex, the system utilizes the difference in the level of the gutter and discharge point (head of water) to discharge the rainwater at high flow rate and velocity, thus, self-flushing and self-cleansing. The advantages of syfonic system includes eliminating large diameter rainwater downpipe, removes perimeter and underground drain, reduce gutter size, improve construction schedule, minimize maintenance work. Figure xx shows North and South roof catchment towards rainwater harvesting tanks installed on site. Rainwater harvested were utilized fully for cooling tower (conditioned air) besides landscape irrigation. Conditioned air is very important to maintain temperature at 18.3 degree Celsius to ensure chocolate does not melt through the process of packaging, wrapping & storage.

Figure 9. Syfonic gutter and Rain Water Downpipe System with North and South rainwater harvesting tank

Water Efficiency in Water Recycling. Wastewater is being treated and recycled leading to reduction in potable water consumption of 34%. In order to reduce the usage of domestic water, portion of the treated water was used for washing the waste water treatment plant (WWTP) equipment, this including static screen, sand filter, activated filter and belt-press as shown in Figure 10.

Reduction in potable water consumption through use of efficient devices. The use of efficient devices and industrial process encourage reduction in potable water consumption. The annual potable water consumption reduction is 54%. Water efficient fittings such as water closet, urinal, water tap with sensor and reduced flow rate are installed.

Figure 10. Waste water being treated and recycled in Waste Water Treatment Plant including washing sand filter, carbon filter, Beltpress machine, Static screen

Water Efficiency in Irrigation and Landscaping. Landscape within Hershey compound is fully irrigated using harvested rainwater and not using potable water at all. Adaptive plants with lower landscape irrigation requirement, which is lower or equal to 0.5 L/m^2/day are selected. Water efficient sprinkler irrigation system is utilised with irrigation efficiency (IE) of 0.625. Figure 11 shows the landscape and irrigation layout.

Figure 11. Landscape layout with irrigation system via harvested rainwater

Metering and Leak Detection System. The water consumption is monitored and managed by water sub-meters at cooling towers, irrigation, kitchens, tenancy use, and industrial process use. Electromagnetic flow meters are equipped at major water usage location as shown in Figure 13. All water sub-meters are linked to Energy Management System (EMS) to facilitate early detection of water leakage. The EMS is able to detect and solve water leaking immediately without further wastage. It is also able to identify root cause and area where water consumption is very high and take necessary steps to reduce water consumption. The excerpt of EMS related to water efficiency as shown in Figure 12.

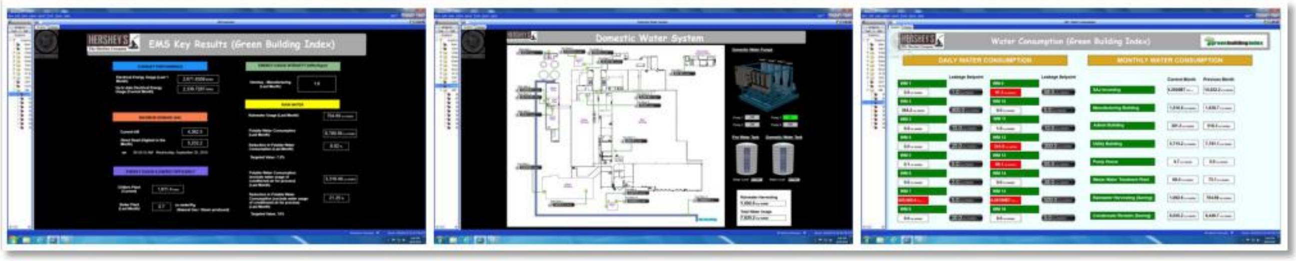

Figure 12. Excerpt of Energy Management System (EMS) related to water efficiency

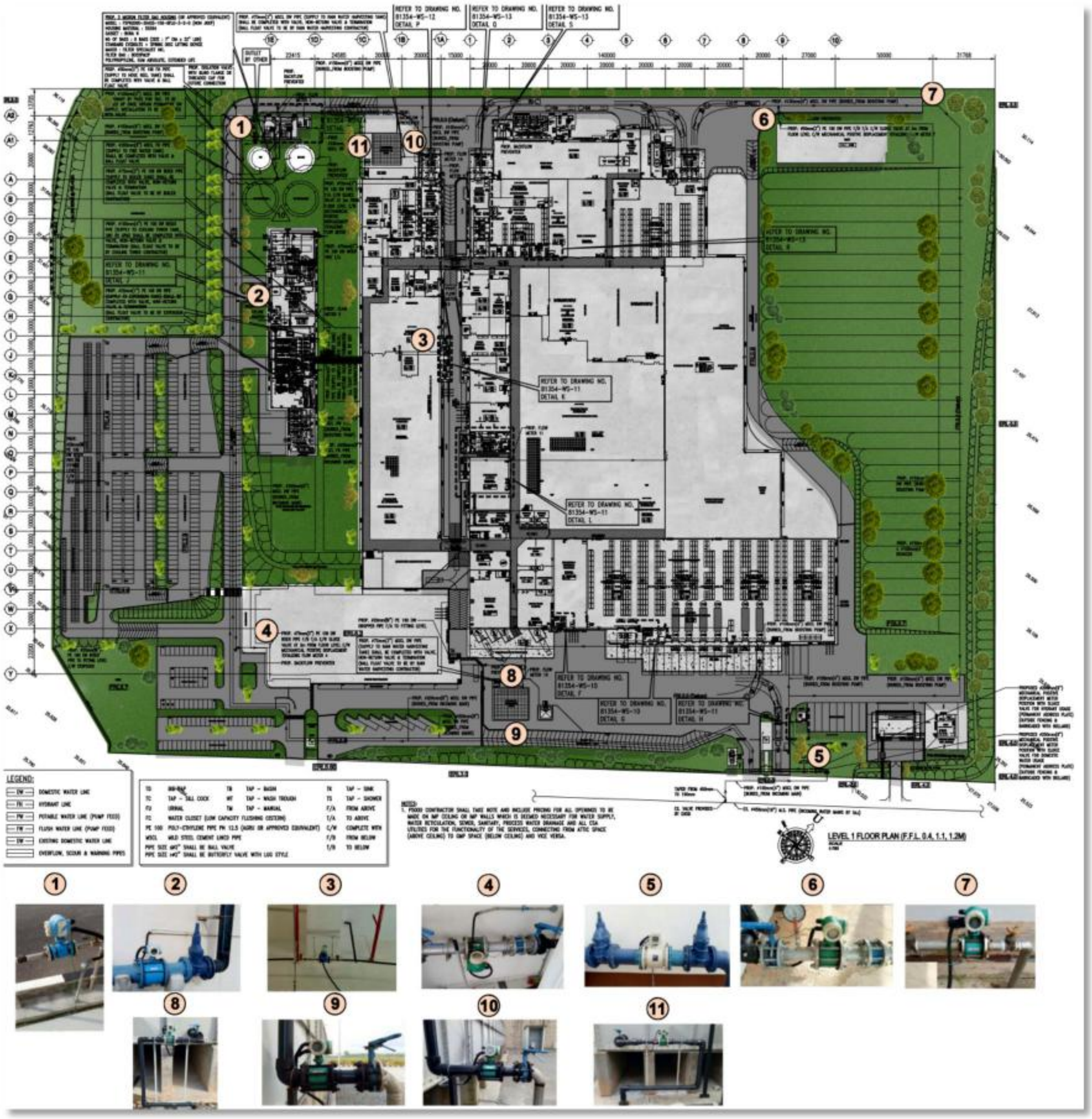

Figure 13. Layout and photos of water submeter

Innovation and Environmental Design Initiatives with Vacuum Degasser System. Vacuum degasser system is implemented to remove micro bubbles and dissolved air from the chilled water system up to 300m^3. It prevents problems associated with air such as corrosion, heat spots and cavitation. Figure 14 shows the vacuum degasser layout and photos installed on site.

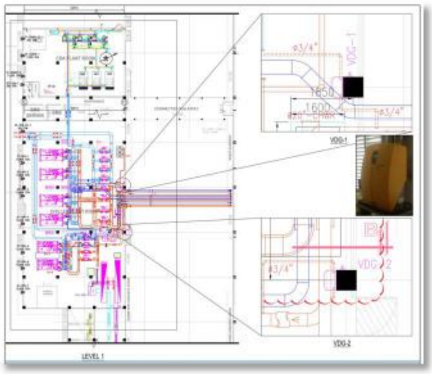

Figure 14. Vacuum degasser layout with photo of actual units installed at site

Innovation and Environmental Design Initiatives with Pressure Independence Balancing Control Valve (PIBCV). Pressure independence balancing control valve (PIBCV) was installed at the air handling unit for controlling the chilled water supply to the unit. The pressure independence balancing control valve, often known as a PIBCV, is a flexible valve that combines flow limitation and balancing capabilities. It enables accurate temperature management while assuring automated and ongoing terminal unit balancing. It is connected into the building management system (BMS). By responding to temperature information gathered from sensors installed in the air-conditioned spaces, this integration enables the PIBCV to provide the best climate control.

Recycling of all Fire System Water during regular testing. Water being used during maintenance of fire pump will be effectively recycled back to the fire tank. An additional dedicated pipeline was added to the system to carry out this novel design, as seen in the figure shown below. Both sprinkler and hydrant pump-set systems can use this environmentally friendly method to make sure that all water is sent back to the fire water tank after testing instead of draining out such large volume of tested water.

Non-chemical water treatment system for condenser. BacComber system was implemented for the condenser water system instead of conventional chemical treatment which is not environmentally friendly. The BacComber system uses one or more pairs of emitters placed in the sump of the cooling tower. The emitters generate Ultra Low Frequency (ULF) electromagnetic radiation wave passing through the water to prevent scale formation and inhibits the growth of bacteria and algae.

Condensate Water Recovery. More than 50% of air handler condensate water of the factory is gathered and pump into plant room's cooling tower makeup tank, thus reduces the domestic water supply. The air handlers on second floor, with PVC drain pipe connected to a temporary condensate reclaim tank at first floor, gathering condensate water into the tank by means of gravity flow. The stored cold water will be pumped to the distant cooling tower makeup tank as soon as water level sensor in the reclaim tank was triggered which indicated that the tank is almost full. The result as per Table 8 shows that the percentage of condensate water reclaimed achieve 72% of total condensate rate.

Table 8. Condensate Water Reclaimed Calculation

ACTUAL CONDENSATE RATE MEASURED		
Date	**Condensate Flowrate**	**Condensate Reclaimed**
1/1/2018	14,186 m3	-
1/2/2018	19,986 m3	5,801 m3
1/3/2018	25,536 m3	5,550 m3
1/4/2018	34,536 m3	9,000 m3
Total Condensate Reclaimed		20,350 m3
Average Condensate Reclaimed		**6,783 m3/month**

CALCULATED EQUIPMENT CONDENSATE RATE	
Equipment	**Condensate Rate**
Air Handling Unit	55.31 USgpm
Fan Coil Unit	1.28 USgpm
Ceiling Cassette	0.29 USgpm
Total Condensate Rate	56.88 USgpm
Total Monthly Condensate Rate	9,431.11 m3/month
% of Condensate Reclaimed	**72%**

Green Education. Green education is implemented by providing multi-information display in the common area to indicate real time building performance like electricity and water usage. It shares the information to the public and serves to encourage and create awareness of going green and to educate the public on the importance of green building. The display is located at cafeteria, where many staffs gathered every day during breakfast, lunch and break time. Information on the lobby display includes Year to Date savings over conventional design energy model; Year to Date savings of actual energy consumption over design model; Equivalent tons of CO^2 emissions eliminated; Equivalent trees planted; Equivalent cars removed from the road.

4. Conclusion

This state-of art-confectionery manufacturing plant was conceived as a statement of sustainability and functionality. Carrying the flagship as Hershey's single largest investment in Asia under 18 years of its presence in the region, within 41 acres of land at Senai Airport City is now the second largest in Hershey's global manufacturing network. Design and built by a local engineering firm, M.E.I. Project Engineers Sdn. Bhd. to the baseline guides of Good Manufacturing Practice (GMP), Global Food Safety Initiatives (GFSI) and Safe Quality Food (SQF), the facility was conferred Gold rated by Green Building Index (GBI) under Industrial New Construction (INC) category.

Acknowledgement

Words can never express our gratitude to the Hershey's Engineering Team who supported the project on the ground for invaluable patience throughout the journey. We could never have undertaken this success without the support from our home office engineers, designers, drafters and architects. Additionally, this endeavor would not have been possible without the support and cooperation from the Hershey family. Thanks should also go to all the local authorities who helped expedite the processing of documents to ensure the projects is run smoothly.

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FIRST DGNB PLATINUM- CERTIFIED FACTORY IN ASIA: A SUSTAINABLE BUILDING DESIGN ACHIEVEMENT ON THE SEMICONDUCTOR FINAL TESTING FACILITY IN BATUKAWAN INDUSTRIAL PARK (BKIP) PENANG, MALAYSIA

Sophia Sheau Wei Than[1], Chie Tung Lim[1], Lai Hoong Lee[1],
Wei Huat Khor[1], Kent Khai Lim[1], Muhammad Azmin Azizan[2]

[1]M.E.I. Consultants Sdn. Bhd., Level 20, BHL Tower 51, Jalan Sultan Ahmad Shah 10050, Penang, Malaysia
[2]Robert Bosch Semiconductor Manufacturing Penang Sdn. Bhd., PMT 821, Persiaran Cassia Selatan 3, Taman Perindustrian Batu Kawan 14110, Bandar Cassia

mei@mei.com.my

Abstract

Robert Bosch has made history by becoming the first factory (PgP5) in Asia received the DGNB Platinum Certification by German Sustainable Building Council. The building design is with Life-Cycle Assessment (LCA) model integration that promotes Green-Energy, life- cycle-cost optimization, sustainability and environmental impacts resulting from building construction and utilization. Optimized building placement for natural daylight harvesting, low-energy building envelope design with an Overall-Thermal-Transmission-Value (OTTV) of <4W/m2K, to achieve sustainable outcomes with biodiversity and landscape design that avoids invasive plant species while promoting habitat connectivity. Utilizes a low Global-Warming-Potential refrigerant, R1233zd (GWP-1) for air-conditioning chillers offering high performance with minimal impact on climate change. Radiant cooling system is implemented through radiant ceiling panels, resulting in reduced energy consumption and lower CO2 emissions. The air-conditioning system's zoning pressurization ensures optimal air distribution, monitored by Temperature- Humidity sensors ensuring machine operation and human comfort. Indoor air quality is maintained via CO2 sensors control. High-efficiency motor (IE5) in the building saves 43,800kW of electricity, contributing to its energy-efficient design. The Rain Water Harvesting system for cooling-tower-make-up water achieved approximately 60% potable water reduction. The building also features with Photovoltaic panels installation (>2,000kWp) and EV chargers to reduce carbon footprint and promote sustainability.

Keywords: DGNB; Life-Cycle-Assessment; Global-Warming-Potential; Radiant-cooling; Photovoltaic.

