The Assessment of New and Renewable Energy and Energy Efficiency Feasible Alternatives and Policies in Indonesia [1, 2]

Royan Nur Huda

ABSTRACT

There has never been a more significant global demand for energy supply and efficiency projects. Between 2012 and 2035, it is anticipated that the need for primary energy and electricity will increase by 50% and 70%, respectively, primarily in emerging countries such as Indonesia, while in developed nations, the transition towards energy-efficient and low-carbon supply technologies will continue. This paper aims to determine the optimal technologies for implementing new and renewable energy in Indonesia, as well as the obstacles and challenges that impede the implementation of renewable energy and energy efficiency initiatives and policies in Indonesia. The author identifies the most suitable technologies for performance in Indonesia using IFE and EFE matrices derived from the SWOT analysis framework, Multi-Attribute Decision Making (MADM), and sensitivity analysis. From this research, we can conclude that geothermal energy, ocean energy, and green hydrogen are the three most promising technologies for the near future in Indonesia. Future research on technological advancement, energy storage, and smart grid integration has room for enhancement.

Keywords: Renewable Energy, Project Financing, Investment, Geothermal, Wind Turbine, Ocean, Hydrogen, Hydropower, Solar PV, Biomass, Nuclear, SWOT, MADM, Electricity, Techno-Economics.

INTRODUCTION

1. 1. Indonesia Overall Sector

“Indonesia is an extensive archipelago with over 17,504 islands spanning 5,000 kilometers across Southeast Asia and Oceania. Indonesia shares land borders with Papua New Guinea, Timor-Leste, and Malaysia and maritime borders with Singapore, the Philippines, and Australia.”[3] “Indonesia has the fourth-largest population in the world, with an estimated 269 million residents.”[4] More than half of the population resides on the island of Java, where economic activity is concentrated, with the remainder dispersed

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[1] How to cite this paper: Huda, R.N. (2023). The Assessment of New and Renewable Energy and Energy Efficiency Feasible Alternatives and Policies in Indonesia; *PM World Journal*, Vol. XII, Issue IX, September.

[2] This paper was originally prepared during a 6-month long Graduate-Level Competency Development/Capacity Building Program developed by PT Mitrata Citragraha, and led by Dr. Paul D. Giammalvo to prepare candidates for AACE CCP or other Certifications. https://build-project-management-competency.com/our-faqs/

[3] Statistics Indonesia. 2020. Total Population Projection Result by Province and Gender (Thousand People), *2018–2020*. Jakarta.

[4] ADB. 2020. Poverty Data: Indonesia

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across Sumatra, Bali, Sulawesi, Kalimantan, Nusa Tenggara, Maluku, Papua, and roughly 6,000 less-populated islands. Indonesia has effectively reduced extreme poverty from 11.5% in 2015 to 9.4% in 2019. “However, the country's island geography makes sustainable economic and infrastructure development in outlying provinces difficult, resulting in ubiquitous regional disparities.”[5]

Regarding purchasing power, Indonesia is the seventh-largest economy in the world and the largest economy in Southeast Asia. “Indonesia's gross domestic product (GDP) has increased by approximately 5% annually, from Rp861.9 billion in 2015 to over Rp1 trillion in 2019.” [6] Historically, the production of commodities and agricultural goods has propelled economic expansion. Coupled with government initiatives to invest in domestic infrastructure, the country's youthful, working-age population has enjoyed a steadily rising standard of living over the past few decades. “In 2019, the contribution of manufacturing to GDP was 19.7%, while the contribution of services was 44.4%.” [7] “The ranking of Indonesia's convenience of doing business rose from 120 in 2014 to 73 in 2019, while the index's subcomponent on electricity access improved from 122 to 33.”[8]

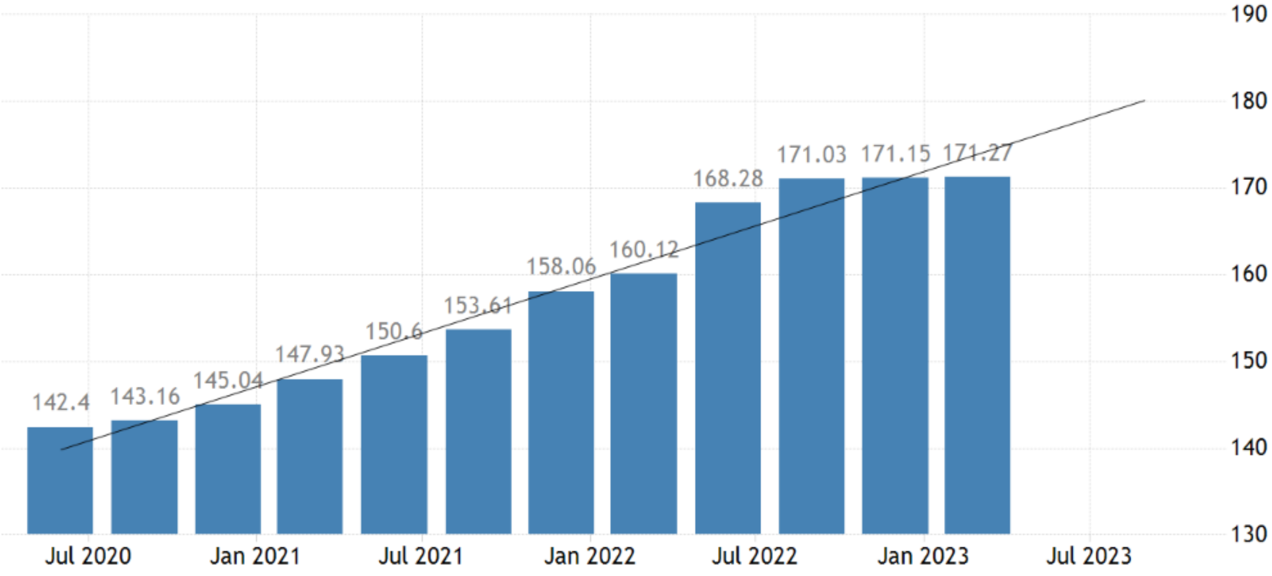

Figure 1 Indonesia GDP Deflator[9]

Indonesia's political and economic development has made extraordinary advances in the twenty-first century. It aspires to attain high-income status by 2045. Despite significant progress, the COVID-19 pandemic has had a devastating human and economic impact,

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[5] ADB. 2020. Basic Statistics, Asia and The Pacific. Manila.
[6] ADB. 2020. Basic Statistics, Asia and The Pacific. Manila.
[7] World Bank Data. 202
[8] World Bank Group. 2015. *Doing Business 2014. Economy Profile Indonesia*. Washington DC; and World Bank Group. 2020. *Doing Business 2019. Economy Profile Indonesia*. Washington, DC.
[9] Statistics Indonesia, 2023.

with growth predicted to contract in 2020 for the first time since the Asian financial crisis in 1997. Since the start of the pandemic, nearly 10 million people have been at risk of falling below the poverty line. "In 2020, the poverty rate is anticipated to increase to 11.9% and 12.2%."[10] The deterioration of the labor market will be felt disproportionately by the most vulnerable, such as informal sector workers, who make up 57% of the labor force, contributing to the rising income inequality since 2009. It is anticipated that economic growth will accelerate in 2021 due to increased discretionary spending by households, a more favorable investment climate, and a global economic recovery. However, the risk of multiple COVID-19 cycles and the global economy's recovery rate and external demand are difficult to predict.

1. 2. Energy in Focus

Developing the energy sector sustainably and equitably is essential to Indonesia's economic growth. Indonesia has abundant natural resources, including lignite, natural gas, metals, and other agricultural and mining goods. "The nation produced 616 million tons of coal, 2.8 million standard cubic feet of natural gas, and 272 million barrels of crude in 2019." [11]"Indonesia is a net exporter of energy, and its energy sector and economy have been based on natural resource extraction, with coal being the country's primary export (11.2% of total energy export value) and palm oil coming in second (8.76%)."[12] Energy is vital to economic development; unreliable data, contradictory national policies, and prevailing organizational structures have led to sector constraints. Even though national electrification rates have increased, infrastructure may not be able to meet future regional demand. As a result of the impact of COVID-19 on public sector revenues, securing financing for necessary national generation capacity enhancements through 2025 poses a challenge. The first administration of President Joko Widodo, which was elected in 2014, began reforming electricity tariff subsidies and facilitating the private sector's access to capital by establishing the Indonesian Capital Market Development Authority.

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[10] ADB. 2020. COVID-19 Active Response and Expenditure Support Program: Poverty Impact Assessment. Jakarta.

[11] Government of Indonesia, MEMR. 2020. *Handbook of Energy & Economic Statistics of Indonesia 2019*. Jakarta.

[12] Statistics Indonesia. 2020. *Indonesia Foreign Trade Statistics Exports 2019*. Jakarta.

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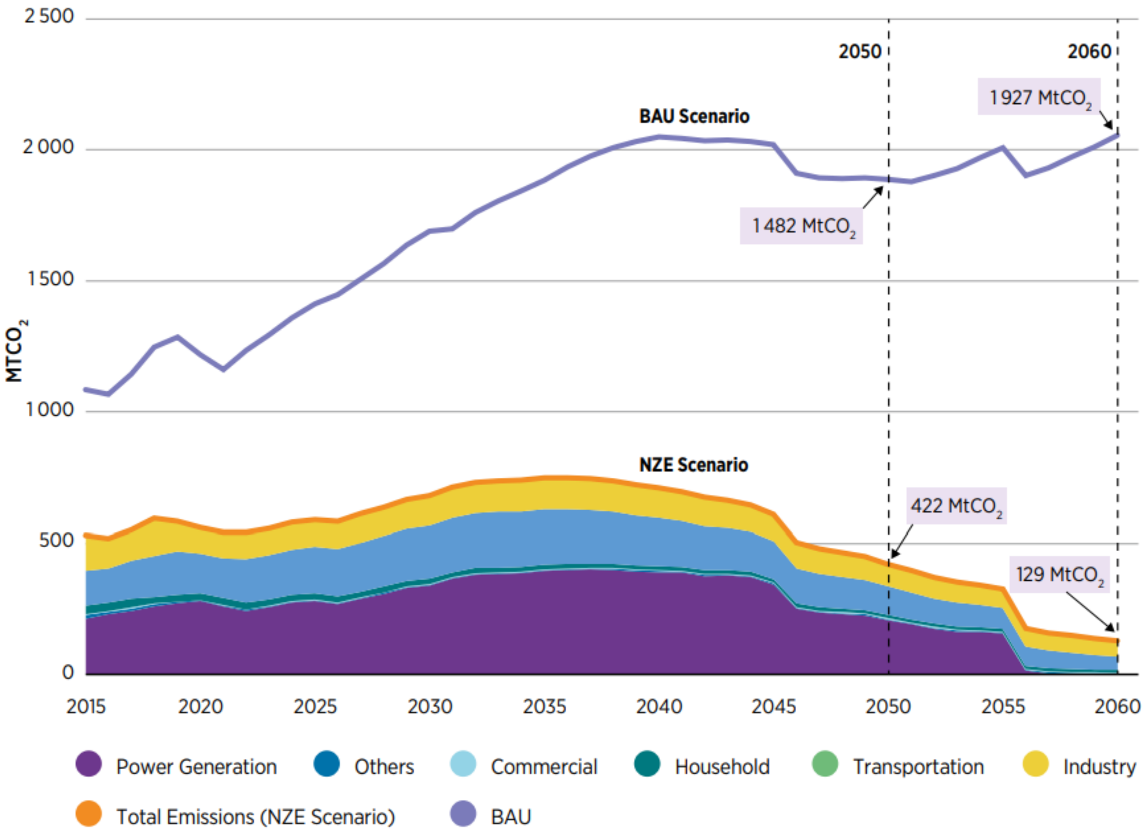

Figure 2 Net-Zero Emission Roadmap for the Energy Sector[13]

The government aimed to attract USD 33.5 billion in energy sector investment by 2022, including USD 17 billion in oil and gas, USD 7.6 billion in electricity, USD 5 billion in coal and minerals, and USD 3.9 billion in renewable energy. The renewable energy investment objective saw the most significant year-over-year increase but remained lower than other subsectors.

By the end of the third quarter of 2022, the energy sector had received only USD 18.7 billion in investments, falling short of the goal. As a result of the high coal price, only the coal and mineral mining sector was able to approach the target, reaching 80% by the end of the third quarter.

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[13] IRENA, 2022, Indonesia Energy Transition Outlook, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Oct/IRENA_Indonesia_energy_transition_outlook_2022.pdf?rev=b122956e990f485994b9e9d7075f696c

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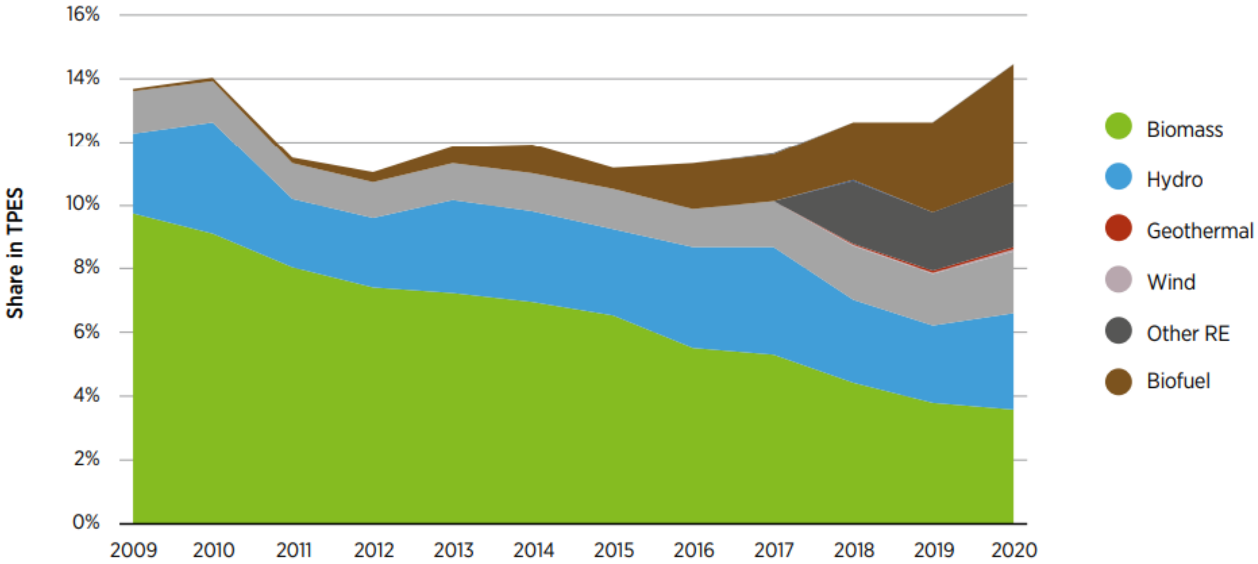

Figure 3 Share of renewable energy in total primary energy supply, 2009–2020[14]

A low investment realization rate in renewable energy resulted from insufficient regulatory changes, such as delays in enacting the New and Renewable Energy Bill and the Presidential regulation on renewable energy tariffs. By the end of the third quarter of 2022, only USD 1.35 billion will have been invested in renewable energy, which is less than 35% of the goal for this year of USD 3.97 billion. The long-awaited replacement for MEMR Regulation No. 50/2017, the most significant barrier to renewable investment, was eventually published in September 2022. However, rather than introducing Feed-in-Tariff as previously anticipated, Presidential Regulation No. 112/2022 only introduced the new price-ceiling mechanism for renewable energy, which could provide developers with improved investment returns. This new regulation should be able to attract investors for renewable energy projects in the coming years, although the outcome will depend on PLN's procurement procedure.

The New and Renewable Energy Bill has been transmitted from the parliament to the government, and the government has responded; however, the bill's issuance will be delayed further due to disagreements over several clauses. Instead of emphasizing support for renewables, the most recent draft includes provisions that incentivize using fossil fuels as alternative energy sources (i.e., coal downstream), indicating continued support for fossil fuels and sending investors conflicting signals.

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[14] IRENA, 2022, Indonesia Energy Transition Outlook, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Oct/IRENA_Indonesia_energy_transition_outlook_2022.pdf?rev=b122956e990f485994b9e9d7075f696c

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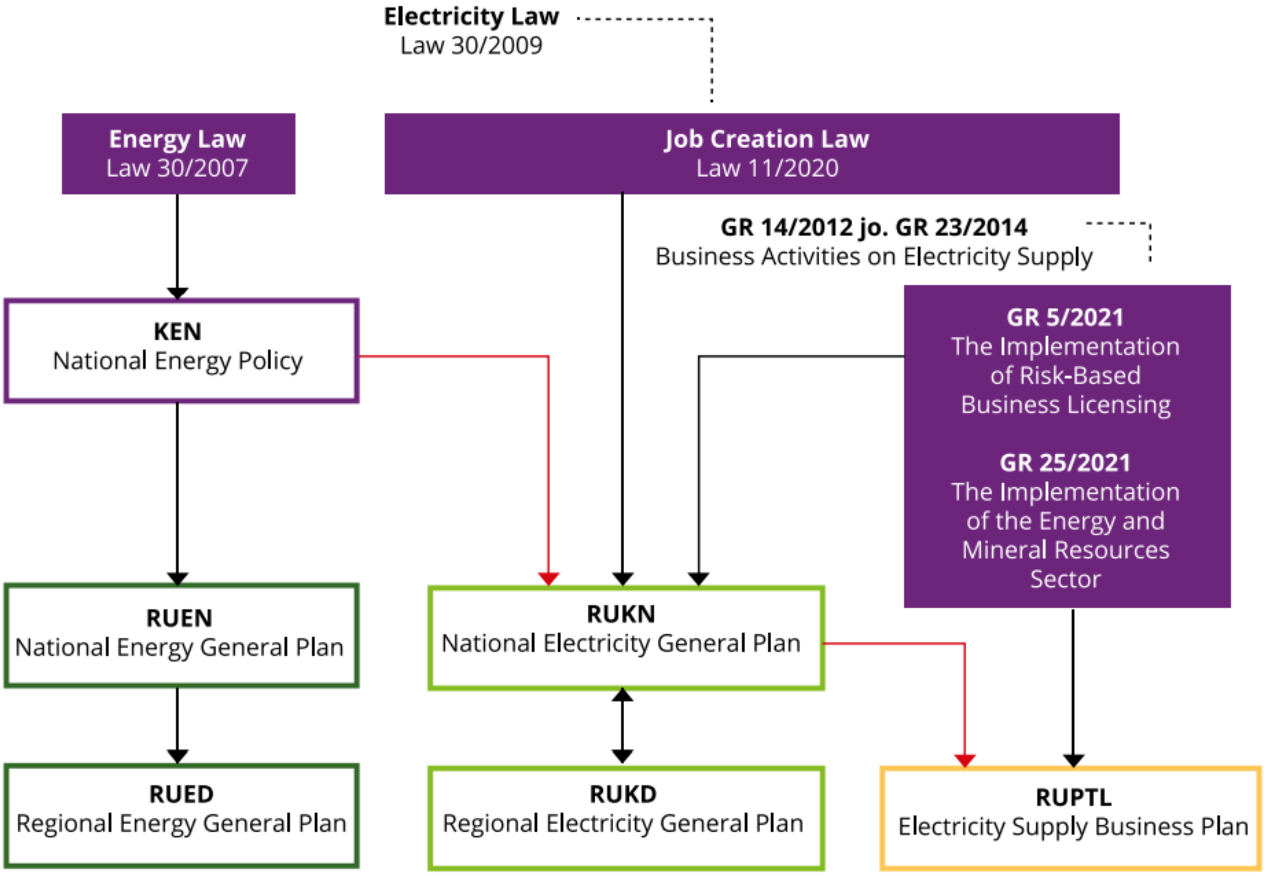