1. Introduction

Global energy-related carbon dioxide emissions increased by 6% in 2021, reaching 36.3 billion tonnes, the highest level ever. This increase of nearly 2.1 gigatonnes from 2020 levels is the largest year-on-year increase in absolute terms for energy-related CO2 emissions [1] and Bosch has set a goal to reduce 15% of CO2 emissions by 2030 [2]. This aligns with the principles of life cycle assessment (LCA) and its application in sustainable building practices. Life-cycle assessment (LCA) is used to evaluate the environmental impact of a product or service [3]. In the context of sustainable building, LCA is used to assess the environmental performance of building materials, systems, and processes.

The project for Robert Bosch Semiconductor Manufacturing Penang Sdn. Bhd. (RBSP) in building the Semiconductor Final Testing Facility Plant of PgP5 presents a comprehensive look on the acceptance and effectiveness of various energy-efficient and sustainable methods in relation to sustainable building design. These multifaceted systems include but not limited to natural daylight harvesting and low-energy building envelop with optimum of the Overall Thermal Transfer Value (OTTV), design with low global warming potential material, applying passive radiant cooling system and zoning pressurization, enhanced with indoor air quality (IAQ), rain water harvesting system, and use of PV & EV chargers form the core planes of this project. In addition to the energy-efficient and sustainable methods, the biodiversity and landscape design is another key feature of this project promoting eco-habitat that is aligned with LCA and local environmental impact. The objective is to empirically evaluate the impact of these systems collectively and individually have on improving the energy efficiency of buildings, boosting indoor environmental conditions, enhancing the use of renewable energy and most importantly, mitigating the associated carbon footprint.

Outstanding to the company's emphasis on the DGNB criteria for Environmental Quality (ENV), Economic Quality (ECO), and Sociocultural and Functional Quality (SOC), RBSP was able to be the first-ever company in Asia to achieve Platinum certification for its building. Hence, through rigorous data collection and analysis, the paper proposes to provide evidence-based insights into the implementation and repercussions of these energy- efficient practices and strategies.

2. Working Principle

Natural Daylight Harvesting. Lighting is one of the largest consumers of electricity and causes of energy related greenhouse gas emission. Natural Daylight Harvesting (NDH) is an important factor to consider in Life-Cycle Assessment studies. By incorporating the Natural Daylight Harvesting (NDH) into the building designs can significantly reduce the consumption of lighting system, subsequently reduce the energy consumption from artificial lighting.

The purpose of the daylighting design is to provide acceptable daylight levels to occupants while minimizing glare and excessive heat gain. The design criterion to envelope building with the NDH to give sufficient mix of the light for the building has been adopted for Bosch PgP5.

Based on the Malaysian Standard MS 1525:20017, daylight factor is used to describe the daylight distribution, penetration and intensity in percentage [4]. In another word, daylight factor is the ratio of the internal illuminance at a point in a room to the instantaneous illuminance outside the building. Besides, it is recommended that the illuminance level for general offices to be about 300 lux to 400 lux and shall be selected for efficient distribution of light without producing discomfort glare.

Overall Thermal Transfer Value (OTTV). The fundamental of low energy building envelope is to be able to block out heat gain into buildings via conductionand solar radiation. Solar heat gain through the building envelope constitutes a substantial share of cooling load in an air-conditioned building. In non-air-conditioned buildings, the solar heat gain causes thermal discomfort. Tominimize solar heat gain into a building is, therefore a very important consideration in the design of an energy efficient building. A design criterion for building envelope with the Overall Thermal Transfer Value (OTTV) hasbeen adopted for Bosch PgP5. The OTTV requirement is a simple, and applies only to airconditioned buildings. The OTTV aims at achieving the design of building envelope to cut down external heat gain and hence reduce thecooling load of the air-conditioning system.

Global Warming Potential. RBSP utilizes a low Global-Warming-Potential refrigerant, R1233zd (GWP-1) for air-conditioning chillers whichoffers high performance while having a minimal impact on climate change. Global Warming Potential (GWP) isan important metric for assessing the impact of greenhouse gases on climate. It measures the heat-trapping efficiency of gases relative to carbon dioxide (CO2), which CO2, the reference gas, has GWP of 1 [5]. GWP values are typically calculated in 100-year timeframe [6] and are used to determine the amount of gas contributingto global warming. For example, R134a has a GWP of 1430 [7], meaning it is 1430 times more efficient at capturing heat than CO2 per century.

The Montreal Protocol, established in 1987, aims to protect the ozone layer by phasing out ozone-depleting substances (ODS) [8]. It led to the worldwide discontinuation of ozone-depleting chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) by 2030 [8]. The Kigali Amendment focuses on reducing hydrofluorocarbons(HFCs), potent greenhouse gases [9]. Emerging trends emphasize transitioning away from high ODP and high GWP refrigerants, like R134a from family of HFCs, in favour of low GWP alternatives for more sustainable cooling systems. To highlight, R1233zd used in RBSP is a one of the hydro-fluoro-olefins (HFOs) [10] and is alsoan ultra-low GWP alternative (GWP =1) [11] to R123 from family of HCFCs. R1233zd is non-flammable, has higher capacity and similar efficiency as R123. R1233zd is used in low pressure centrifugal chillers, which are typically employed to cool big buildings [12].

The understanding of Global Warming Potential (GWP) and the environmental impact of refrigerants is paramount. RBSP prioritizes environmental responsibility by opting for R-1233zd, a low GWP refrigerant. This choice aligns with global efforts to reduce greenhouse gas emissions and combat climate change. RBSP emphasize sustainability, green energy, and responsible practices. The use of R-1233zd reflects our commitment to a more eco-friendly and sustainable future.

Radiant Cooling System. Radiant heating and cooling systems are a type of HVAC technology that uses both convection and radiation to transfer heat to or from the environment [13]. In the context of radiant cooling using radiant ceiling panels with closed ceilings, roughly 70% of heat transfer occurs through radiation, while approximately 30% occurs through convection. To facilitate the exchange of heat between the room and the ceiling, the ceiling's temperature is deliberately kept lower than the ambient room temperature. As the air in the room warms up due to environmental changes, the warm air rises due to lower density, then it cools down on the surface of the chilled ceiling and falls again. This heat transfer process is known as free convection, as it does not involve any movement of air that is forced by external means. For radiation heat transfer, all heat sources in a room remove their warmth from the chilled ceiling. These sources include the surface of the floor, furniture, and humans. The ceiling dissipates the cooling load by transporting the heated water to the chiller to cool. As radiation heat transfers directly tempers objects in a room rather than the room air, a pleasant atmosphere can be created [14].

Zoning Pressurization. The main equipment that is used to achieve pressurized zoning is the makeup air unit (MAU). A typical method for cooling and dehumidifying the air in the Make-up Air Unit (MAU) involves passing chilled water through the cooling coil. To enhance energy efficiency, a strategy involving the utilization of both Medium Temperature (MT) and Low Temperature (LT) Chilled Water systems is employed. Besides, the MAU units utilize IE5 motors, which offer superior energy efficiency compared to the more commonly used IE3 motors [15]. Improved efficiency will result in decreased power usage and energy expenses, while also promoting a more eco-friendly and environmentally conscious approach to air conditioning and humidity control.

Indoor Air Quality (IAQ). Indoor Air Quality (IAQ) is of paramount importance for the health and well-being of building occupants. It encompasses the quality of air within and around structures and directly impacts the immediate and long-term health of individuals. Understanding and controlling indoor air pollutants is crucial to reducing health risks and ensuring a safe and comfortable indoor environment for all [16].

The primary causes of indoor air quality (IAQ) problems often originate from indoor pollution sources, with building materials and furnishings playing a significant role. Many building materials, furnishings, and products used can release gases or particles into the air, contributing to IAQ issues. Using environmentally friendly materials, which are characterized by being solvent-free, low in volatile organic compounds (VOCs), and halogen- free, can significantly enhance indoor air quality (IAQ).

Rain Water Harvesting System. This system can sustainably source water in areas with consistent and reliable rainfall such as in Malaysia. Thesesystems are comprised of catchment areas (roof), filtration systems and water tanks. The roof and canopy of a building acts as catchment areas, collecting large amount of rainwater. Water will then flow through gutters and drain pipes to the Continuous Deflective Separation (CDS) Filtration Unit. Here, small pollutant particles are separated from rainwater with a separation screen, while oil, which may or not be present, floats above denser rainwater and is removed by the oil retention baffle. The CDS Filtration Unit requires minimal maintenance as the separation screen is capable of self-cleaning, where the collected pollutant particles sink and is stored in the litter sump below the separation screen. The filtered water is then stored in an underground tank.

PV and EV Charger. The photovoltaic (PV) effect, a fundamental phenomenon in the field of solar energy, operates through the interaction of sunlight with semiconductor materials, primarily silicon [17]. By connecting multiple PV cells into modules and arrays, the cumulative electrical output can be scaled to meet diverse energy demands [17]. In grid- tied systems, inverters are employed to convert DC electricity into alternating current (AC) for integration with the electrical grid. The photovoltaic effect thus serves as the underlying principle enabling the sustainable conversion of sunlight into electrical energy, holding promise for clean and renewable power generation.

Biodiversity and Landscape Design. Biodiversity at site is a fundamental component of ecosystems and plays a crucial role in their functioning and resilience. The term "biodiversity at the site" refers to the range of living things and ecosystems that exist in a particular place or region. This covers all life forms, from plants and animals to microorganisms, as well as all of their interactions and connections. Biodiversity is built out of three intertwined features which are ecosystem diversity, species diversity and genetic diversity. The more these features are intertwined, the denser and more resilient the net becomes. By considering biodiversity in the Life-Cycle Assessment (LCA), the environmental impact of the product or process can be more accurately evaluated, leading to more informed decision-making and the development of more sustainable solutions.

Promoting habitat connectivity through biodiversity at the site and landscape design can have several benefits for biodiversity conservation. Connectivity between habitats has been found to increase the spillover of plant biodiversity, with greater species richness observed in non-target habitats around patches connected by corridors[18]. This means that by promoting habitat connectivity through biodiversity at the site and landscape design, wecan enhance the movement of species and the exchange of genetic material, leading to more diverse and resilientecosystems. By incorporating biodiversity at the site and landscape design, we can help create and maintain theseconnected habitats, supporting biodiversity in urban areas.

3. Results and Discussion

Natural Daylight Harvesting. According to the sun direction at the semiconductor final testing facility (PgP5) which located in Batu Kawan Industrial Park (BKIP), Penang, Malaysia, the orientation of the building is almost parallel to the path of the sun throughout the year. This shows that daylight availability for the office space during the working hours (8.00 am to 5.00pm) is more than sufficient and glare protection for the south office space is much needed for visual comfort.
As per German Sustainable Building Council (DGNB), a numerical model is established to evaluate the daylighting performance of the simulation zone (office). There were three type of stimulation models carried out at the area; (1) daylight study, (2) energy consumption, and (3) thermal comfort. The material used and the properties of the office façade in the building are describe in detail in Table 1.

Table 1. Office Facade Options

Configuration	1	2	3	4	5
Roof	Concrete 150mm (conductivity= 1.44 W/mK) 100mm Rockwool (conductivity= 0.035 W/mK)				
Glazing	Single Glazed SHGC= 0.72 Visible Transmittance=85% U-value=5.50 W/m^2K	Double glazed + low-e (6+12+6)SHGC= 0.27 Visible Transmittance= 47% U-value= 1.50 W/m^2K			
Green Wall	Light (80% transparency)		Dence (20% transparency)		
Skylight	No			Translucent skylight Visible and heat transmittance 50% Wide 1.20m	No
Vertical Fins	Yes				No

Based on the stimulation model results, the concept which developed from recommended solution has been developed to the vertical green façade design with 80% greening. In term of daylight colour rendering, Top IGU stopray 50T have been applied to all south office working spaces which is the double-glazed system.

Overall Thermal Transfer Value (OTTV). According to the Malaysia code of practice on energy efficiency, OTTV of the building envelope having a total air-conditioned area exceeding 4,000m3 and above should not exceed 50W/m2. Calculation of OTTV for Bosch PgP5 based on the heat conduction through wall and windows, solar heat gain through the double-glazed windows, as well as properties of the building envelop material including the insulated wall panel as shown in Table 2 is 4.75 W/m2 which has achieved 90.5% lower than the minimum of 50.0 W/m2.

Table 2. OTTV Calculation Data

		Area (m^2)	OTTVi	Ao x OTTVi
SOUTH	Metal sheet	1836.6	1.2	2203.92
	CMU 250mm + Double Glazing	757.1	21.2448	16084.42
	Zenbes 150mm	113.8	9.2625	1054.0725
WEST	Metal sheet + Double Glazing	458.7	4.63676	2126.8808
	CMU 250mm + Double Glazing	66.65	26.3018	1753.0156
NORTH	Metal sheet 60mm	2588.6	1.2	3106.32
	Zenbes 150mm	155.4	9.2625	1439.3925
EAST	Metal sheet 50mm	136.1	1.2	163.32
	CMU 250mm	61.1	2.25	137.475
	Zenbes 150mm	282.3	9.2625	2614.8038
TOTAL		**6456.35**		**30683.62**

$$OTTV = \frac{A_O \times OTTVi}{Area} = \frac{30683.62}{6456.35} = 4.75\ W/m^2 \quad (1)$$

Global Warming Potential. To validate that R1233zd used in RBSP not only is more environmentally friendly than traditional refrigerant but also has higher performance in terms of energy efficiency and cost saving, R134a is used as a comparison as shown in Table 3. Consequently, the adoption of R1233zd in the chiller results in substantial energy savings, totaling 304,804 kWh per year when compared to the R134a-based chiller. This translates to an impressive 11% reduction in energy consumption. Additionally, the use of R1233zd leads to annual cost savings of RM 90,933, representing another 11% reduction in annual operating expenses.

Table 3. Energy and Cost Analysis

Refrigerant Type	R1233zd	R134a
Chiller Type	VSD Centrifugal	VSD Centrifugal
GWP	1	1,430
Chiller Tonnage (RT)	500	500
Chilled Water In/Out (°C)	5.0/11.0	5.0/11.0
Condenser Water In/Out (°C)	32.0/38.0	32.0/38.0
Energy Efficiency (Assume Average Chiller Loading Factor Factory), 0.05(100%) + 0.25(90%) + 0.3(80%) + 0.25(70%) + 0.1(60%) + 0.05(50%)) (kW/Ton.R)	0.5570	0.6266
Energy Usage (kWh/Year)	2,439,660.0	2,744,464.40
Energy Saved Compared to R134a	304,804.20 kWh/year (11%)	

Radiant Cooling System. As mentioned, the implementation of radiant cooling systems may lead to more energy savings as compared to conventional cooling systems. This energy saving primarily arises from the absence of a fan in radiant cooling systems, which means the energy typically consumed by fans in conventional cooling systems can be conserved.
By using equation 3, the CFM is evaluated to be 6036 cubic feet per minute based on total cooling load of 38kW and ΔT of 19.8°F. Given average fan coil units have capacities of 1100 cfm [25], at least 6 unit of fan coil unit is required to meet the flow rate requirement. The fan will be operating with 3 inches of water static pressure and is assumed to have 70% efficiency. The CFM of the fan can be converted to power consumption in kilowatts (kW) using the following formula. Table 4 show the power consumption and the energy cost of the fan respectively.

$$Q = 1.085 * CFM * \Delta T \quad (2)$$

$$Power\ Consumption\ (kW) = \frac{746 * CFM * Static\ Pressure\ (inch\ water)}{6356 * Efficiency * 1000} \quad (3)$$

Table 4. Energy and Cost Analysis of Fan

Parameters	
Power Consumption (kW)	3.04
Total Power Consumption a year (24/7) kWh/year	26630.40
Peak Period - 14 hours per day (RM0.355/kWh)	5514.71
Off-Peak Period - 10 hours per day (RM0.219/kWh)	2429.99
Total Energy Cost Per Year (RM)	7944.70

Zoning Pressurization. To prove that using both MT and LT Chilled Water for the MAU saves more energy and is more environmentally friendly than using only LT Chilled Water, we performed an energy analysis between MAU using LT chilled water for cooling and dehumidification versus MAU using MT Chilled water for cooling and LT Chilled water for dehumidification. Significantly less power on average (0.4246) is consumed bythe chiller providing MT Chilled Water than by the one using LT Chilled Water (0.5570), and this fact should benoted. Table 5 reveals a significant energy savings per year for RBSP when opting for MT & LT Chilled Water to serve the MAU in all areas. This energy-efficient strategy alignsperfectly with RBSP's commitment to environmental sustainability and green building principles by prioritizing energy savings and operational efficiency.