Figure 4 Electricity Sector Planning in Indonesia[15]

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[15] IRENA, 2022, Indonesia Energy Transition Outlook, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Oct/IRENA_Indonesia_energy_transition_outlook_2022.pdf?rev=b122956e990f485994b9e9d7075f696c

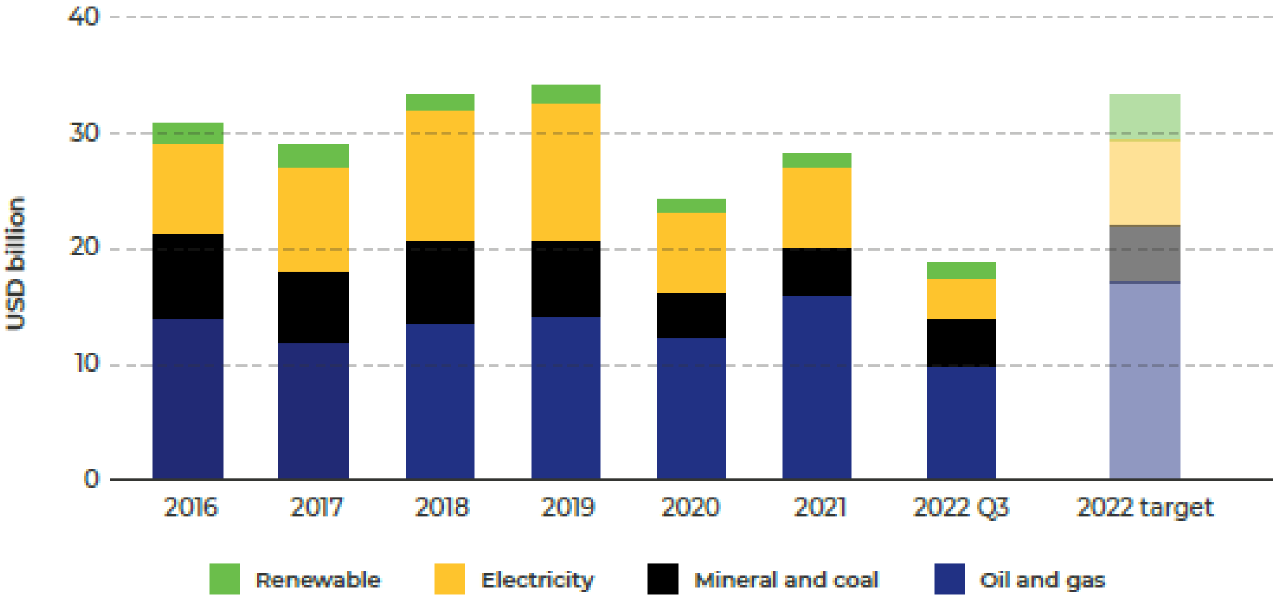

Figure 5 Investment allocation in the energy sector (2016-2021) [16]

The paper's objectives are as follows:

1. How to determine the optimal technologies for new and renewable energy implementation in Indonesia?
2. What obstacles and difficulties impede implementing of renewable energy and energy efficiency projects and policies in Indonesia?

METHODOLOGY

Research is a scientific endeavor; therefore, it must be conducted methodically, logically, or reasonably, using accurate data or facts. Below is an illustration of the methodology for development:

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[16] 2016-2021 data from MEMR, 2022b, 2022 Q3 from MEMR's preliminary data per November

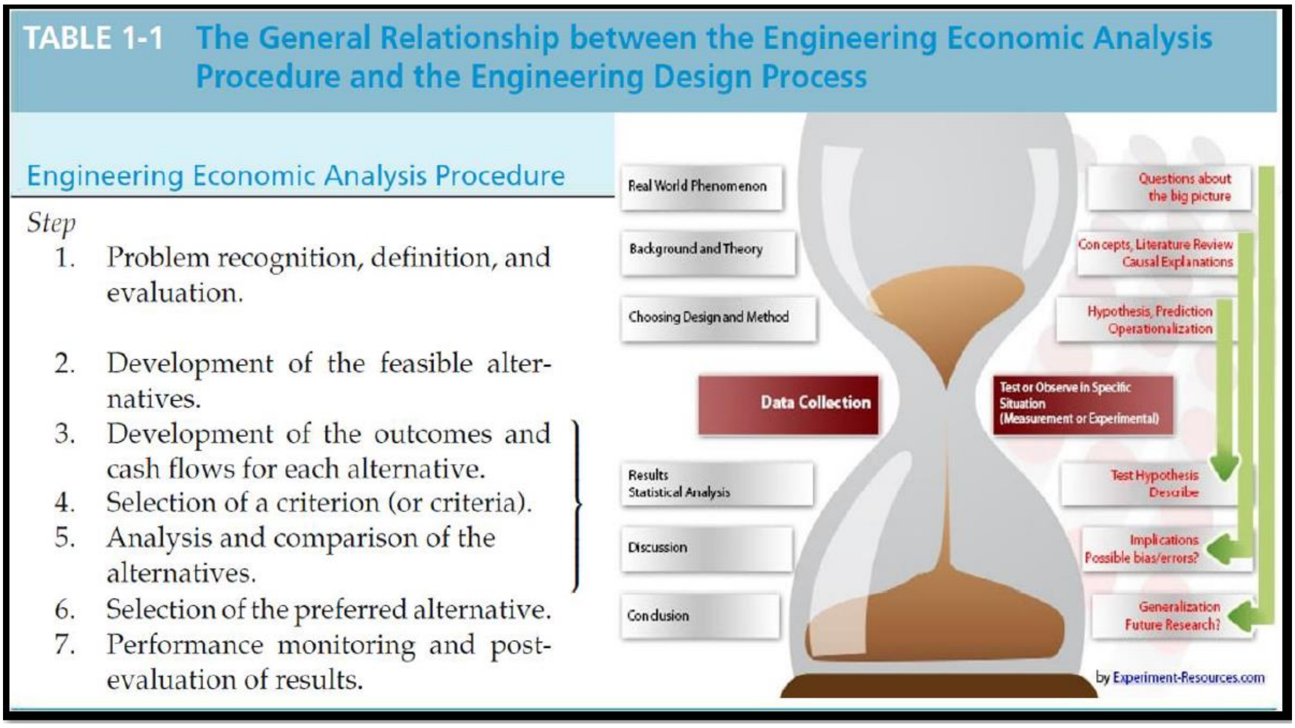

TABLE 1-1 **The General Relationship between the Engineering Economic Analysis Procedure and the Engineering Design Process**

Engineering Economic Analysis Procedure

Step

1. Problem recognition, definition, and evaluation.
2. Development of the feasible alternatives.
3. Development of the outcomes and cash flows for each alternative.
4. Selection of a criterion (or criteria).
5. Analysis and comparison of the alternatives.
6. Selection of the preferred alternative.
7. Performance monitoring and post-evaluation of results.

Figure 6 Procedure of Engineering Economics Analysis[17]

Step 1 - Problem Definition

Alternative technologies, fuels, and management systems are incorporated into energy-efficient initiatives that diminish heat and electricity usage. New and Renewable Energy Supply initiatives generate heat and electricity from sources of energy that are rapidly replenished. Their recent prominence in modern society has been fueled by their low environmental impact compared to fossil fuel alternatives. However, as they mature, energy-efficient and renewable technologies must demonstrate their environmental and economic benefits. This paper evaluates projects using methods that account for the specific economic, environmental, and energy characteristics of renewable and energy-efficient technologies.

Before these investments can be financed and implemented, each of the countless energy efficiency and supply projects must be identified, shortlisted, modeled, and economically evaluated. Some will be huge investments, such as geothermal and hydroelectric power schemes, while others will be modest energy-efficient measures, such as installing home attic insulation. All necessitate a methodical approach to evaluating their relative costs and benefits. This paper presents and illustrates the evaluation tools required to make these decisions as effectively as possible.

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[17] Sullivan, G. W., Wicks, M. E., & Koelling, C. P. (2019). Engineering Economy 16th Edition. Chapter 2 Cost Concepts and Design Economics, Page 31.

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Step 2 – Development of the Feasible Alternatives

Due to its geographic location, natural resources, and energy demands, Indonesia possesses a substantial renewable energy potential. Here are several potential renewable energy sources in Indonesia:

- **Solar PV Energy**: Indonesia is situated close to the equator and obtains an abundance of sunlight throughout the entire year. Solar energy has significant potential, especially for decentralized and off-grid applications in remote areas. The development of utility-scale solar power plants and rooftop solar photovoltaic systems can contribute to the nation's renewable energy objectives.

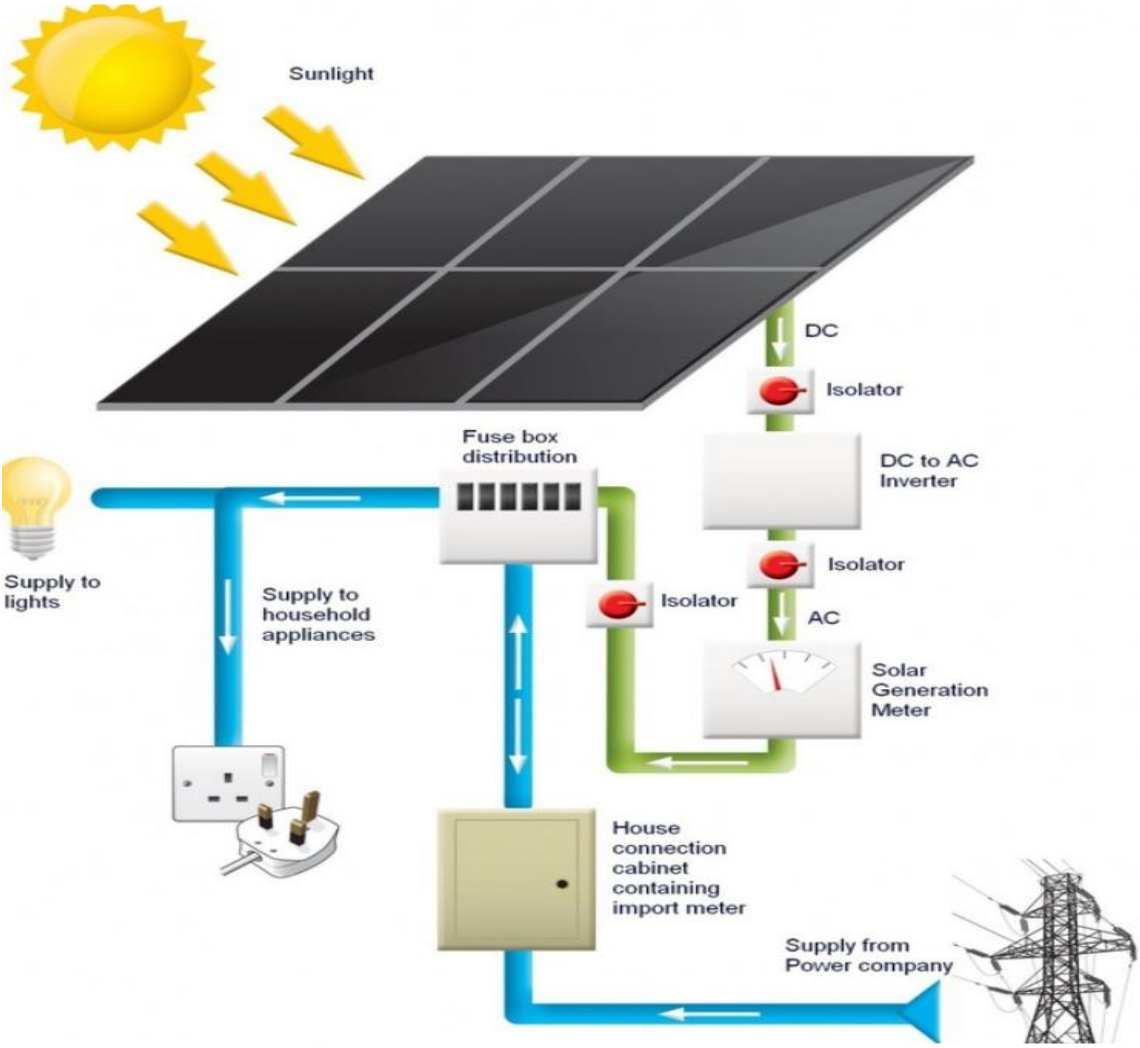

Figure 7 Solar PV Illustration[18]

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[18] *Solar PV*. (n.d.). Roof Integrated Solar by Viridian Solar. https://www.viridiansolar.co.uk/resources-4-0-solar-PV.html

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- **Wind Energy**: Certain areas of Indonesia, including the eastern portion of the archipelago and the coastal regions, have favorable atmospheric conditions. Wind farms and wind turbines can be deployed to harness wind energy and generate electricity. However, wind energy development is still in the early stages in Indonesia.

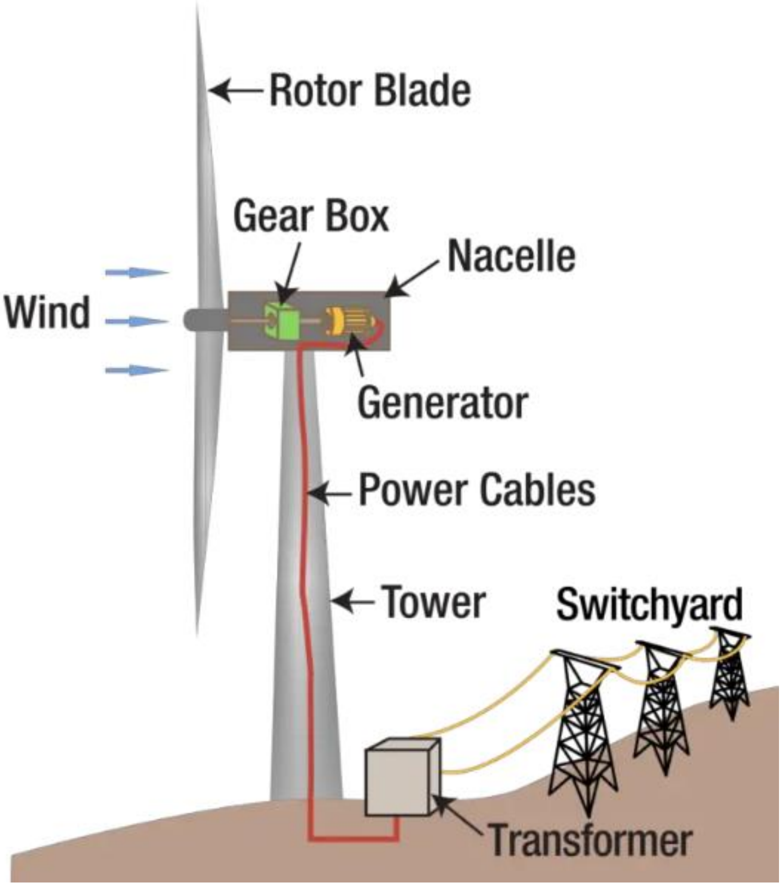

Figure 8 Wind Energy Illustration[19]

- **Geothermal Energy**: Indonesia's location within the Pacific Ring of Fire provides abundant geothermal resources. Geothermal power facilities generate electricity using the Earth's heat. Indonesia is the second-largest geothermal energy producer in the world, and there is considerable untapped potential for future development.

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[19] *How wind power plant works?- Complete explanation*. (2020, June 29). Mechanical Booster. https://www.mechanicalbooster.com/2017/12/wind-power-plant.html

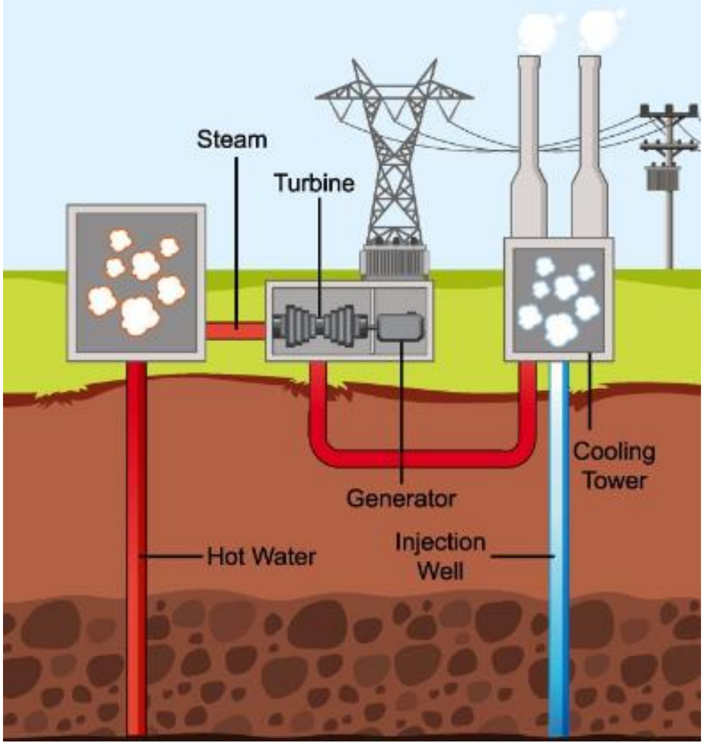

Figure 9 Geothermal Energy Illustration[20]

- **Nuclear Energy**: Nuclear energy technology refers to the processes and systems generating electricity from nuclear reactions. It harnesses the energy released during nuclear fission or fusion to produce heat, converted into electricity through steam turbines and generators. Atomic fission involves splitting the nucleus of an atom, while nuclear fusion consists of combining the nuclei of two atoms.