Table 5. Energy Comparison by Using MT & LT Chilled Water Compared to LT Chilled Water Only

Energy Analysis (24/7)	**LT Chilled Water Only**	**MT & LT Chilled Water**
MAU-501-02-01 & 02 (kW/year)	468,918.41	961,861.88
MAU-501-02-04 (kW/year)	64,568.90	127,054.69
MAU-501-02-05 (kW/year)	311,200.93	613,909.88
MAU-501-02-06 (kW/year)	182,063.13	343,137.62
Total Power Consumption (kW/year)	2,366,128.65	2,045,964.07
Energy Saving (kW/year)	466,384.08 (19.7%)	

Table 6 displays the energy comparison between IE3 and IE5 motors. Assumption is made for the loading factor of each MAU in this comparison. There is a noteworthy disparity in equipment costs, with IE5 motors being substantially more expensive than their IE3 counterparts. Nevertheless, even with the higherinitial investment required for IE5 motors, the energy savings they generate offset the additional upfront cost within a span of 5 years. The data clearly indicates that IE5 motors exhibit significantly lower power consumption across various rated loads in comparison to IE3 motors. This substantial reduction in power usage can be attributed to the superior efficiency of IE5 motors, which enablesthem to achieve the same output while consuming less energy when compared to IE3 motors.

Table 6. Energy Comparison between IE3 and IE5

Energy Analysis (24/7)	**IE3**	**IE5**
MAU-501-02-01 & 02 (kWh/year)	405,654.44	235,078.07
MAU-501-02-04 (kWh/year)	252,311.11	236,843.47
MAU-501-02-05 (kWh/year)	53,734.53	41,457.95
MAU-501-02-06 (kWh/year)	31,240.60	37,541.31
Total Power Consumption (kWh/year)	1,626,982.75	1,770,233.65

Indoor Air Quality (IAQ). An assessment on the indoor air quality (IAQ) has been carried out in PgP5. Total 64 parameters of VOCs, TVOCs and Formaldehyde in the selected location have been analyzed. Overall, the TVOC levels across all sampling locations are below 500 µg/m³, and formaldehyde measurements do not exceed 30 µg/m³, thereby meeting the DGNB requirements. Themeasurements of formaldehyde and individual volatile organic compounds at four sampling locations, as detailed in Appendix 3.6-1 and 3.6-2, reveal that TVOC levels are consistently below 12.5 µg/m³ in P1 Cleanroom (Front), P2 Cleanroom (Back), and P3 Office (Back). However, P4 Office (Front) records a TVOC level of 207 µg/m³. Notably, formaldehyde concentrations at all four locations remain within acceptable limits, aligning with the criteria stipulated by DGNB. It is important to emphasize that the selected rooms for air quality assessment adequately represent significant fitting types within the building, making them indicative of potential pollution from building materials employed.

Rain Water Harvesting System. Table 7 depicts the average monthly rainfall in Batu Kawan measured in millimeters per square meter (mm/m²). The lowestrainfall occurs in January with 68 mm/m², while the highest rainfall is recorded in September with a substantial 324 mm/m².The trend in Batu Kawan's rainfall pattern showcases a distinct wet season and dry season. The months of April to Octobergenerally experience higher rainfall, with a peak in September, indicative of the monsoon season.

Conversely, the monthsfrom November to March exhibit lower rainfall, with January being the driest. This cyclical pattern of wet and dry seasonsis a characteristic climatic feature of Batu Kawan. There are three Rain Water Harvesting tanks as seen in Table 8 being constructed in PgP5. Based on maximum rainfall which is in October and assumed with six months monsoon session, theestimated rain water collected is 1866m^3. In accordance to the Penang water tariff, the water cost saving is approximatelyRM3000.00.

Table 7. Average Monthly Rainfall

	Month											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mean rainfall [l/m²]	68	69	117	231	218	162	201	217	324	330	225	136.0

Table 8: Technical Data of Rainwater Harvesting Tanks in Phase 1

	RWHT 1 (West)	RWHT 2 (East)	RWHT 3 (Entrance Building)	Remarks
Area (m^2)	108m x 48m = 5184	114m x 48m = 5472	(171m x 15.5m) + (20m x 54m) =3731	
Volume of RWHT (Based on October's rainfall 195.89m^3/day)	70.6	74.5	50.8	195.89
Remaining Volume	41.5	43.8	29.9	114.11
Proposed Volume of RHWT (m^3)	112	118	81	311
Proposed dimension of RWHT (RC Tank)	20m(L) x 3m(W) x 2m(D)	20m(L) x 3m(W) x 2m(D)	15m(L) x 3m(W) x 2m(D)	

PV and EV Charger. Table 9 indicates PgP5 power consumption recorded in the electrical bills throughout a period of 12 months starting from July 2022 to June 2023 with an average of maximum demand of 816.25kW. The maximum capacity according the Energy Commission guidelines for grid connected solar PV for commercial customer is 85% of the maximum demand which calculated as 693.81kW in AC and equivalent to 901.96kW in DC.

Table 9. PgP5 Electrical Consumption Throughout 12 Months Period

Meter Reading Date	Recorded Main Peak kWH	Main Peak kW	Average MD	85% of MD	DC Value
31/07/2022	52,276.00	444	816.25	693.81	901.96
31/08/2022	163,162.00	665			
30/09/2022	163,464.00	687			
31/10/2022	193,420.00	760			
30/11/2022	286,836.00	960			
31/12/2022	298,272.00	822			
31/01/2023	319,410.00	799			
28/02/2023	298,131.00	929			
31/03/2023	334,986.00	936			
30/04/2023	319,815.00	952			
31/05/2023	336,922.00	933			
30/06/2023	331,438.00	908			

Considering the local sun peak hour is assumed to be 3.5, the monthly energy can be generated from the solar PV with the specification in Table 10 is approximate to 94,705.8kWh which is also the amount of energy that can be saved throughout the year. However, the recorded main peak kWH in Table 9 shows a much higher values indicating more energy being saved compared to the assumed value than the installation of the solar PV with the capacity of 901.96kWp using the solar panel according to the specification in Table 10 will only takeup the roof spaces as indicated in Figure 1 while also still having enough space to install another 885.6kWp of solar PV should the maximum demand for PgP5 increases in the future.

Table 10 presented below provides specifications for the utilized PV system and Figure 1 offers a comprehensive view ofthe PV roof installation, including both a top-down layout view of the building and an isometric representation.

Table 10. Specification of Solar Panel (JKM575N_72HL4)

	STC	NOCT
Maximum Power (Pmax)	575Wp	432Wp
Maximum Power Voltage (Vmp)	42.22V	39.60V
Maximum Power Current (Imp)	13.62A	10.92A
Open-circuit Voltage (Voc)	50.88V	48.33V
Short-circuit Current (Isc)	14.39A	11.62A
Module Efficiency STC (%)	22.26%	
Operating Temperature (℃)	-40℃~+85℃	
Maximum system voltage	1000/1500VDC (IEC)	
Maximum series fuse rating	25A	
Power tolerance	0~+3%	
Temperature coefficients of Pmax	-0.30%/℃	
Temperature coefficients of Voc	-0.25%/℃	
Temperature coefficients of Isc	0.046%/℃	
Nominal operating cell temperature (NOCT)	45±2℃	

Figure 1. Comprehensive Solar PV Installation Layout

On top of the installation of the rooftop solar PV connected to the grid, PgP5 also include the installation of solar PV withthe capacity of 24kWp at the west façade area which is not connected to the grid as per specified in the Table 11. The westfaçade solar PV contributes to additional energy saving of 1,400kWh to the rooftop solar PV (94,7056kWh) monthly fromthe average monthly electrical consumption which is 231,526kWh according to the recorded electrical consumption in Table 9.

Table 11. Technical Specification for Installation of West Facade Solar PV

Technical Specification	
Capacity*	24 kwp
Quantity of Panels	48 pcs
Specific Yield (kwh/kwp) **	700 yearly
First Year Generation	16,800 kwh
Average Monthly	1,400 kwh

Aside from the installation of solar PV above, Robert Bosch also realized the installation of a total of three EV charging stations for the PgP5 car park area complying to the mobility infrastructure under the DGNB requirement.

Biodiversity and Landscape Design. The building outdoor area now has measures in place to support new and native animal species such as Mammal, Bird, Invertebrate, Reptile and Amphibian. Diversity of animal species on building has been divided into three different zones as shown in Figure 2.

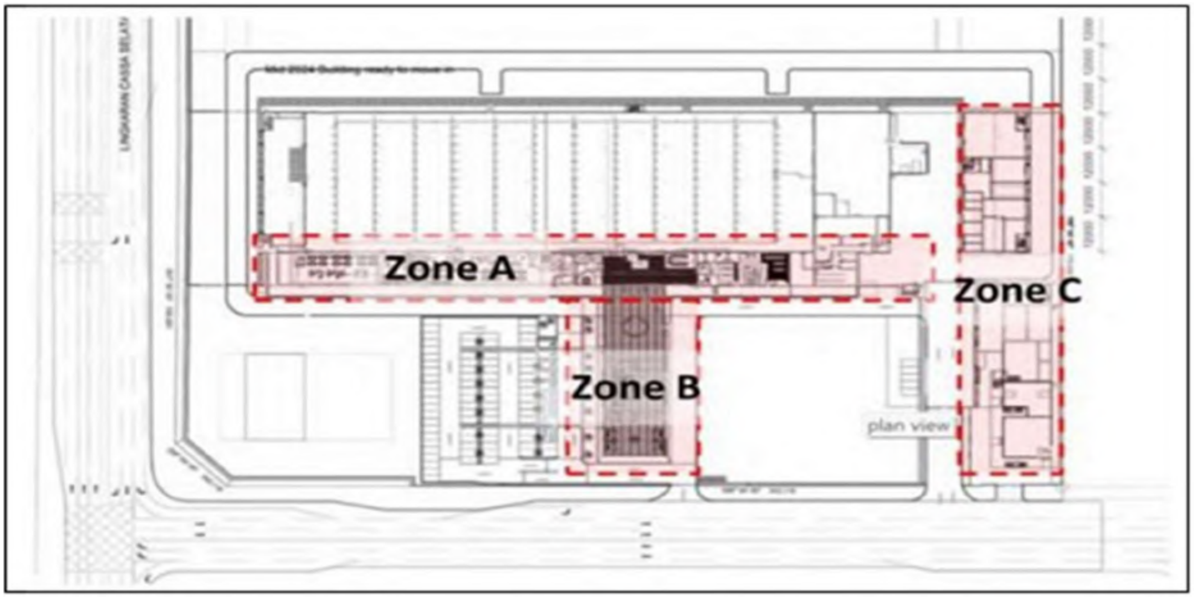

Figure 2. PgP5 Diversity of Animal Species on the Building

The quick-growing climber with flowers of Tristellateia Australasiae which will be in bright yellow have been used for building vertical greening, pergolas, trellises and fences at both Zone A. It can be trained to serve as a low hedge or as ground cover. It is appropriate for gardens, parks, or highway medians. By planting Tristellateria Australasiae at Zone B, the flowers will visit by bees, butterflies, and sunbirds. Thunbergia grandiflora at Zone C, a green plant with a rapid growth rate that is good for butterflies and honey bees contained in vertical planting.

Biodiversity Strategy and Habitat Connectivity. Long-term biodiversity strategy can benefit the local environment. It will provide for future site development is devised and implemented for the building and its immediate environs. A 6 m wide green space with a bioswale and raingarden design near the entrance could help establish connections between the nearby biotopes that lead to the north bioretention canal as per Figure 3. 2-year detailed maintenance schedule has been provided to encourage the suitable condition for vegetations. Whereas at the north of the land plot, total 12,400 m2 of self-sustaining forest which to be carried out in 4 phases within 7 years have also been carried out.

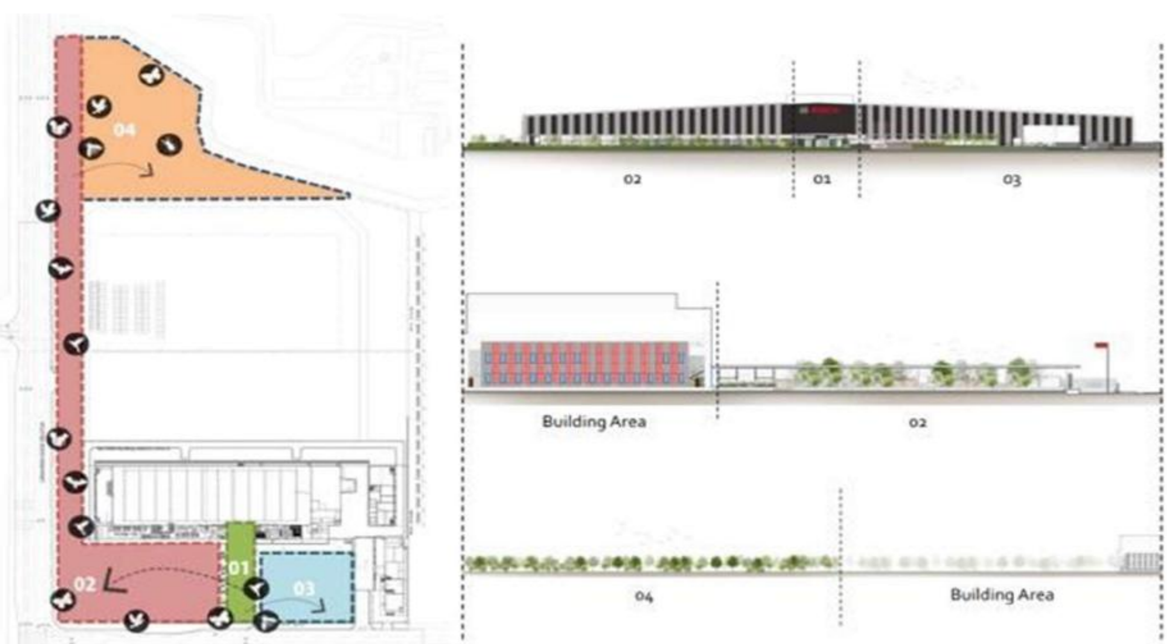

Figure 3. Example of Biodiversity Strategy and Habitat Connectivity Design

4. Conclusion

In summary, the Semiconductor Final Testing Facility (PgP5) located in Batu Kawan Industrial Park has successfully obtained the DGNB Platinum accreditation, thereby becoming the first facility in Asia that has been awarded this prestigious accreditation. The architectural design of the building combines sustainable strategies, including the utilisation of natural sunshine to optimise energy efficiency, the implementation of a low-energy building envelope design, the incorporation of biodiversity and landscape elements, and the adoption of refrigerants with low Global-Warming-Potential. The adoption of energy-efficient practices and techniques have led to enhanced energy efficiency, indoor environmental quality, and use of renewable energy sources, while simultaneously reducing the carbon footprint.

Acknowledgement

We would like to express our sincere gratitude to Robert Bosch Semiconductor Manufacturing Penang Sdn. Bhd. for their invaluable support and collaboration throughout the duration of this project, especially during these challenging times. Despite the difficulties posed by the pandemic, their expertise and commitment, along with the assistance of the Global Real Estate Integrated Projects, Planning and Realization team (GR/PPR) as well as facility team (FCM), have been instrumental in the successful completion of our project. We would also like to acknowledge the home office engineers, designers, drafters, and management supports for their unwavering dedication and invaluable input during these unprecedented times. Additionally, we extend our thanks to all the local authorities who have expedited the processing of documents, ensuring a smooth and seamless execution of the project. Without the support and collaboration of all these individuals and organizations, this project would not have been possible. We are truly grateful for their contributions and look forward to future opportunities for collaboration.

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PENSTOCK REINFORCEMENT LARONA HYDRO POWER PLANT

Baso Murdin[1], Anom Prasetio[2], Kiamuddin[2], Zainuddin[3] and Fahmi Izdiharrudin[1]

[1]Energy Management Vale Indonesia, Sorowako, South Sulawesi, Indonesia
[2]Hydro Dams & Surveillance Management Vale Indonesia, Sorowako, South Sulawesi, Indonesia
[3]Environment and Permit Management Vale Indonesia, Sorowako, South Sulawesi, Indonesia

baso.murdin@gmail.com

Abstract

In supporting Nickel Company to achieve a production target of 90,000 tons of nickel in 2025, additional supply of electrical energy is needed to achieve this production target. One of the methods that can be used to increase electrical capacity is penstock reinforcement. This case study specifically pertains to the Larona Hydro Power Plant. The results of study that the Larona penstock remains in good condition and can function properly. Based on material test results for Larona Penstock per ASTM A537 Class 2. Associated with the plan to increase the operating discharge of the Larona penstock from 51 m3/s to 53 and 56 m3/s, the water hammer pressure increased by about 14% based on simulation results, and some of the penstock sections need reinforcement. The proposed penstock reinforcement consists of the longitudinal application of stainless steel strips and other treatments to the mechanical and structural components. Fatigue analysis is used for get design penstock pipes. With an average vibration of 0.5 mm/s, the remaining life of the penstock is 53.33 years after Penstock Reinforement. With the strengthening carried out, the remaining life of the Larona penstock is expected to be more than 50 years. The maximum stress that occurs in the belt structure is 132.59 MPa, which is still less than the allowable stress of 138 MPa for SUS 316 stainless steel material and The maximum displacement is 4.08 mm.

Keywords: Increase Electricity Power; Penstock Reinforcement; Fatigue Analysis; Remaining Life

1. Introduction

In supporting PT. Vale Indonesia Tbk (PTVI) to achieve a production target of 90,000 tons of nickel in 2025, of which 10,000 tons will be donated through the RKEF (Rotary Kiln Electric Furnace), additional supply of electrical energy is needed to achieve this production target. This additional electrical energy will be obtained from increased electricity production in PTVI's 3 hydropower plants. Based on production capacity, Larona HEPP has the highest capacity of 180 MW, followed by Balambano HEPP with 116 MW and Karebbe HEPP with 104 MW in the cascade scenario. Optimization of vulnerable production capacity is found in the Larona hydropower infrastructure system which is quite old for more than 40 years. Larona hydropower plant has 3 (three) turbine units and has been operating since 1979 with an average continuous power production of 165 megawatts. With the age of having reached 43 years of operation, PT. Vale Indonesia has conducted several assessments on the building facilities and equipment of the Larona hydropower plant.

Assessment on the penstock of the Larona hydropower plant which has been carried out internally by PT. Vale Indonesia requires a third party to verify and complete data and analysis of the penstock. From the assessments that the feasibility and the life time of the Larona Hydropower Plant penstock structure can be identified.

2. Materials and Methods

The methodology by conducting site visits to the Larona hydropower plant for the purpose of visual observations and the collection of vibration data from the penstock pipes. Subsequently, we are actively engaged in the comprehensive assessment of penstock fatigue, employing a flow-induced vibration analysis approach. Concurrently, we have commenced the preparation of detailed engineering designs aimed at enhancing the structural integrity of the Larona penstock pipes. In tandem with this process, we are also in the midst of developing construction drawings, acquiring material samples, and meticulously estimating implementation and construction costs.

3. Results and Discussion

Penstock Reinforcement. In this condition the flow in the penstock is simulated when the wicket gate is closed starting from t=0 seconds to t= 7.5 seconds or 15 seconds, where the wicket gate is completely closed. The simulation is performed by dividing the wicket gate area into smaller parts and closing it part by part sequentially. The plan to increase the operational discharge of the larona penstock pipe from 51 m3/s to 53 m3/s and 56 m3/s can be carried out after the penstock reinforcement is carried out. From Simulation, with the increase in flowrate from 51 m3/s to 53 m3/s and 56 m3/s, the maximum water hammer pressure will also increase from 4.27 MPa to 4.87 MPa or an increase of 14%. In order for an increase in pressure due to water hammer is not excessive, Larona penstock valve closing time not less than 15 seconds.

Based on the calculation, the existing pipe need a reinforcement between segments of MC#4 – MC#14 because of the ultimate stress is exceeds the allowable stress of pipe material. To reduce the stress that occurs on the penstock pipe, the reinforcement should be applied to increasing the degree of stiffness on the pipe and saddle structure. The reinforcement will be added on penstock pipe is a pipe support system with a belt (Stainless steel plate) on body of pipe that can be seen on the Figure below. The support modification type model consists of three restraints, one in a vertical direction, and two skew restraints at an angle of 90. This support is applied from MC#4 – MC#14. Since the saddle support extends along the length of the pipe every 2 m length a set of these models is modeled.

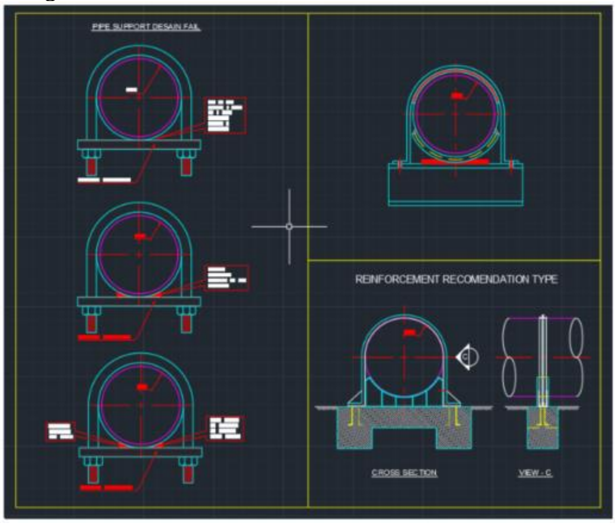
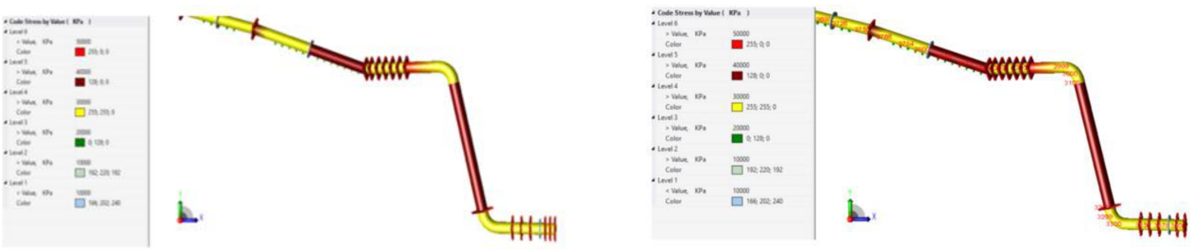


Figure 1. Reinforcement Design



(a) (b)

Figure 2. (a) Existing Design (b) After Reinforcement

The stress analysis simulations above do not take into account the vibrations that occur in the penstock. Vibration that occurs continuously will cause fatigue stress on the pipe material. By increasing the flowrate in the penstock, it is possible to cause the vibration to become even greater. Therefore, the vibration problem must be addressed first. From this under graph shows a summary of stress along the penstock. Under normal conditions, the calculated stress is still far below the allowable stress. During the water hammer stress will increase sharply as the internal pressure increases. The effect of the seismic load in transverse direction is significant compared to the load from the water hammer. High stress occurs between MC#4 and MC#14 of the penstock, where the stress exceeds the allowable stress.

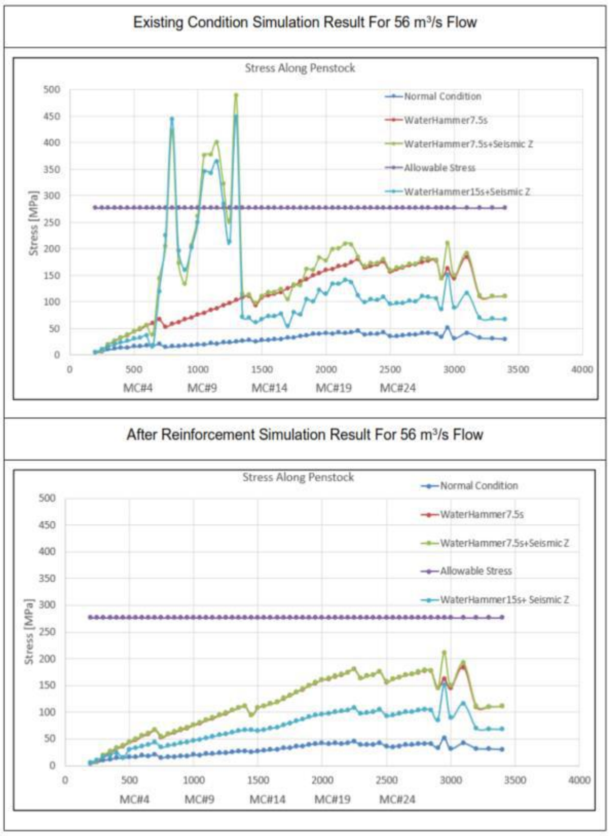
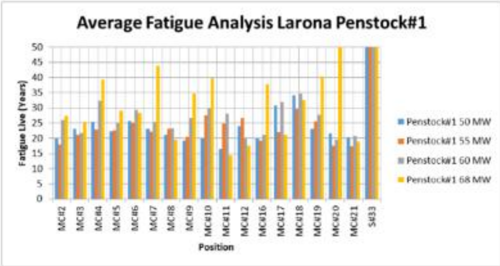


Figure 3. Before after condition for reinforcement design

Remaining Life of Fatigue Larona Penstock. One of the important parts in a hydropower system operation is the penstock pipe, which is the pipe that distributes water from the headpond to the powerhouse, the pipe is made of metal and experiences vibration due to the empty period of the pipe, the mass of water in the pipe, concrete conditions, seismicity and elastomer conditions. Penstock pipes can work 24 hours a day, the age of the pipes can reach 30 years or even more, to find out the remaining fatigue life of the larona penstock, an analysis of the remaining fatigue life is carried out, by taking vibration data that occurs when the pipe is in operating condition with a normal pattern 50 MW, 55 M, 60 MW operations, load rejection and flying start tests were carried out on 3 units of Larona penstock pipes. Penstock pipes can work 24 hours a day, the age of the pipes can reach 30 years or even more, to find out the remaining fatigue life of the larona penstock, an analysis of the remaining fatigue life is carried out, by taking vibration data that occurs when the pipe is in operating condition with a normal load of 50 MW, 55 MW, 60 MW operations, load rejection and flying start tests were carried out on 3 units of Larona penstock pipes.

By analyzing the fatigue of the penstock pipe, it is hoped that it will be able to show the vibration limits that are still permissible within safe limits according to DNV RP F105, and find out the fatigue life from the smallest to the largest from the actual vibration data. So that it can be identified and prepared for initial mitigation/prevention steps to reduce vibration in pipes experiencing critical vibration conditions. In calculating the remaining life of the penstock pipe using assumptions taken from the standard with details of Allowable Damage 0.1, Safety Factor 0.25, Material A537 Class-2, Yield Stress 412 Mpa, Allowable Stress 277 Mpa, Year COD 1978, Current year 2023, The exposure time is 45 years and the Corrosion Allowance is 3 mm where we set a maximum fatigue crack limit of 3 mm. If this limit has been reached by the penstock pipe, then the failure process can be stated to have started to occur.

In good vibration conditions, when the vibration level reaches 1.86 mm/s for penstock #1, its remaining fatigue life is estimated to begin in the next 15 years, with a fatigue rate of 0.21 mm/year in segment 11. When considering the average vibration level in penstock #1, which is 1.06 mm/s, the remaining fatigue life is predicted to commence in the next 25 years, with a fatigue rate of 0.12 mm/year. For penstock #2, in good vibration conditions with a level of 2.17 mm/s, its remaining fatigue life is anticipated to start in the next 12 years, with a fatigue rate of 0.24 mm/year in segment 9. When looking at the average vibration level in penstock #1, which is 1.14 mm/s, the remaining fatigue life is projected to begin in the next 23 years, with a fatigue rate of 0.13 mm/year. Lastly, in good vibration conditions with a level of 1.74 mm/s for penstock #3, its remaining fatigue life is expected to initiate in the next 15 years, with a fatigue rate of 0.2 mm/year in segment 12. Considering the average vibration level in penstock #1, which is 0.98 mm/s, the remaining fatigue life is estimated to begin in the next 27 years, with a fatigue rate of 0.11 mm/year.It is expected that the vibration magnitude can be reduced to 0.5 mm/s using various types of reinforcement so that it is predicted that the remaining fatigue life of the penstock pipe will begin after 53.33 years with a fatigue track of 0.06 mm/year.



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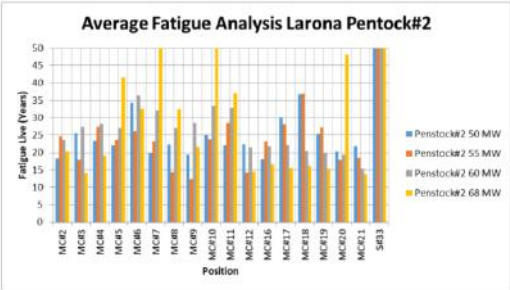
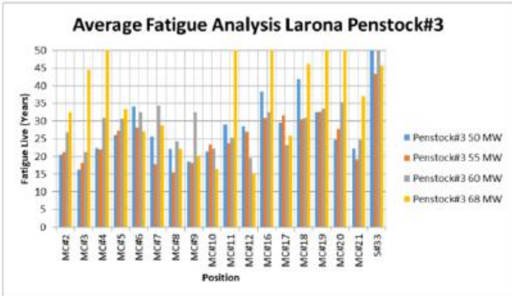


(b)



(c)

Figure 4. Average Fatigue Analysis Larona (a) Penstock#1 (b) Penstock#2 (c) Penstock#3

Reinforcement Design Trials. Stress analysis on the penstock pipe is modeled using Caesar Software II. The stress calculation will be carried out on the entire length of the penstock pipe. The analysis was carried out in accordance with ASME code B31.3 concerning Process Piping Systems with load cases originating from continuous loads, operational loads, expansion loads, and hydrostatic loads & earthquakes. Pipe modeling consists of defining geometry, material properties, loading conditions, modeling supports, and other tools. The assumptions and conditions applied to the modeling are carried out in such a way that they are as close as possible to the actual conditions that will occur during the operation of the penstock pipe. The output of the calculation is the voltage and displacement. When the analysis results meet all design requirements and comply with ASME code B31.3, the penstock pipe system design is deemed acceptable. Below is a flowchart for stress analysis simulation in Caesar. At this study stage to optimize the reinforcement system several variations of the options will be made as below.