  In a nuclear power plant, nuclear fission reactions occur within a reactor core, where nuclear fuel, typically uranium or plutonium, undergoes controlled fission reactions, releasing tremendous. This heat produces steam from water, which drives turbines to generate electricity. The process is generally carbon-free, can produce large amounts continuously, and has large quantities of electricity to provide baseload power.

  The implementation of nuclear energy in Indonesia's archipelago has been a topic of discussion and debate for several decades. Indonesia has expressed interest in developing nuclear power as part of its long-term energy diversification strategy to meet increasing electricity demand and reduce reliance on fossil fuels. However, several challenges and considerations have influenced the pace and scale of nuclear energy implementation in the country, such as Safety and Public Perception, Regulatory and Institutional Framework, Energy Demand and

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[20] *Geothermal energy: Renewable or non-renewable resource*. (2022, April 18). Let's Talk Geography. https://letstalkgeography.com/geothermal-energy-renewable-or-nonrenewable-resource/

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Alternatives, Infrastructure and Investment, and Technological Considerations; in selecting the right nuclear reactors technology, such as traditional pressurized water reactors (PWRs) or newer advanced designs like small modular reactors (SMRs), can impact the feasibility and cost-effectiveness of nuclear energy implementation.

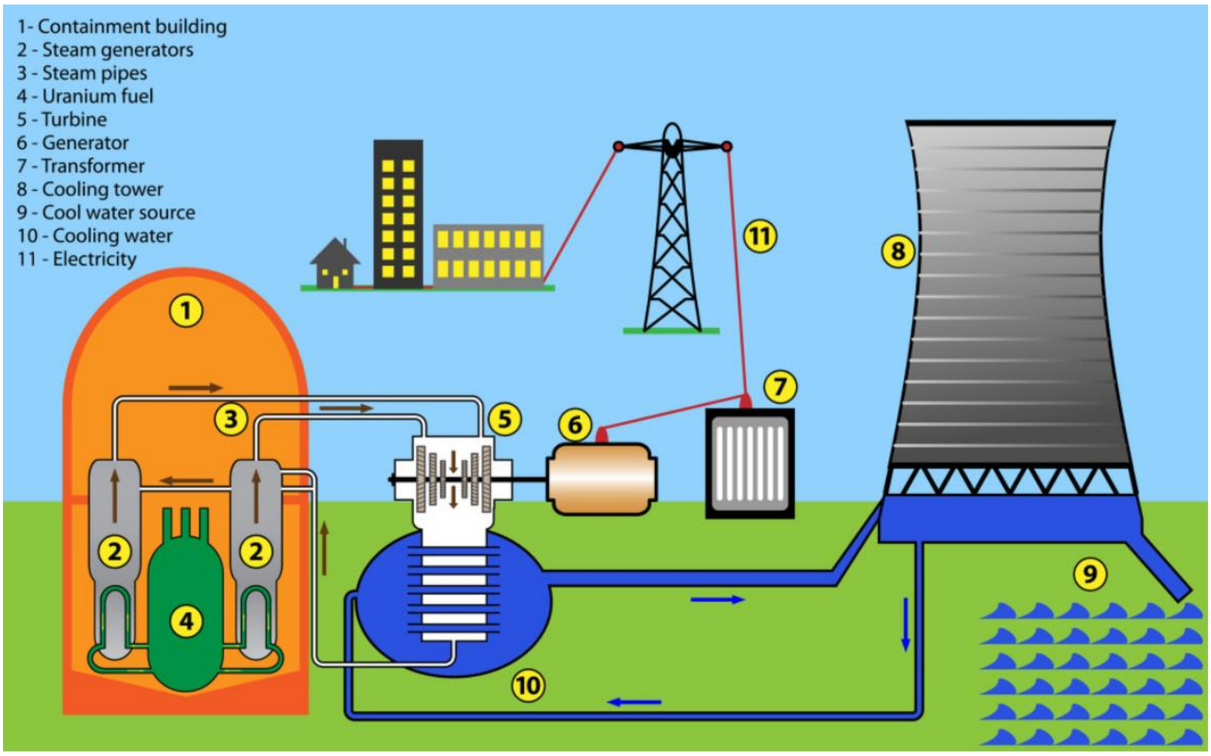

Figure 10 Nuclear Energy Illustration[21]

- **Hydropower**: With its abundant rivers and water resources, Indonesia has significant hydropower potential. Large-scale hydropower facilities and micro-hydro systems can generate electricity, especially in regions with suitable topography and water resources. However, the development of hydropower should consider environmental and social impacts.

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[21] IAS, P. (2018, February 28). *Nuclear fission, components of nuclear reactor, types of nuclear reactors*. PMF IAS. https://www.pmfias.com/nuclear-fission-nuclear-reactor-types/

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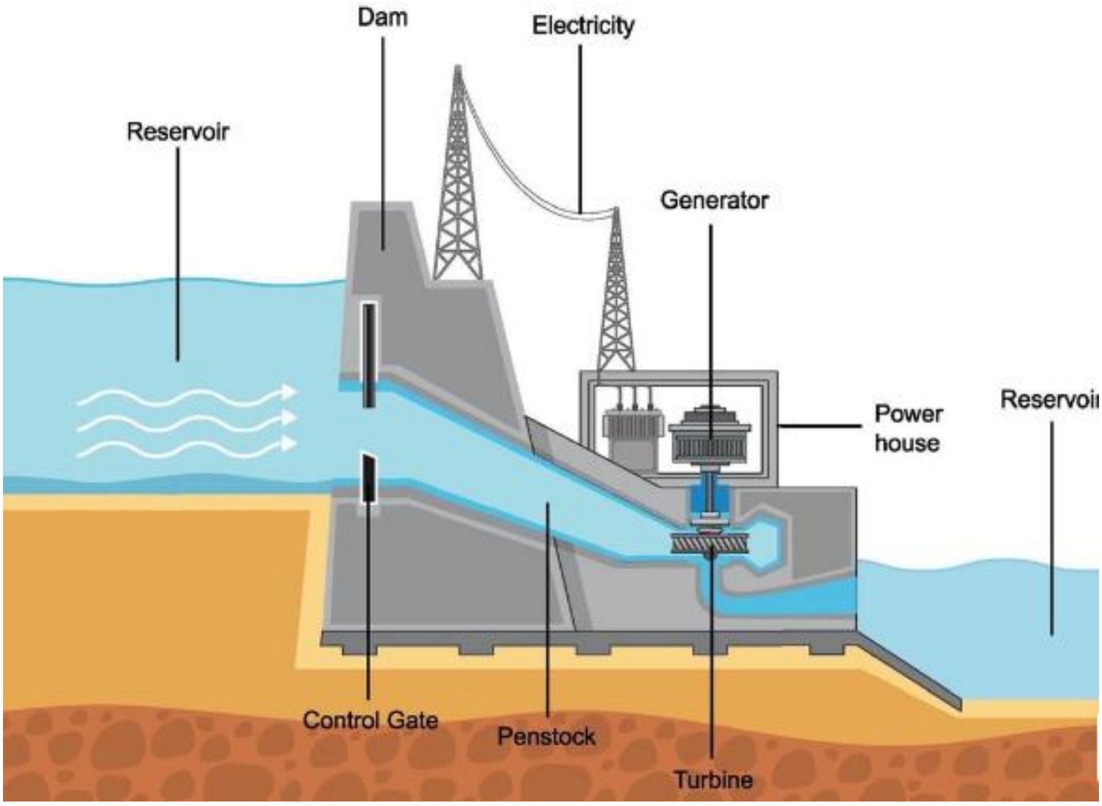

Figure 11 Hydropower Illustration[22]

- **Biomass and Bioenergy**: Indonesia has abundant biomass resources, such as agricultural residues, organic refuse, and palm oil byproducts. Biomass can generate electricity, create biogas for cooking and heating, and serve as a feedstock for biofuel production. Promoting sustainable biomass utilization can help meet renewable energy objectives.

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[22] *Download diagram showing hydro-powered electrical power plant for free*. (2021, January 22). Vecteezy. https://www.vecteezy.com/vector-art/1949334-diagram-showing-hydro-powered-electrical-power-plant