- Option-1: the distance between the belts is 2 meters on segments that require reinforcement.
- Option-2: the distance between the belts is 4 meters on segments that require reinforcement.
- Option-3: the distance between the belts is 2 and 4 meters (combine) on segments that require reinforcement.
- Option-4: the distance between the belts varies (4, 8, 10, 12, 14, and 16 meters) on the segment that require reinforcement.
- Option-5: belt placement in certain areas with such a configuration using a total of 138 belts in each penstock pipe.
- Option-6: belt placement in certain areas with such a configuration using a total of 56 belts in each penstock pipe.
- Option-7: belt placement in certain areas with such a configuration using a total of 62 belts in each penstock pipe.
- Option-8: belt placement in certain areas with such a configuration using a total of 63 belts in each penstock pipe.

In the diagram below, the stress differences in each reinforcement model from option 1 to option 8 will be presented. As a basis for determining the reinforcement options to be selected. In reinforcement options 1-6 which are analyzed only up to MC# 22 while for reinforcement options 7-8 are analyzed from MC# 2 to MC# 28.

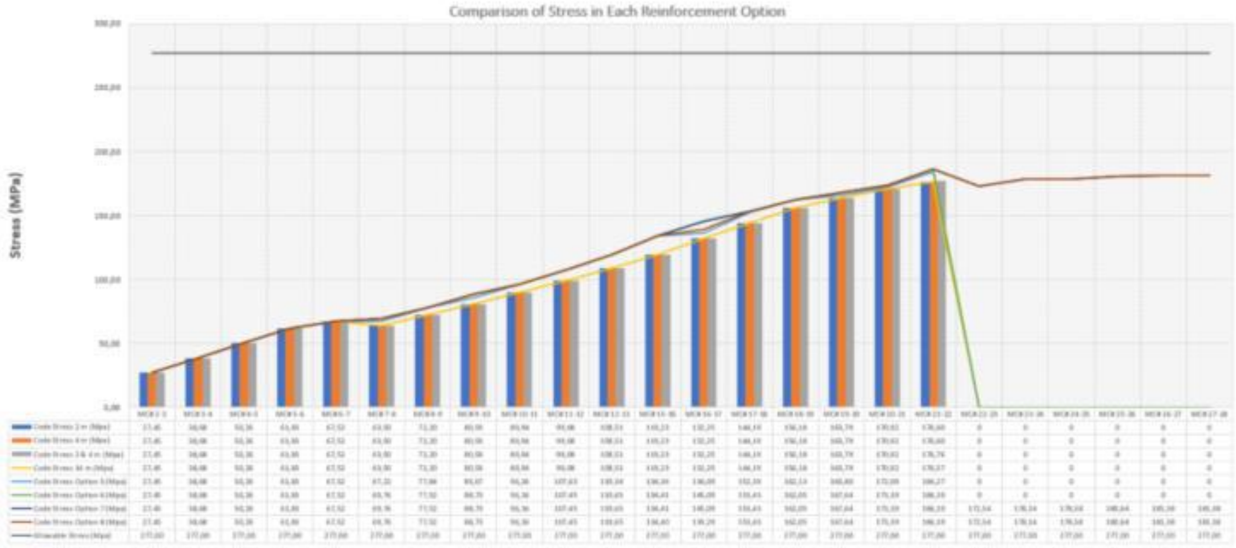


Figure 5. Comparison of stress in each reinforcement option

In the description of the choice of reinforcement above, where the stress difference that occurs is still below the allowable stress, and the maximum displacement is in the MC# 16-17 area of 2.1407 mm at option 7, taking into account the flexibility or elasticity of the penstock reinforcement to accommodate if stress occurs due to fluid flow and elastomer function, and then an analysis of option 8 was carried out, which resulted after analyzing the reinforcement from MC#2 to MC#27 the maximum displacement is 1,9490 mm so it is recommended to use reinforcement option 8.

4. Conclusion

The Larona hydropower plant, despite being the highest capacity plant at 180 MW, is facing challenges due to its age of over 40 years. An assessment of the Larona penstock infrastructure revealed the need for reinforcement between segments MC#4 to MC#14 due to stress levels surpassing allowable limits. This reinforcement involves the addition of a support system with stainless steel plates to enhance structural integrity. Furthermore, a comprehensive analysis of penstock fatigue was conducted, considering factors such as vibration, load variations, and operating conditions. The analysis aimed to determine the remaining fatigue life of the Larona penstock pipes and assess the impact of vibrations on their longevity. It was found that under good vibration conditions, the remaining fatigue life varies depending on the penstock pipe, with estimates ranging from 12 to 27 years. The goal is to reduce vibration levels to 0.5 mm/s through various types of reinforcement to extend the remaining fatigue life to approximately 53.33 years. Stress analysis of the penstock pipe was performed using Caesar Software II, adhering to ASME code B31.3. Several reinforcement options were explored, with Option 8 being recommended due to its ability to maintain stress levels below allowable limits and a maximum displacement of 1.9490 mm. In summary, addressing the challenges posed by the aging Larona hydropower plant's penstock infrastructure is crucial to meet PTVI's production targets. The proposed reinforcement measures, coupled with fatigue analysis and stress simulations, provide a comprehensive strategy to ensure the continued safe and efficient operation of the penstock system.

Acknowledgement

We would like to express our sincere appreciation to the management and staff of the Vale Indonesia for their invaluable cooperation and for providing access to the facilities and data necessary for this study. Without their support, this research would not have been feasible.

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GRIZZLY REDUCTION KILN FATIGUE ANALYSIS

Baso Murdin[1], Asep Suharto[2], Fahmi Izdiharrudin[1], Danto Joro[1], and Muhtar Wahab[3]

[1]Energy Management Vale Indonesia, Sorowako, South Sulawesi, Indonesia
[2]Capital Proj. & Const. Department, Vale Indonesia, Sorowako, South Sulawesi, Indonesia
[3]Persatuan Insinyur Indonesia (PII) Sorowako, South Sulawesi, Indonesia
baso.murdin@gmail.com

Abstract

To optimize maintenance system in calcine production at the nickel kiln company, a fatigue analysis investigation is conducted on the grizzly, which functions to filter calcine materials. Early materials fatigue due to thermos-mechanical load on grizzly support can be mitigated by additional cooling process. Thus, air supply from instrument air nickel company characterized with 30ºC temperature is also utilized as cooling air to partially remove thermal stress on the grizzly support. The internal flow of cooling air is expected to sufficiently remove the heat via combined convection and conduction from the cooling air toward the surface of grizzly bars and support. The study indicates that cooling process utilizing air from instrument air leads to air flow characteristics of 70 psi, by which 115 SCFM air is able to reduce material temperature down by 77.9 ºC. This study is alternative cooling condition utilizing cooling air from either the blower or service air which aims at evaluating the effect of pressure supply air to the operation condition of grizzly. Further, simulation of structural integrity based on finite element method was carried out to assess the materials fatigue of grizzly bars and support due to cycles of calcine loading.

Keywords: Grizzly, Fatigue Analysis, Cooling System

1. Introduction

Grizzly is a equipment of the production process of calcine in reduction kiln. It plays a vital role in supporting the various activities involved in the process, such as the separation of materials. Mitigating the early effects of thermal stress and fatigue can help prevent structural failure and minimize the risk of downtime. Preventive maintenance approach can extend the lifespan of the grizzly and reduce the need for costly repairs and replacements. It can also improve the efficiency of the process by ensuring that the grizzly is functioning properly.

The main objective of this research is to conduct a comprehensive evaluation of the grizzly's structural integrity when subjected to thermo-mechanical loads. Additionally, the study seeks to investigate the impact of cooling air on reducing thermal stress levels. The optimization of operating conditions is also a key focus of the research, with the aim of ensuring longevity and maximizing efficiency. Furthermore, the study aims to compare a range of different materials and cooling methods to identify the most effective strategies for addressing early material fatigue and preventing thermal stress in the grizzly.

2. Materials and Methods

The assessment method used in this study involved a numerical approach based on Computational Fluid Dynamics (CFD) to evaluate the air flow characteristics within the cooling air and the surface temperature distribution of the grizzly bars and support. This was followed by finite element analysis to assess the safety factor of the grizzly structure designed from stainless steel (SS).

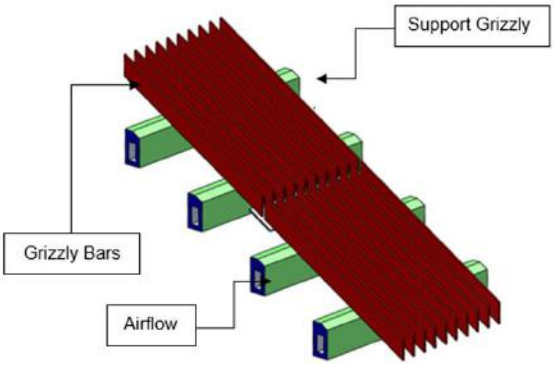
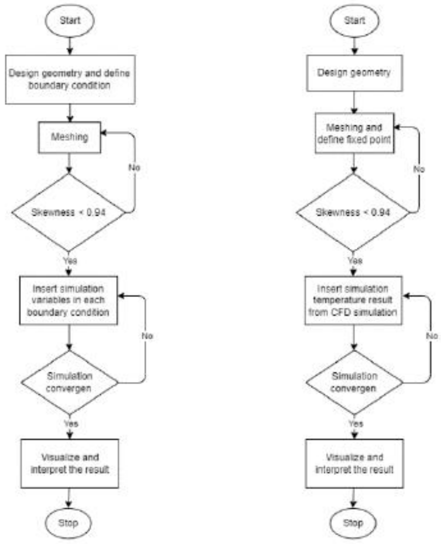


Figure 1. Grizzly Design

The workflow for the assessment method is described in Figure 2, which includes the CFD simulation of cooling air and the finite element simulation of the grizzly structure.



(a) (b)

Figure 2. (a) CFD simulation of cooling air (b) finite element simulation of grizzly structure

Table 1. Boundary Conditions

Materials (Calcine)	
Density (g/cm^3)	3.98
Specific heat (J/kg·K)	513.85
Thermal conductivity (W/m·K)	27.9
Boundary condition	
Pressure inlet pipe (psi)	15-80 psi
Pressure outlet pipe (psi)	Pressure outlet
Mass flow inlet grizzly (kg/s)	0.44
Mass flow outlet grizzly (psi)	0.032
Wall	No slip condition

Table 2. Material Properties

Properties	Material					
	SS 309L	SS 304L	SS 316	SS 347	SS 309	SS 316L
Conductivity (W/m K)	42.2	26.58	25.46	26.1	15.6	15
Specific Heat (J/kg K)	320	490	490-530	500	502	500
Density (Mg/m^3)	8	8	7.87-8.07	7.9-7.96	8	8
Young Modulus (GPa)	123	190-210	190-205	193	204.98	199.94
Ultimate Tensile Strength (MPa)	510 - 743	480	480-620	515	750	460
Yield Strength (MPa)	400	170	290	205	300	189
Poisson Ratio	0.3	0.31	0.275		0.275	0.31
Boundary Condition						
Temperature	Imported form CFD simulation					
Fixed Point	Left and right surface of grizzly bars					

The materials selection for the grizzly bars and supports was based on the assessment of corrosion properties. Several alternatives of austenitic stainless steel (SS309, SS316L, SS309L, SS304L, SS316, and SS347) were considered, and their corrosion rates and corrosion levels were evaluated. Overall, the assessment method involved CFD simulation, finite element analysis, and corrosion properties assessment to determine the suitable material and evaluate the structural integrity of the grizzly structure

3. Results and Discussion

The assessment method in this study involved the utilization of cooling air from the thermal plant to mitigate the thermal stress on the grizzly support. There are 3 analysis in this paper, cooling system, structural integrity assessment, and cost evaluation.

Structural Integrity Assessment. The recommended material for the fabrication of grizzly bars and supports is SS 304L. This recommendation is based on several factors, including corrosion resistance characteristics, availability of the material, and the simulation results of structural integrity.In terms of corrosion resistance, SS 304L has been assessed to have a corrosion rate and corrosion level that are on par with other alternatives, such as SS 309 and SS 316. This indicates that SS 304L has a high resistance to corrosion, which is important for the grizzly bars and supports that are prone to sulfurization. Additionally, the availability of SS 304L as a material makes it a practical choice for fabrication. It is widely used in various industries and readily accessible for manufacturing purposes.

Table 3. Material Corrosion Rate

Properties	Material					
	SS 309	SS 309L	SS 316	SS 316L	SS 304L	SS 347
Corrosion Rate (mmpy)	0.00883	0.01590	0.005325	0.025	0.0507	0.021
Corrosion Level	3	4	3	4	5	4

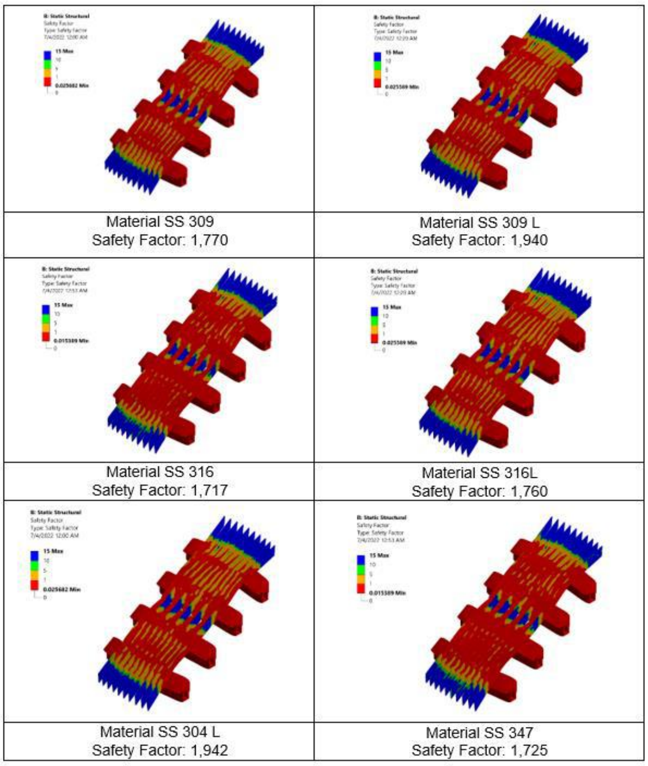


Figure 3. Fatigue Simulation

Furthermore, the simulation results of structural integrity based on finite element method analysis suggest that using SS 304L can extend the lifetime of the grizzly structure up to 10 months. Comparing the ultimate tensile strength of SS 304L to SS 309, the maximum lifetime limit of the grizzly structure made of SS 304L can reach 14.5 months. These results indicate that SS 304L provides sufficient strength and durability to withstand the cycles of thermos-mechanical loading experienced by the grizzly bars and supports. Overall, considering the corrosion resistance characteristics, availability, and the simulation results, SS 304L is recommended as the material for the fabrication of grizzly bars and supports.

Cooling System. The cooling air, characterized by a temperature of 30ºC, was supplied from 12 compressors and utilized to remove heat from the grizzly bars and support. The assessment method in this study involved the utilization of cooling air from the thermal plant to mitigate the thermal stress on the grizzly support. The cooling air, characterized by a temperature of 30ºC, was supplied from 12 compressors and utilized to remove heat from the grizzly bars and support.

To evaluate the effectiveness of the cooling process, Computational Fluid Dynamics (CFD) simulations were conducted to analyze the air flow characteristics within the cooling air and the surface temperature distribution of the grizzly bars and support. The simulation results showed that the cooling air could reduce the material temperature by 77.9 ºC. Furthermore, finite element analysis was performed to assess the structural integrity of the grizzly structure. The simulation considered the interaction between the calcine loadings on the grizzly bars and the cooling air in the grizzly support. The safety factor of the grizzly structure, designed from stainless steel (SS), was evaluated to ensure its durability under the thermo-mechanical loading conditions.

The assessment also included the selection of suitable materials for the grizzly bars and supports. Several alternatives of austenitic stainless steel (SS309, SS316L, SS309L, SS304L, SS316, and SS347) were evaluated based on their corrosion rates, corrosion levels, and safety factors. Among the alternatives, SS309L and SS304L were recommended due to their high safety factors (1.94 and 1.942, respectively) and comparable corrosion rates. the assessment method involved the utilization of cooling air from the thermal plant, CFD simulations to analyze air flow characteristics and temperature distribution, finite element analysis to assess structural integrity, and the selection of suitable materials for the grizzly bars and supports.

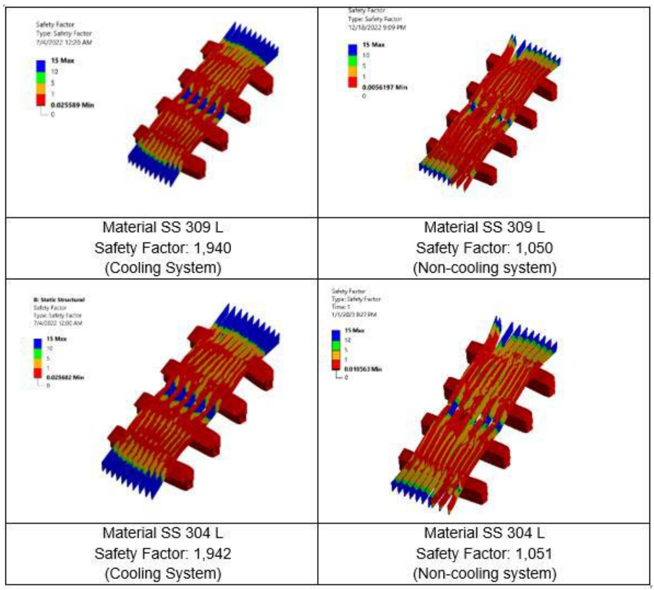


Figure 4. Cooling System Simulation

Cost Evaluation. The suggested flow rate for the blower system used in cooling the grizzly structure is 1000 SCFM (Standard Cubic Feet per Minute). This flow rate was determined based on the CFD simulation results, which showed that the temperature drop in the grizzly support was better at 1000 SCFM compared to 2500 SCFM. The analysis demonstrates the cost-effectiveness of using a blower for cooling compared to instrument air by comparing the operating costs of both systems. According to the cash flow analysis, the cost of using instrument air for cooling is 3.95 USD/MCF, while the cost of using a blower is only 0.59 USD/MCF. This significant difference in cost is due to the lower energy consumption of the blower system compared to the instrument air system. Furthermore, the blower system offers energy savings, resulting in a cost reduction of 64,910.19 USD per year. This cost savings contributes to the overall cost-effectiveness of using a blower for cooling the grizzly structure. By considering the lower operating cost and the energy savings achieved with the blower system, it is evident that using a blower for cooling is a more cost-effective option compared to instrument air. Overall, the analysis demonstrates the cost-effectiveness of using a blower for cooling by comparing the operating costs and energy savings of the blower system with the instrument air system

4. Conclusion

In summary, the research findings support the selection of SS309L and SS304L materials for grizzly bars and supports due to their high safety factors and comparable corrosion rates. Utilizing cooling air from service air, as indicated by Computational Fluid Dynamics (CFD) simulations reducing material temperatures by 77.9 ºC, is recommended to ensure structural integrity. The optimization of operating conditions confirmed the necessity of cooling air to maintain a safety factor above 1.6 under mechanical loads. Notably, the analysis underscores the cost-effectiveness of employing a service air for cooling, resulting in significant annual cost savings of 64,910.19 USD compared to instrument air. In conclusion, these recommendations offer a holistic approach to enhancing safety, durability, and cost-effectiveness in grizzly structure management.

Acknowledgement

We would like to express our sincere appreciation to the management and staff of the Vale Indonesia for their invaluable cooperation and for providing access to the facilities and data necessary for this study. Without their support, this research would not have been feasible.

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NICKEL INDUSTRIAL DECARBONIZATION PROGRAM STUDY CASE IN SOROWAKO SMELTER

Baso Murdin[1], Zainuddin[2], Busyairi[1], Wahyu Setydjati[1] and Fahmi Izdiharrudin[1]

[1]Energy Management Vale Indonesia, Sorowako, South Sulawesi, Indonesia
[2]Environmental Management Vale Indonesia, Sorowako, South Sulawesi, Indonesia
baso.murdin@gmail.com

Abstract

A comprehensive analysis of the decarbonization program for the nickel industry, focusing on the strategic measures and technological advancements required to achieve sustainable and low-carbon operations. As the global urgency to combat climate change intensifies, industries must actively contribute to reducing greenhouse gas emissions and transitioning towards a greener and more environmentally responsible future. To facilitate the decarbonization process, the paper evaluates a range of existing and emerging low-carbon technologies applicable to nickel production. This assessment covers breakthroughs in cleaner power generation, energy-efficient program, and innovative carbon capture. The integration of these technologies into nickel operations can significantly reduce emissions. Two initiatives aimed at reducing carbon emissions are the GHG emission roadmap and low-hanging fruit program. GHG emission roadmap includes development project, advanced project and implementation, with a focus on enhancing energy efficiency, adopting renewable energy sources, and deploying carbon-neutral processes. Identifying and implementing low-hanging fruit initiatives can be an effective way to kickstart the process and begin reducing greenhouse gas emissions relatively quickly and with minimal effort for utilities facilities such as steam, water, air, and power consumption. These initiatives are typically straightforward and have a high potential for carbon reduction. In conclusion, the decarbonization program for the nickel industry target for 2030 offers a promising pathway towards sustainable and low-carbon operations until 33% absolute reduction of GHG emissions. Target energy and carbon intensity are 400 GJ/Ton and 17.56 TCOe/Ton Ni.

Keywords: Decarbonization program, GHG emission roadmap, Low-hanging fruit program

1. Introduction

Sorowako smelter is committed to formulating a strategic plan framework for achieving energy efficiency and setting targets for corrective actions. The method applied to the decarbonization program is to massively implement long and short-term plans to obtain optimal results. These measures not only reflect the company's responsibility to the environment, but also efforts to support global efforts to address climate change. In addition, company has also taken concrete steps in integrating the latest technology and innovation into their operations. This includes the use of green and sustainable technologies in their production processes, which not only helps reduce the company's carbon footprint but also makes a positive contribution to overall operational efficiency. The company has understood that decarbonization is not only a social responsibility, but also a smart business strategy. By focusing on energy efficiency, company not only plays an important role in environmental conservation, but also creates opportunities for sustainable and competitive growth in the future.

2. Materials and Methods

The implementation of the Energy Management System is PT Vale Indonesia's effort to comply with regulations, improve environmental performance, support the achievement of energy conservation to achieve energy KPIs or efficiency targets. the achievement of energy conservation to achieve energy KPIs or energy efficiency targets, restrain energy efficiency targets, restraining the increasing rate of energy intensity, therefore Therefore, as an improvement, Sorowako Smelter follows ISO 50001: 2018 with the following steps as follows:

Certificate of Competency. Sorowako Smelter has 1 Energy Manager and 7 people as Energy Auditors. Energy Auditors with certified competence in accordance with the Minister of Energy and Mineral Resources Regulation No. 14.

Energy Planning. PT Vale Indonesia's energy planning is divided into two in accordance with the ISO 50001:2018 approach, namely strategic planning and tactical.

Setting Goals Objectives and Action Plans. The energy team sets proposed energy goals and objectives that are consistent with the energy policy, measurable, and take into account the energy context. with the energy policy, are measurable, take into account the energy context of the organization and the results of the energy review, taking into account the SEU. The energy team proposes a plan to achieve the goals and objectives by specifying what will be done, resources, accountability, timelines, work evaluation methods used and accountability, time to complete, work evaluation methods used and verification methods.

Data Collection. The energy team plans the collection of energy data that will be used in energy performance monitoring. Some of the data required: energy consumption energy consumption related to SEUs, relevant variables for SEUs and operational criteria related to SEUs. If data collection involves measurements, the energy auditor ensure the accuracy and repeatability of measuring instruments. The energy manager checks and approves the energy data collection plan.

Management Support. The company determines and provides the resources needed for establishment, implementation, maintenance, and continuous improvement of energy performance and Energy management. Resource provision includes:

- Appointment of an energy team that has certified energy managers, energy auditors, and other technical certificates. and other technical certificates
- Equipment with energy-efficient technology.
- Energy data collection infrastructure, as well as financial support.

Operation. Operational Planning and Control: Establishment of criteria for processes and support and socializing the criteria.

3. Results and Discussion

Sorowako Smelter is committed to formulating a strategic plan framework for achieving energy efficiency and setting targets for corrective actions. The method applied to the decarbonization program is to massively implement long and short-term plans to obtain optimal results. These measures not only reflect the company's responsibility to the environment, but also efforts to support global efforts to address climate change. In addition, Sorowako Smelter has also taken concrete steps in integrating the latest technology and innovation into their operations. This includes the use of green and sustainable technologies in their production processes, which not only helps reduce the company's carbon footprint but also makes a positive contribution to overall operational efficiency. The company has understood that decarbonization is not only a social responsibility, but also a sound business strategy. By focusing on energy efficiency, Sorowako Smelter not only plays an important role in environmental conservation, but also creates opportunities for sustainable and competitive growth in the future.

Energy Consumption. The calculation of energy consumption covers the volume of energy use within the company, including heavy equipment operations at nickel ore mining operations and the nickel in matte production process. The energy consumed is sourced from hydropower electricity supply, which is renewable energy, as well as thermal power generation and the use of fossil fuels, which is non-renewable energy. which is non-renewable energy. The calculation of total energy consumption uses the method of summing the volume of energy sources used, then converted to Gigajoule (GJ) units. The total energy consumption in 2022 reached 26,689,441 GJ, a decrease of 6.52% from 2021 The use of renewable energy from hydropower amounted to 7,797,981 GJ, reaching 29.72% and the use of renewable energy from hydropower amounted to 7,797,981 GJ. reached 29.72% and the use of energy from Biodiesel B30 amounted to 580,915 GJ, reaching 2.18% of the total energy demand; the remaining 18,175,588 GJ, or 68.10%, was non-renewable energy with the largest volume of with the largest volume from the use of Marine Fuel Oil (MFO) amounting to 9,054,678 GJ, an increase from 2021 of 8,087,926 GJ.

Table 1. Energy Consumption

Energy Source	Allotment	2022	2021	2020
Non-Renewable Energy				
Coal	Drying Kilns	3,042,982	4,969,801	5,390,589
	Reduction Kilns – Reductant	3,226,793	3,002,054	3,767,909
	Reduction Kilns - Combustion	1,623,993	1,973,050	2,453,737
	Total Firing Kilns	**7,893,769**	**9,944,905**	**11,612,235**
High Speed Diesel (HSD)	Thermal Generators	2,505	23,181	7,692
	Steam Boilers	6,803	14,268	44,124
	PP Dryer Furnaces & others	314,317	332,241	396,459
	Reduction Kilns	47,087	34,943	32,524
	Refining – Nickel 78%	36,774	39,450	43,589
	Heavy Vehicles	1,409,258	1,676,108	1,820,529
	Light vehicles, trucks, and others	1,528,897	1,847,138	2,023,073
	Total	**2,547,463**	**2,291,223**	**1,936,386**
High Sulfur Fuel Oil (HSFO)	Steam Boilers	11,764	22,983	502.25
	Drying Kilns	1,971,654	640,555	593,444
	Reduction Kilns	7.,071,259	7,424,387	7,226,966
	Total	**9,054,678**	**8,087,926**	**7,820,912**
Gasoline*	**Light Vehicles**	**6,624**	**3,616**	**8,593**
Renewable Energy				
Hydropower**	Processing Plants	7,797,981	8,223,745	8,639,474
Biodiesel B30		580,916	687,367	764,239
Non-Renewable Energy + Renewable Energy				
Total		**26,689,441**	**28,551,417**	**30,628,679**

Energy Savings. Sorowako smelter have commitment to carry out energy savings through a strategic plan in the form of strategic plan in the form of GHG & energy roadmap energy program, energy efficiency energy efficiency program, and Low-Hanging Fruit Program. GHG roadmap energy program has a target of until 2030 with an energy intensity of 400 GJ/Ton. The medium-term program has energy savings in the year 2022 of 1,849,279 GJ or equivalent to 6.93%. Low-Hanging Fruit Program program is an improvement in each utility and mine processing process that can save up to 60,067 GJ or equivalent to 0.22%.

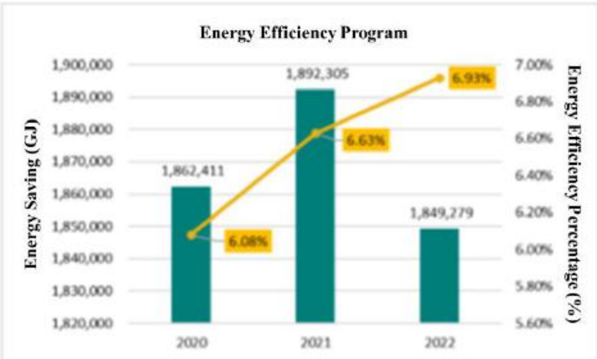

Figure 1. Energy Efficiency Program

Environmental Impacts. Climate change risk management is one of the focuses of company sustainability, and is managed referring to the Task Force on Climate Related Financial Disclosure (TCFD). We established the Roadmap to Carbon Neutral 2050. The short-term target short-term targets are achieved with solutions efficiency energy efficiency solutions and maximizing the use of renewable energy renewable energy; the medium-term target 2030 is a 33% reduction in absolute scope 1 and 2 emissions; the long-term target is to achieve net zero emissions by 2050. is to achieve carbon neutral (net zero emission) by 2050. Company is able to reduce GHG emissions from 2020-2022 by 2,015,867; 1,864,888; and 1,640,387 GJ. And carbon intensity of 27.91; 28.52; and 27.30 tCO2e/tNi.