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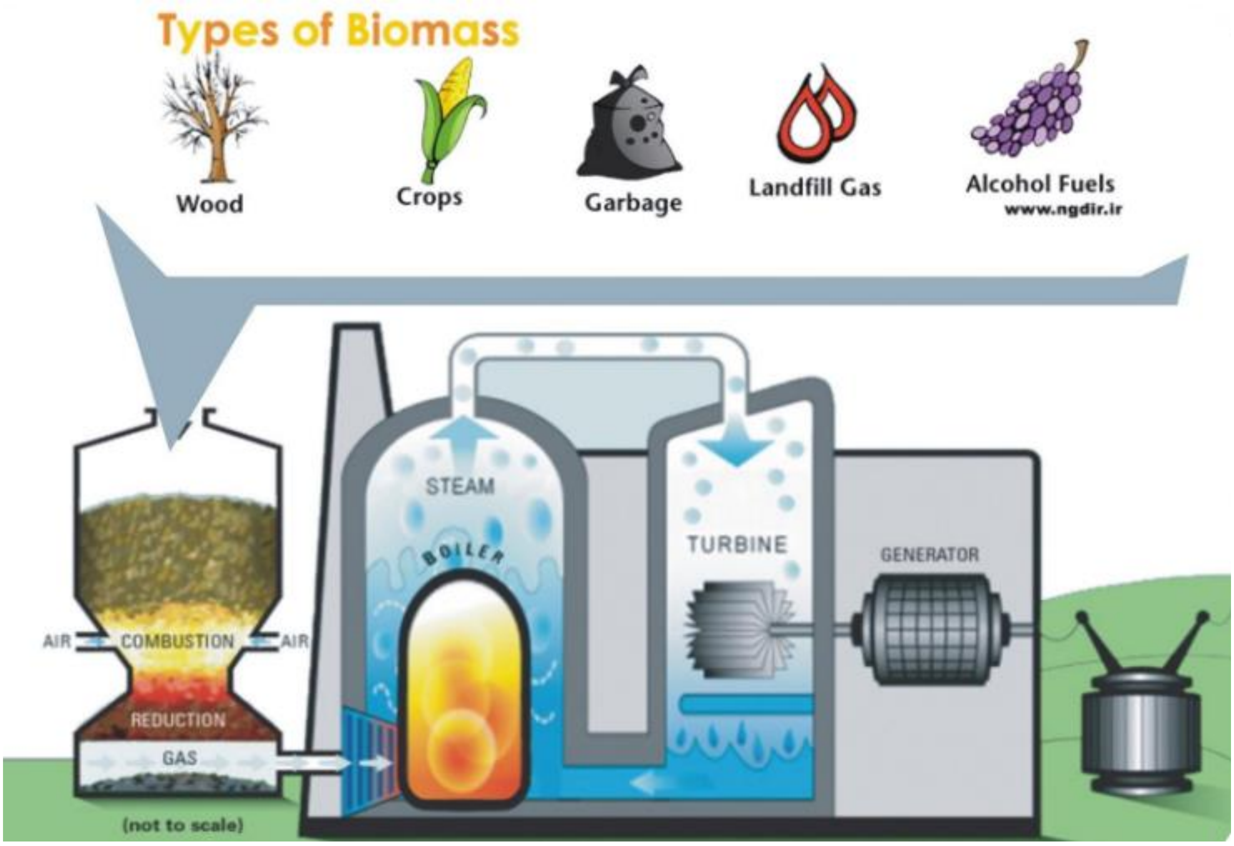

Figure 12 Biomass Illustration[23]

- **Ocean Energy**: The oceans present opportunities for energy technologies like tidal and wave power. Even though these technologies are still in the early phases of development, they can contribute to Indonesia's coastal renewable energy mix.

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[23] *Numbers*. (2023, February 28). Numbers -. https://www.energycompanynumbers.co.uk/renewable-energy-explained/

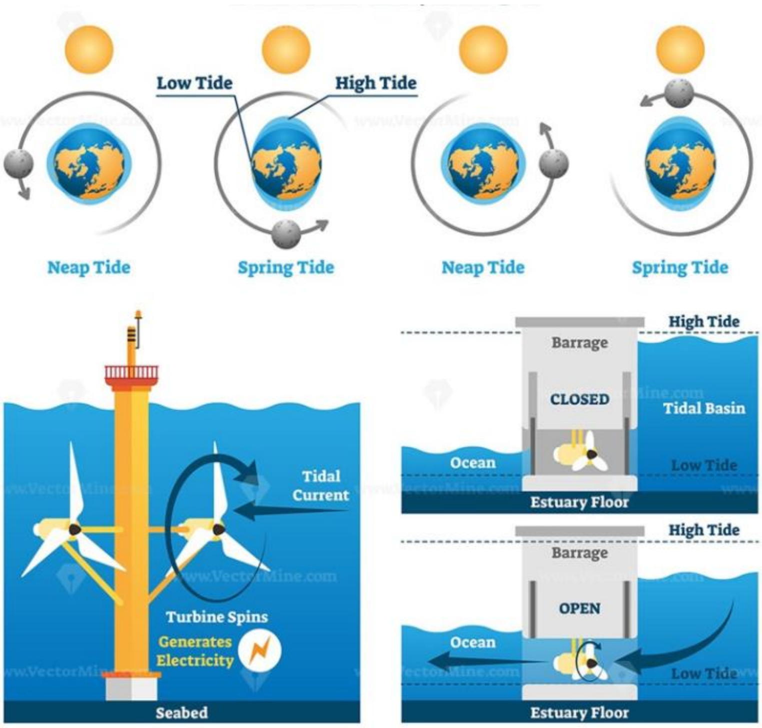

Figure 13 Tidal Energy Illustration[24]

- **Green Hydrogen**: Indonesia can become a major exporter of hydrogen generated from renewable energy sources. The country's sufficient renewable energy resources, such as solar, wind, and geothermal, can be utilized to produce green hydrogen, thereby fostering international trade and economic growth.

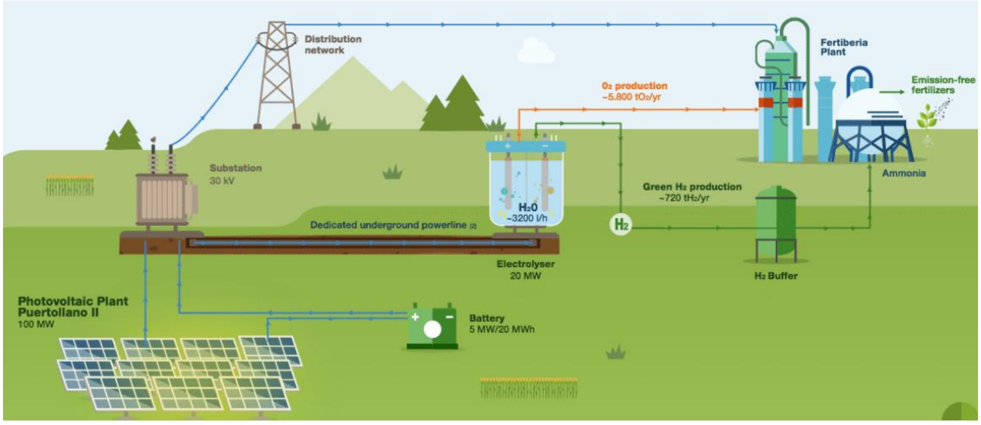

Figure 14 Green Hydrogen Illustration[25]

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[24] VectorMine. (2020, May 8). *Tidal energy vector illustration | Tidal energy, tidal power, energy projects*. Pinterest. https://in.pinterest.com/pin/732538695628572616/

[25] *Zero emission ammonia production from green hydrogen*. (2020, November 10). respectmyplanet.org. https://www.respectmyplanet.org/publications/fuel-cells/zero-emission-ammonia-production-from-green-hydrogen

Step 3 – Development of the Outcomes.

The SWOT analysis framework is a strategic planning instrument used to evaluate a subject's strengths, weaknesses, opportunities, and threats, such as a business, product, project, or industry. It provides a structured method for evaluating internal and external factors that can influence the subject of analysis. Here is a breakdown of each of the SWOT analysis's components:

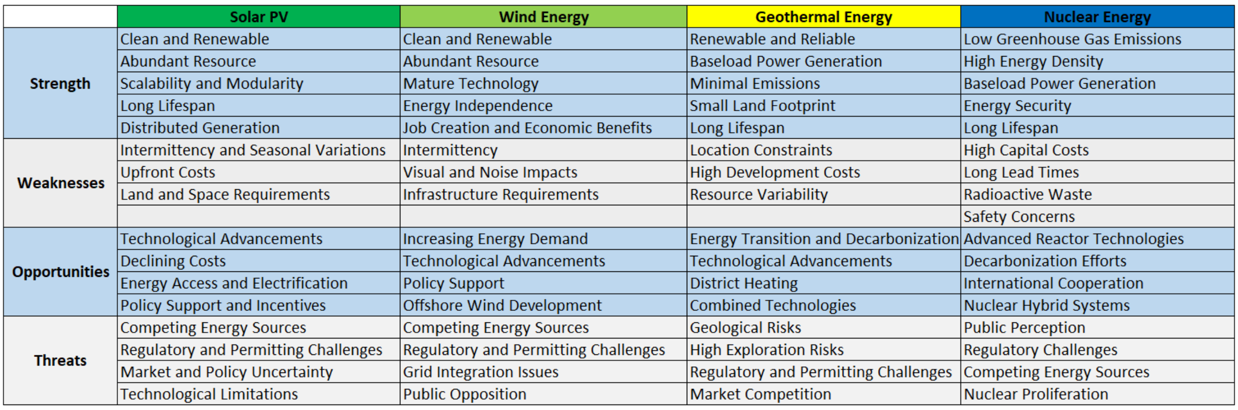
Strengths represent the inherent positive characteristics and advantages of the analyzed subject. This involves identifying the subject's core competencies, resources, and distinctive capabilities that offer it a competitive advantage. Strengths include a solid brand reputation, a skilled workforce, cutting-edge technology, cost advantages, and a loyal customer base.

Weaknesses reflect internal factors that restrict or challenge the subject. The subject may need to improve relative to competitors in these locations. Weaknesses include obsolete technology, a lack of market presence, limited resources, inefficient processes, and inadequate customer service.

Opportunities are external factors and potential growth and development avenues. The subject can exploit These advantageous circumstances, trends, or market conditions. Opportunities include emergent market trends, new technologies, alterations in consumer behavior, expanding markets, and supportive government policies.

Threats include external factors and obstacles that could impede the success or viability of the subject. These factors beyond the subject's control pose hazards or potential negative consequences. Factors such as intense competition, economic downturns, regulatory changes, altering consumer preferences, and technological disruptions can constitute threats.