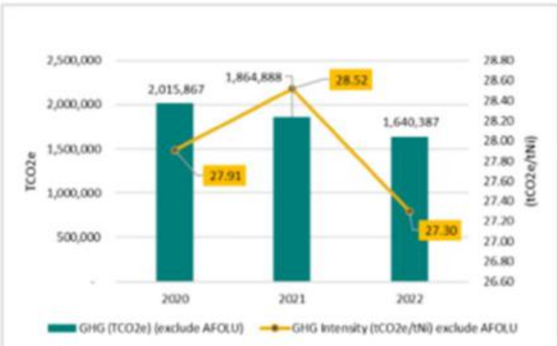

Figure 2. GHG Intensity

Energy Intensity. Energy intensity is calculated as the total energy required from electricity and fuel consumption, for the production of one ton of nickel in matte. The calculation does not energy use outside the company. The Energy intensity value in 2022 reached 444.16 GJ/ton Ni, higher than in 2021 of 436.64 GJ/ton Ni.

Table 2. Energy Intensity

Description	Unit	2022	2021	2020
Total Nickel Production	Ton	60,090	65,388	72,237
Total Energy Used	GJ	26,689,441	28,551,417	30,628,679
Energy Intensity	GJ /Ton Ni	444.16	436.64	424.00

Short Term Program. To achieve the target of reducing energy consumption, Company makes and implements energy efficiency innovations or improvements that do not require time. implement energy efficiency innovations or improvements that do not require long time and low cost. The energy efficiency program (Low hanging Fruit) that is done in the short term in 2023 has an energy reduction target of 0.22 GJ/Ton of Nickel. short-term in 2023 has an energy reduction target of 0.22 GJ / Ton of Nickel or equivalent to a GHG reduction of 2514 Tones of Nickel. GHG reduction of 2514 tons Coe. The program is expected to reduce energy costs by $1.43 million. Below is shown the energy efficiency program of PT Vale Indonesia in 2023. The program has impacted to this target is Alternative Hydropower Supply Line Program For Auxiliary Network, HPA Compressor Replacement, Potable Water Improvement and PB#2 Optimization.

Alternative Hydropower Supply Line Program For Auxiliary is configuration of two 150kV busbars where one of them is a line to supply the auxiliary grid and the other line to supply the furnace grid makes maintenance activities on the 150kV busbar very difficult to carry out because this activity will disrupt the production process. So PTVI must divert the normal auxiliary power source from 2 hydroelectric power plants to a power source from a 45 MW diesel power plant during maintenance or repair activities on one of the 150kV busbars every year. The high operating costs and potential increase in GHG emission production that will arise due to the operation of this diesel power plant is the background for PTVI to carry out this project to overcome problems with energy efficiency and the environment

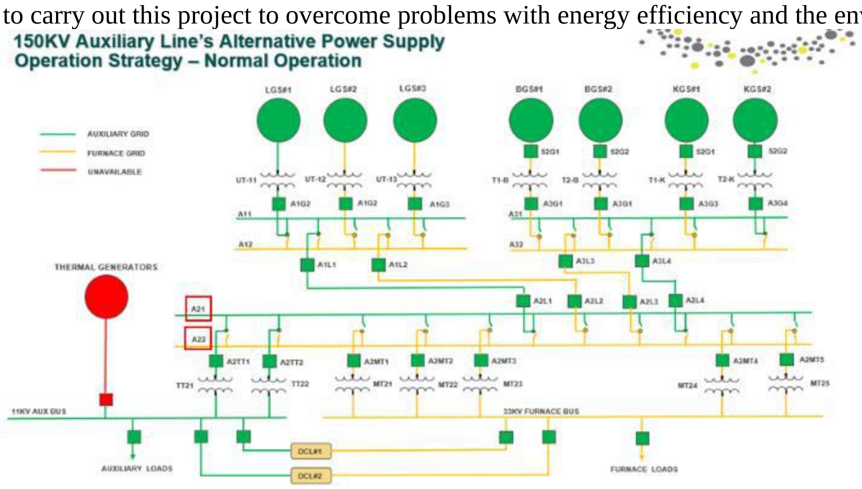

Figure 3. Auxiliary Lines Alternative Power Supply Scheme

Replace the compressor in the converter area with a capacity of 3,500 HP with improved instrument air pipe distribution. With this program, the air pressure in the converter area is able to maintain pressure up to 80 psi and saving energy 82,256 GJ/year. Similar to the previous program, potable water improvement is a pipe improvement program with energy saving process water pump saving energy up to 111 GJ.

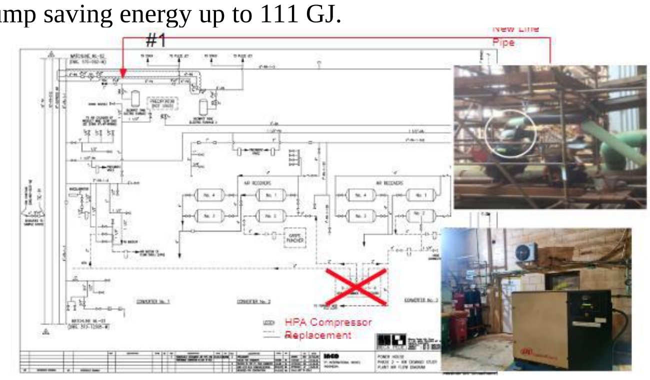

Figure 4. Replacement HPA Compressor Scheme

Electric boiler operates as the main boiler and is backed up by Packed boiler#2. In EB back up, PB#2 does heating up 3 times a day for 15 minutes to maintain steam drum temperature 150-180 deg C. and requires HSD or biodiesel fuel of 240,000 liters per year. PB#2 Optimization is the assessment of heating up can be reduced by opening the main steam valve to maintain steam drum temp 150-180 deg C. Heating up the steam header using steam, the frequency of heating-up becomes only 1x per week.

Long-Term Plan. The long-term decarbonization plan aims to reduce emissions and reduce dependence on fossil fuels or coal and save operational energy costs below 35%. Long-term programs that have been implemented include geomembrane lining, electric boiler, product burner replacement, and modular screening station.

The geomembrane lining program for the Larona hydropower plant was designed to improve efficiency and restore 15 MWh of power. The program involved the installation of new geomembranes or repairs to existing geomembranes around the hydropower infrastructure. Geomembranes are waterproof linings used to minimize water leakage and increase water storage in hydropower reservoirs. With this program, the right geomembrane will be selected, installed and periodically maintained to ensure the integrity of the system. This will help reduce water leakage and improve the operational efficiency of the hydropower plant. By reducing water loss and increasing storage, the geomembrane lining program aims to restore 15 MWh of electrical power production. This will provide significant economic and environmental benefits, while maintaining the sustainability of Larona Hydropower operations.

Figure 5. Lining Geomembran in Larona Hydropower

The Electric Boiler operation program to replace PB#2 operation aims to save the use of Marine Fuel Oil (MFO). MFO is an expensive fossil fuel and has a poor environmental impact. By adopting Electric Boiler, the program reduces significant operational costs and eliminates carbon emissions resulting from MFO combustion. Electric Boilers use electrical energy to generate the heat required in operational processes, reducing fuel costs and improving energy efficiency by up to 135,081 GJ. With the implementation of this program, PB#2 will become more sustainable, reduce negative environmental impacts, and save operational costs up to IDR 17,845,100,418 per year. In addition, it will also improve the sustainability and operational efficiency of the facility, making it a sustainable and economical solution in the long run.

Figure 6. Electric Boiler

Product Burner Replacement is a strategic initiative aimed at improving operational efficiency in fuel usage within the dryer and kiln. Under this program, existing burners that have inefficient fuel consumption will be replaced with new, more fuel-efficient burners. The burner replacement process involves selecting a burner that suits the operational needs, including the required heat capacity and the type of fuel used. These more efficient burners are designed to produce heat with less fuel wastage with an energy efficiency of up to 21,163 GJ per year. This can result in significant operational cost reductions of up to IDR 3,613,815,943. With this program, companies or installations can achieve energy efficiency goals and contribute to global efforts to reduce the impact of climate change.

Figure 7. Burner Replacement

The Modular Screening Station Operation Program is a strategic initiative aimed at optimizing screening operations while reducing the mileage required by transport vehicles. In this context, the program will reduce the travel distance from 9.60 km to 7.12 km, thereby significantly reducing the consumption of High-Speed Diesel (HSD) fuel used. Modular Screening Stations will be placed closer to the source or screening point of interest, reducing transport vehicle trips. This will save HSD fuel and reduce the carbon emissions produced by these vehicles. In addition, more efficient use of HSD will also reduce operational costs associated with transportation. The program will leverage efficient logistics technologies and strategies, including real-time monitoring to better manage deliveries and hauls. Thus, the Modular Screening Station Operation program will provide the dual benefits of reduced operational costs and reduced environmental impact by reducing the use of fossil fuels.

Figure 8. Modular Screening Station

4. Conclusion

In an effort to support the government's program to reduce net zero emission (NZE) by 2050, Sorowako Smelter Tbk has a target of reducing energy intensity by 400 GJ/Ton and carbon emissions by 17.56 TCOe/Ton Ni. To facilitate the decarbonization program, Sorowako Smelter evaluated various existing and emerging low-carbon technologies that can be applied in nickel production. This evaluation includes breakthroughs in energy efficiency and innovations in carbon capture. Sorowako Smelter has a long-term program in the form of GHG Emission Roadmap, energy efficiency program and Low-Hanging Fruit program. energy efficiency program and the Low-Hanging Fruit Program. The GHG Emission Roadmap includes project development, project realization, and project implementation. The program focuses on increasing energy efficiency, using renewable energy sources, and implementing carbon neutral processes. carbon neutral process. The energy efficiency program was able to save up to 1,892,305 GJ or equivalent to 6.93% and reduced emissions by 1,640,387 tCO_2e from 2,200,00 tCO_2e. Meanwhile, the Low-Hanging Fruit Program is an activity to identification and implementation of programs to support nickel production levels on the side of the utility systems such as Steam, Water, Water and Power. This initiative has the potential for energy efficiency of up to 60.07 GJ or able to save energy up to 0.22% per year, energy intensity reduction of 0.22 GJ. intensity reduction of 0.22 GJ/Ton Ni, GHG Reduction Calculated 2514 Ton COe and saving cost up to $1.5 M.

Acknowledgement

We would like to express our sincere appreciation to the management and staff of the Vale Indonesia for their invaluable cooperation and for providing access to the facilities and data necessary for this study. Without their support, this research would not have been feasible.

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PLANT AIR COMPRESSOR OPTIMIZATION STUDY CASE IN SOROWAKO SMELTER

Baso Murdin[1], Muh. Amirul Wahyi C.[2], Danto Joro[1], Fahmi Izdiharrudin[1], and Rismal Muchtar[3]

[1]Energy Management Vale Indonesia, Sorowako, South Sulawesi, Indonesia
[2]Utilities Operation Vale Indonesia, Sorowako, South Sulawesi, Indonesia
[3]Persatuan Insinyur Indonesia (PII), Sorowako, South Sulawesi, Indonesia
baso.murdin@gmail.com

Abstract

Plant air constitutes substantial component providing supply air for production process in smelter. Air supply from air plant should comply the process demand. Due to pressure drop, the actual capacity is found merely 36 000 SCFM. Data record in 2012 indicated that the air supply demand was 27,000 SCFM with a pressure spanning between 71.11 and 99.56 psi (5.0 -7.0 kg/cm2). The demand of air supply is expected to increase up to 31,000 – 35,000 SCFM. Under certain conditions, the demand of compressed air could be as high as 36 000 SCFM. It is therefore essential to evaluate the capacity, including velocity, pressure drops, and other relevant parameters, since the pressure drop occurs and has led to air pressure below the capacity of the piping system. The installation of these taps is found less considering the air balance in the header pipe. This situation leads to lack of air supply and/or pressure during the normal condition of operation. The unbalance condition of piping system has led to an anomaly to the thermal plant which has been compensated by additional compressors. To get balance condition is piping improvement in several area which indicates pressure low condition. Piping improvements are implemented in the converter, coal mill, furnace, kiln, and dryer areas.

Keywords: Supply and demand plant air, pressure drop, piping improvements

1. Introduction

Air plant constitutes substantial component providing supply air for production process in smelter. Air supply from air plant should comply the process demand. In general, components of air supplier consist of several parts, including compressor, pipeline, air sector system, air dryer, separator tank and reservoir, and trap. Following the design, the total of air capacity generation is ca. 49 000 SCFM. However, due to pressure drop, the actual capacity is found merely 36 000 SCFM. Data record in 2012 indicated that the air supply demand was 27 000 SCFM with a pressure spanning between 71.11 and 99.56 psi (5.0 -7.0 kg/cm2). The demand of air supply is expected to increase up to 31 000 – 35 000 SCFM. Under certain conditions, the demand of compressed air could be as high as 36 000 SCFM. It is therefore essential to evaluate the capacity, including velocity, pressure drops, and other relevant parameters, since the pressure drop occurs and has led to air pressure below the capacity of the piping system. In this regard, compressed air system shall not only be considered energy intensive utility but also efficient utility. After several period, compressor performance as well as the compressed air deteriorates significantly. Analysis carried out by means of engineering approach and field inspection indicated several taps in the header pipe has been added to supply several equipment requiring large air supply, such as grizzly kiln, atomizing kiln and dryer, emergency air converter, converter punchers, blow pot, coal mill, slipring washer, and others. These taps have been installed without appropriate calculation and adequate consideration which has led to significant pressure drop in the system. The installation of these taps is found less considering the air balance in the header pipe. This situation leads to lack of air supply and/or pressure during the normal condition of operation.

The unbalance condition of piping system has led to an anomaly to the thermal plant which has been compensated by additional compressors. Nonetheless, the air velocity in piping system exceeds the capacity of standard piping system. Air pressure drops down under the standard amplitude, particularly in converter area. Air velocity, which is as high as 23 – 30 m/s, is considered exceeding the standardized air velocity. Therefore, assessment on the air piping system and air compressors is required to evaluate the system performance.

2. Materials and Methods

Engineering method carried out following the flowchart depicted in Figure 1. Initial stage began with pipe routing as well as data confirmation for both thermal and process plant (Point 1). Re-routing step will be utilized as reference to develop the as-built drawing (Point 7) to perform HYSYS and ANSYS simulation (Point 4). HYSYS and ANSYS simulations are required to detail data which cannot be directly measured using measurement tools available at site. Furthermore, these simulations have been carried out to obtain the system performance under various operation modes.

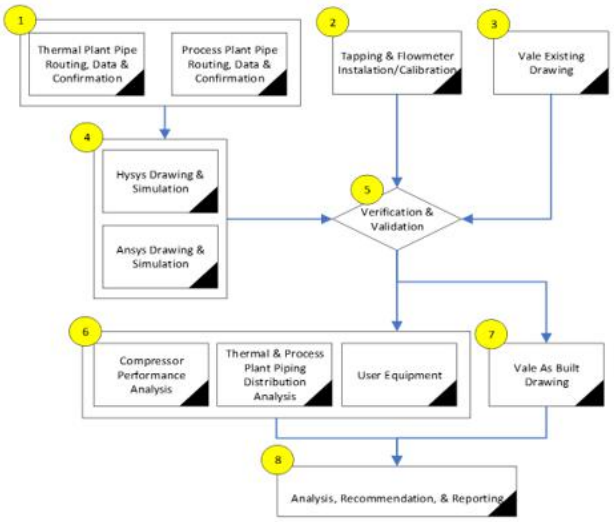

Figure 1. Workflow Method

Activities of 1 is carried out in parallel with installation and flowmeter calibration (Point 2). The installation of new flowmeters at several point is required to obtain real air condition in piping system. These activities are considered substantial for validation of simulation using both HYSYS and ANSYS (Point 5). In addition, existing drawing data is required as reference for verification and validation (Point 3).

Results on HYSYS and ANSYS simulation that have been verified and validated are further analyzed to evaluate: (a) compressor performance; (b) distribution pipe analysis; and (c) user equipment analysis (Point 6). The undertaken analysis will be considered to recommend further actions to improve piping and compressed air system (Point 8).

3. Results and Discussion

The objective of study is to assess the performance of compressed air system and its distribution including evaluation of compressor performance at Sorowako Smelter. This assessment has been carried out in piping system in thermal plant to identify the capacity of compressed air, i.e., velocity and pressure drop. This work also deals with an analysis of the adequacy of air compressor required in thermal plant and detection of leaks in piping system

Compressor System. The air compressor is one of the energy user utilities at PT. Vale Indonesia serving to provide a supply of compressed air to meet the needs of pressurized air in the process plant and air sector (instrument air). Several performance parameters used for compressor performance assessment and analysis are efficiency (isentropic, adiabatic, isothermal, volumetric), compression ratio, and specific energy consumption (SEC). In addition, this sub-chapter also discusses the correlation between compressor performance analysis and reliability analysis of compressed air systems at PT. Vale Indonesia. The main parameters used to analyze the compressor performance at PT. VALE INDONESIA is the polytropic efficiency (%) and the specific energy consumption (kW/SCFM). Figure 2 and Figure 3 show a comparison of the polytropic efficiency and specific energy consumption of the compressor based on the actual condition and design (nameplate) data.

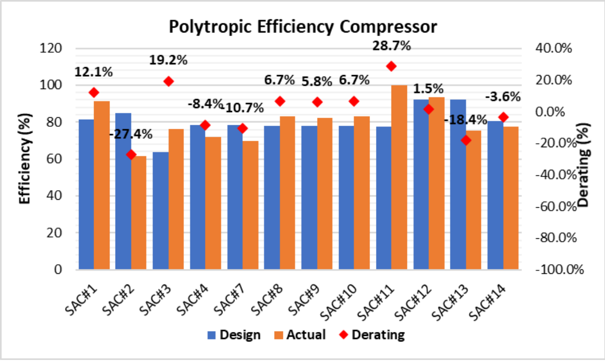

Figure 2. Compressor Efficiency

Piping Distributions System. Pipe sizing and selection is a crucial step in the design of a piping system. Pipe selection comprises of determination of the pipe diameter and thickness. The selection is based on 2 criteria, i.e., velocity and allowable pressure drop. For Adequacy Check, the existing velocity and pressure drop were re-calculated. This is important to ensure the adequacy of pipe size with the current flow rate. The first approach using the pipe segment to accommodate the length, size and fittings of the existing pipe. One pipe segment represents one line number and hence, the existing velocity and overall pressure drop of each line number is obtained. Pipe segments in Hysys are also used to determine the destination pressure or the final pressure of the tapping point. Once the stream was built, the equipment and pipe segment were added. The second approach is to calculate the velocity and pressure drop per 100 ft. The calculation of velocity is based on equation 2.13 from API Recommended Practice 14E. The acceptable values of velocity and pressure drop are 60 ft/s (13 m/s) and 0.5 Psi, respectively, while the pressure drop calculation is based on the Darcy Equation from the GPSA Engineering Data Book.

Ansys simulation was undertaken to estimate the turbulence intensity and details of the pipe modification. Turbulence intensity is defined as the ratio of the standard deviation of the fluctuating air velocity to the average air velocity, which represents the intensity of the fluctuating air velocity in the pipe. This simulation used the same input boundary conditions as the simulation done in Hysys. Therefore, the initial estimation calculation performed using Hysys can be represented in the form of velocity, pressure, turbulence intensity, and temperature contours via Ansys simulation.

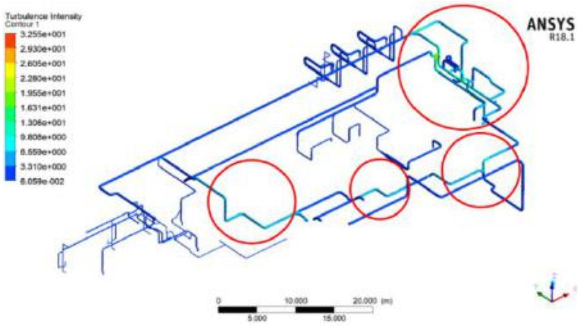

Figure 3 Turbulence Intensity in Pipe Distributions

The highest to the lowest amplitude of physical parameters is represented by color gradation from red to green and blue. These physical parameters include the velocity, pressure, turbulent intensity and temperature whose contour is obtained for a certain plane(s) or walls. Therefore, the contour profile of all parameters presented here should be considered an initial design estimation. Nonetheless, it can already represent the contour gradation in every modification that will be made.

User Distributions System. Process Plant at Sorowako Smelter is dedicated to process ore to become matte which is ready to be packaged. This section has many processes and various areas. There are four main areas, i.e., Dryer, Kiln, Furnace and Converter with different compressed air capacity requirements.

The compressed air is supplied from the utilities section according to flowrate and pressure through 5 (five) header pipe lines: 1) 12 inch Header Pipe, 2) 10 inch Header Pipe, 3) 6 inch Header Pipe (2 lines) for the south and north areas, and 4) 3 inch Header Pipe. Certain areas and process/equipment are supplied from certain header.

Assessment on the process plant is carried out for several purposes:

- To calculate and measure flow capacity at the process plant following the maximum standard of compressed air that flows based on the standard diameter of the pipe distribution in the process plant.
- To compare the compressed air flowrate based on the estimation of the calculation/simulation and direct measurement.

To obtain opportunities to improve the performance of compressed air distribution in pipe distribution so that the process demand can be properly met, and losses can be reduced that leads to a more efficient system.

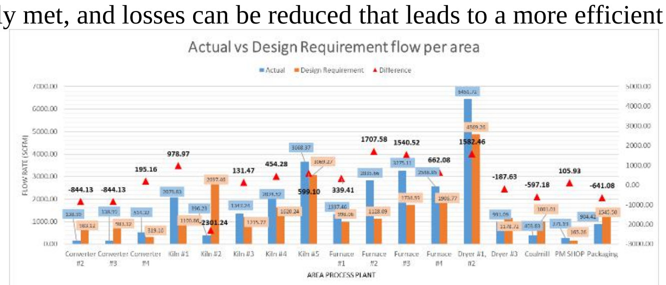

Figure 4. Flow Requirement Per Area

Piping Distribution Improvement. Improving air distribution is an important step in ensuring that the air circulation system in an area or facility runs efficiently and optimally. To achieve this goal, we have designed a series of improvements to the air distribution pipe system. These improvements are carefully designed to improve efficiency and more even air distribution throughout the relevant areas.

1. Converter Area

According to measurement data on the converter header, it was found that the pressure to the emergency tank around 56 psi. This condition often causes a trip on the converter, this is due to several reasons. One of them is due to the large number of demand in header pipe of 6 inch (I), which makes the distributed flowrate also high. So that with a high flow that exceeds the standard capacity of the pipe will be directly proportional with the high of pressure drop. Hence, a modification was made by creating a new branch through the 10-inch main header to converters #2, #3, and #4. Then for the header pipe using 6 inch NPS, then for the pipe to each converter tank it will still use 4 inch size as the existing conditions.

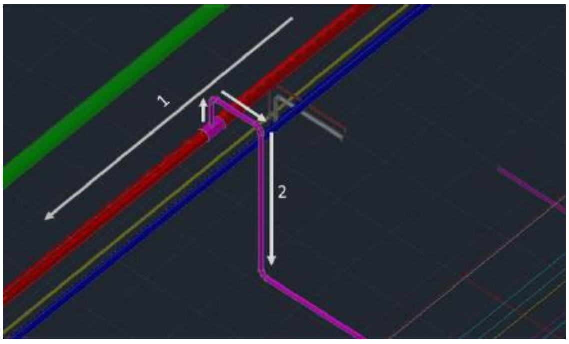

Figure 1 Design for Converter Area

Then this following is a simulation comparison between the pressure and flowrate values for each converter.

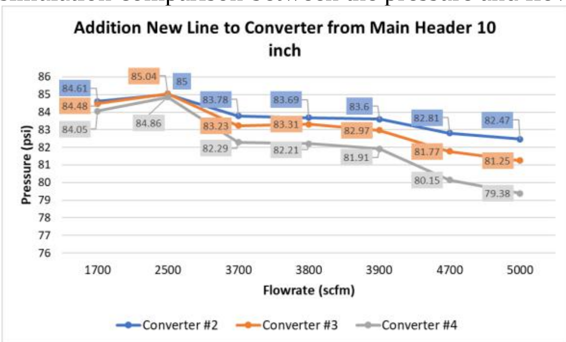

Figure 2 Improvement Data Converter Area

With the graph above it can be described that if the flow rate value is increased up to 5000 scfm, then the pressure will still have a high enough value. It can be seen that converter #2 still has a value of 82 psi, converter #3 is 81.25 psi and converter #4 is 79.38 psi.

2. Coalmill Area

After engineering calculation, it was found that the pressure value to coalmill area is too small. And the lowest of pressure value is around 43 psi. This is due to the size of the pipe in the coalmill header is too small whereas if the distributed flow rate is high, it will make a significant pressure drop. The pipe header in coalmill area can be seen on the illustration below.

Figure 3 Design for Coalmill Area

And the following is a comparison in bar chart between existing conditions with two modifications

Figure 4 Improvement Data Coalmill Area

3. Dryer Area

Based on the measurement results, it was found that there was a considerable difference in the pressure value between the 10 inch pipe leading to the ex-building of 88.73 psi and the 8 inch pipe after passing through the ex-building to around 76.83 psi. Hence, there is recommendation to be given with an additional line that goes directly to the 8 inch pipe from the 10 inch pipe without through the ex-building

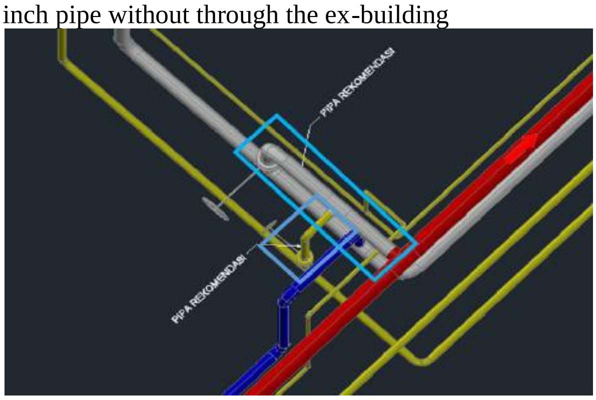

Figure 5 Design for Dryer Area

The existence of this improvement has the effect of increasing the pressure for each area. The graph above shows a comparison between the pressure in existing condition and pressure after improvement. The results above can provide a pressure increase around 11 psi to 14 psi.

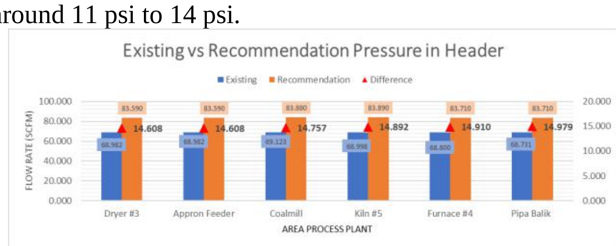

Figure 6 Improvement Data Dryer Area

4. Furnace Area

According to the measurement results that have been found, the pressure value entering the furnace area #1 and furnace #2 has a fairly low value. Where the input pressure on the header furnace is around 67 psi, then the pressure entering the equipment is around 57-58 psi. Therefore, a recommendation is needed so that the pressure entering the furnace #1 and furnace #2 areas has a high value. By make a new line through the 6 inch (II) pipe, Which currently there is no flow through the pipe. So it will be re-operated in area near the HSFO tank. A new line is made through the 6 inch pipe (II), then tie in to the 4 inch pipe (furnace header). The following is an illustration of the new line leading to furnace #1 and furnace #2.

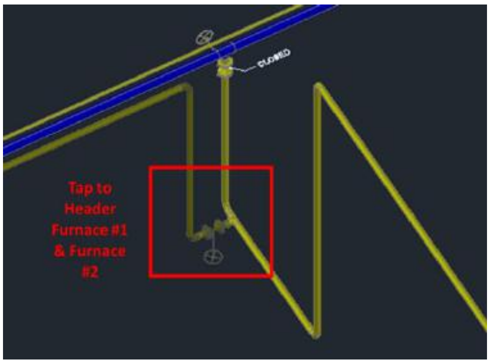

Figure 7 Design for Furnace Area

Therefore, it is need to make a new recommendation by doing a new tie-in through a 6 inch (II) header pipe to get a high pressure value. As shown in Table 10 in the pressure column (Recommendation), it can be seen that there is an increase in pressure at the furnace header input and on each equipment. Below is a comparison of the bar graphs for pressure in actual conditions and after recommendations

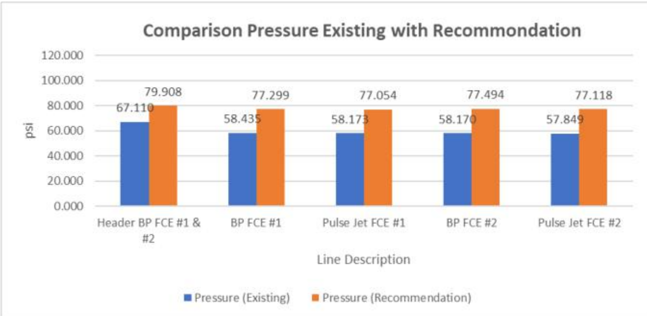

Figure 8 Improvement Data Furnace Area

4. Conclusion

In conclusion, it is imperative to conduct a comprehensive evaluation of the piping system's capacity, including factors such as velocity, pressure drops, and other relevant parameters. The installation of taps in specific areas, particularly where pressure is consistently low, will be a crucial step toward achieving a balanced and efficient air distribution system. These necessary piping improvements are planned for implementation in various key areas, including the converter, coal mill, furnace, kiln, and dryer sections. The plant air system plays a vital role in providing the necessary supply air for the production processes within the smelter. However, our analysis has revealed several significant challenges in maintaining an optimal air supply. The actual capacity of the air plant, due to pressure drop issues, currently stands at a modest 27,000-28,000 SCFM, which falls short of the expected demand.

Acknowledgement

We would like to express our sincere appreciation to the management and staff of the Vale Indonesia for their invaluable cooperation and for providing access to the facilities and data necessary for this study. Without their support, this research would not have been feasible.

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