Details of the SWOT analysis of each technology based on the literature are as follows:



	Solar PV	Wind Energy	Geothermal Energy	Nuclear Energy
Strength	Clean and Renewable	Clean and Renewable	Renewable and Reliable	Low Greenhouse Gas Emissions
	Abundant Resource	Abundant Resource	Baseload Power Generation	High Energy Density
	Scalability and Modularity	Mature Technology	Minimal Emissions	Baseload Power Generation
	Long Lifespan	Energy Independence	Small Land Footprint	Energy Security
	Distributed Generation	Job Creation and Economic Benefits	Long Lifespan	Long Lifespan
Weaknesses	Intermittency and Seasonal Variations	Intermittency	Location Constraints	High Capital Costs
	Upfront Costs	Visual and Noise Impacts	High Development Costs	Long Lead Times
	Land and Space Requirements	Infrastructure Requirements	Resource Variability	Radioactive Waste
				Safety Concerns
Opportunities	Technological Advancements	Increasing Energy Demand	Energy Transition and Decarbonization	Advanced Reactor Technologies
	Declining Costs	Technological Advancements	Technological Advancements	Decarbonization Efforts
	Energy Access and Electrification	Policy Support	District Heating	International Cooperation
	Policy Support and Incentives	Offshore Wind Development	Combined Technologies	Nuclear Hybrid Systems
Threats	Competing Energy Sources	Competing Energy Sources	Geological Risks	Public Perception
	Regulatory and Permitting Challenges	Regulatory and Permitting Challenges	High Exploration Risks	Regulatory Challenges
	Market and Policy Uncertainty	Grid Integration Issues	Regulatory and Permitting Challenges	Competing Energy Sources
	Technological Limitations	Public Opposition	Market Competition	Nuclear Proliferation

Table 1 SWOT Analysis Comparison (1)[26]

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[26] The author

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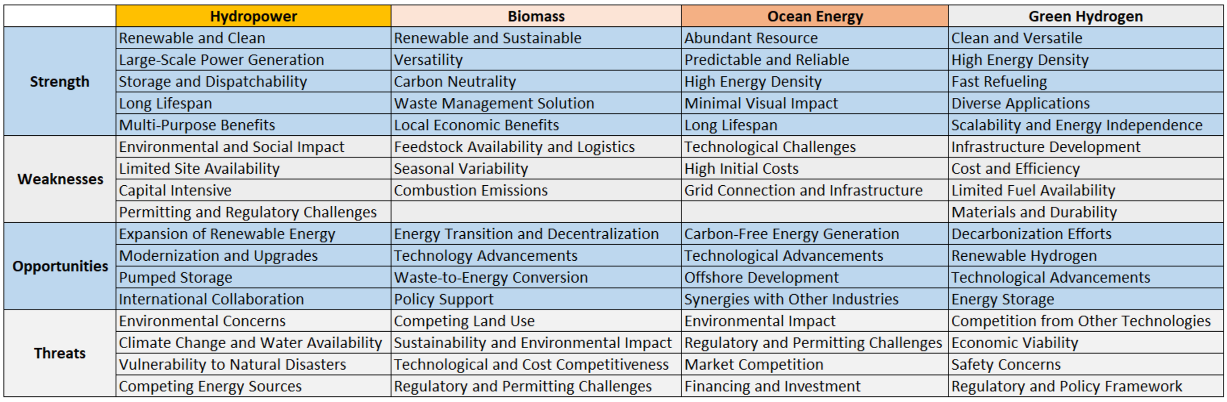

	Hydropower	Biomass	Ocean Energy	Green Hydrogen
Strength	Renewable and Clean	Renewable and Sustainable	Abundant Resource	Clean and Versatile
	Large-Scale Power Generation	Versatility	Predictable and Reliable	High Energy Density
	Storage and Dispatchability	Carbon Neutrality	High Energy Density	Fast Refueling
	Long Lifespan	Waste Management Solution	Minimal Visual Impact	Diverse Applications
	Multi-Purpose Benefits	Local Economic Benefits	Long Lifespan	Scalability and Energy Independence
Weaknesses	Environmental and Social Impact	Feedstock Availability and Logistics	Technological Challenges	Infrastructure Development
	Limited Site Availability	Seasonal Variability	High Initial Costs	Cost and Efficiency
	Capital Intensive	Combustion Emissions	Grid Connection and Infrastructure	Limited Fuel Availability
	Permitting and Regulatory Challenges			Materials and Durability
Opportunities	Expansion of Renewable Energy	Energy Transition and Decentralization	Carbon-Free Energy Generation	Decarbonization Efforts
	Modernization and Upgrades	Technology Advancements	Technological Advancements	Renewable Hydrogen
	Pumped Storage	Waste-to-Energy Conversion	Offshore Development	Technological Advancements
	International Collaboration	Policy Support	Synergies with Other Industries	Energy Storage
Threats	Environmental Concerns	Competing Land Use	Environmental Impact	Competition from Other Technologies
	Climate Change and Water Availability	Sustainability and Environmental Impact	Regulatory and Permitting Challenges	Economic Viability
	Vulnerability to Natural Disasters	Technological and Cost Competitiveness	Market Competition	Safety Concerns
	Competing Energy Sources	Regulatory and Permitting Challenges	Financing and Investment	Regulatory and Policy Framework

Table 2 SWOT Analysis Comparison (2)[27]

Step 4 – Selection of the Criterion

Using a SWOT analysis, the author will select the top three technologies from the above feasible technology alternatives. The author employed the simple additive weighting (SAW) method and sensitivity analysis of the baseline SAW method; the SAW method is one of the most popular and prominent multi-criteria methods. The total score for an option is determined by adding the weights of each selected criterion. Due to the impossibility of adding two criteria with different measurement scales, a standard numerical scaling system is required to enable the addition of the various criteria for each option. Estimating the total aggregate score for each option involves multiplying the score on each criterion by the importance weighting for that criterion and then summing these products across all the criteria questions. Using this method, the aggregate weighted score, V_i, for project option $_i$ can be expressed as follows:

$$V_i = \sum_{j=1}^{j=n} w_j r_{ij}$$

(Equation 1)

Where:

W_j = weight for criterion *j*

R_{ij} = score for option *i* on criterion *j*

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[27] The author

The data input into the decision model is seldom known with complete certainty. Sensitivity analysis allows the decision maker to gauge the effect of incremental changes in criterion weights and valuations on the final result.

FINDINGS

Step 5 – Analysis and Comparison of Potential NRE in Indonesia

To generate an IFE (Internal Factor Evaluation) and EFE (External Factor Evaluation) matrix from a SWOT analysis:

- Identify Internal Factors: List the strengths and weaknesses identified in the SWOT analysis as internal factors and the opportunities and threats as external factors.
- Assign Weighting: Assign each internal factor a weighting that indicates its relative importance. The weighting can be determined by impact, significance, or priority, among other variables. Utilize a scale from 0 to 1, with 1 representing the most significant weight.
- Consider the Factors: Evaluate each internal factor and designate a number between 1 and 4 to indicate the factor's strength. 4 shows a significant strength, 3 indicates a moderate strength, 2 indicates a minor strength, and 1 indicates a weakness.
- Determine the Score: Multiply each factor's weighting by its rating. The result is the factor's respective ranking.
- Add Up the Scores: Add the ratings for each internal and external factor together. The total score represents the situation's comprehensive inner strength and external environment.

Following these steps, we can construct an IFE matrix that evaluates internal strengths and weaknesses and an EFE matrix that evaluates external opportunities and threats. These matrices offer a structured method for analyzing and quantifying the factors identified in the SWOT analysis, allowing us to gain insight into the situation. From the above explanation, we can determine all the feasible alternative score as follows:

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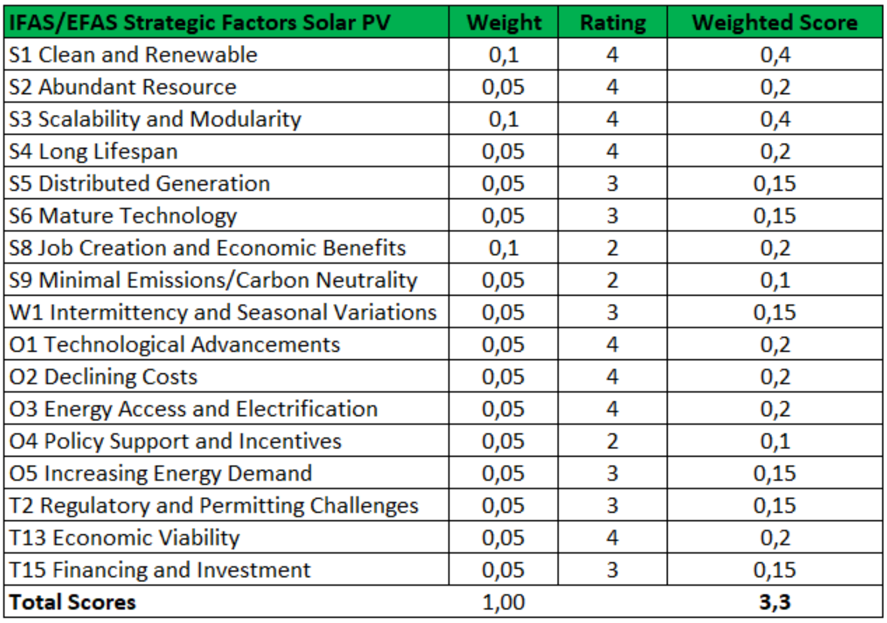
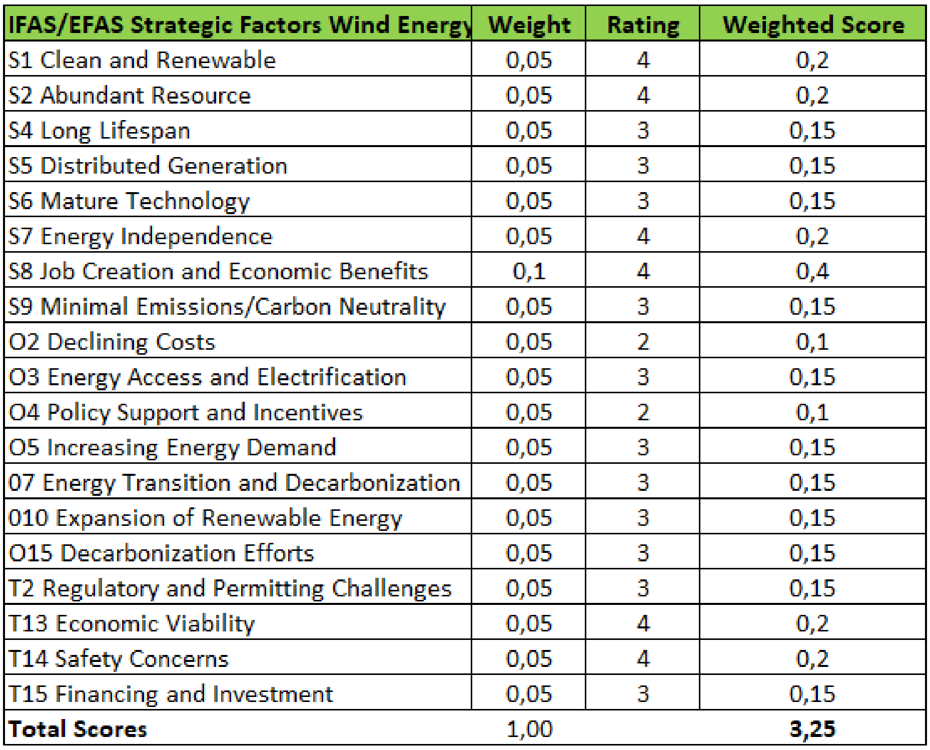


IFAS/EFAS Strategic Factors Solar PV	Weight	Rating	Weighted Score
S1 Clean and Renewable	0,1	4	0,4
S2 Abundant Resource	0,05	4	0,2
S3 Scalability and Modularity	0,1	4	0,4
S4 Long Lifespan	0,05	4	0,2
S5 Distributed Generation	0,05	3	0,15
S6 Mature Technology	0,05	3	0,15
S8 Job Creation and Economic Benefits	0,1	2	0,2
S9 Minimal Emissions/Carbon Neutrality	0,05	2	0,1
W1 Intermittency and Seasonal Variations	0,05	3	0,15
O1 Technological Advancements	0,05	4	0,2
O2 Declining Costs	0,05	4	0,2
O3 Energy Access and Electrification	0,05	4	0,2
O4 Policy Support and Incentives	0,05	2	0,1
O5 Increasing Energy Demand	0,05	3	0,15
T2 Regulatory and Permitting Challenges	0,05	3	0,15
T13 Economic Viability	0,05	4	0,2
T15 Financing and Investment	0,05	3	0,15
Total Scores	1,00		**3,3**

Table 3 IFE/EFE of Solar PV[28]



IFAS/EFAS Strategic Factors Wind Energy	Weight	Rating	Weighted Score
S1 Clean and Renewable	0,05	4	0,2
S2 Abundant Resource	0,05	4	0,2
S4 Long Lifespan	0,05	3	0,15
S5 Distributed Generation	0,05	3	0,15
S6 Mature Technology	0,05	3	0,15
S7 Energy Independence	0,05	4	0,2
S8 Job Creation and Economic Benefits	0,1	4	0,4
S9 Minimal Emissions/Carbon Neutrality	0,05	3	0,15
O2 Declining Costs	0,05	2	0,1
O3 Energy Access and Electrification	0,05	3	0,15
O4 Policy Support and Incentives	0,05	2	0,1
O5 Increasing Energy Demand	0,05	3	0,15
07 Energy Transition and Decarbonization	0,05	3	0,15
010 Expansion of Renewable Energy	0,05	3	0,15
O15 Decarbonization Efforts	0,05	3	0,15
T2 Regulatory and Permitting Challenges	0,05	3	0,15
T13 Economic Viability	0,05	4	0,2
T14 Safety Concerns	0,05	4	0,2
T15 Financing and Investment	0,05	3	0,15
Total Scores	1,00		**3,25**

Table 4 IFE/EFE of Wind Energy[29]

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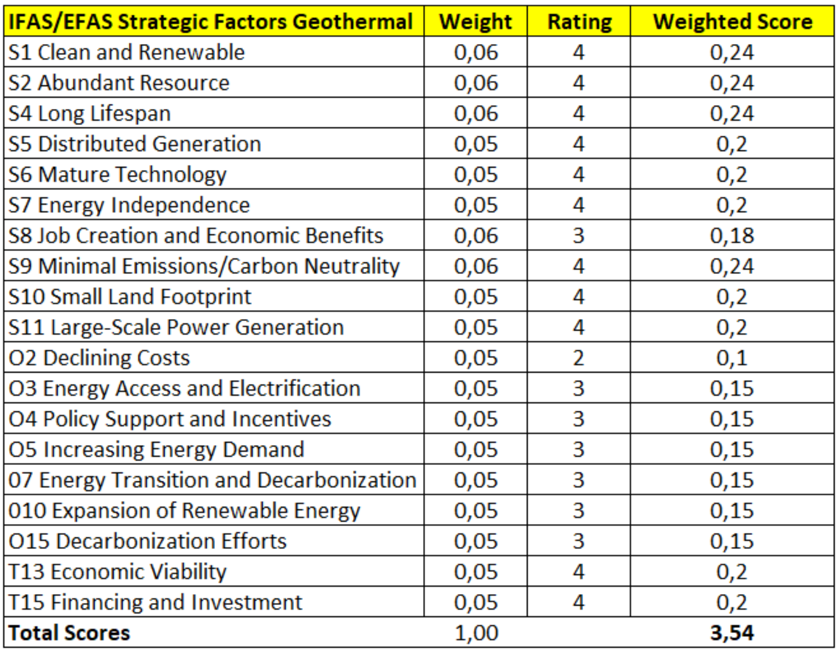
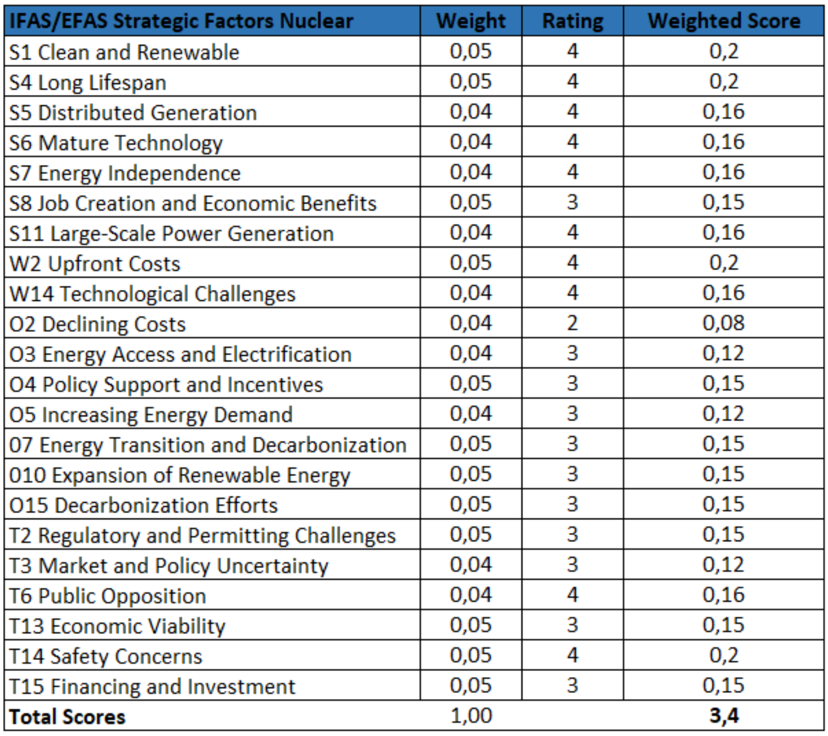


IFAS/EFAS Strategic Factors Geothermal	**Weight**	**Rating**	**Weighted Score**
S1 Clean and Renewable	0,06	4	0,24
S2 Abundant Resource	0,06	4	0,24
S4 Long Lifespan	0,06	4	0,24
S5 Distributed Generation	0,05	4	0,2
S6 Mature Technology	0,05	4	0,2
S7 Energy Independence	0,05	4	0,2
S8 Job Creation and Economic Benefits	0,06	3	0,18
S9 Minimal Emissions/Carbon Neutrality	0,06	4	0,24
S10 Small Land Footprint	0,05	4	0,2
S11 Large-Scale Power Generation	0,05	4	0,2
O2 Declining Costs	0,05	2	0,1
O3 Energy Access and Electrification	0,05	3	0,15
O4 Policy Support and Incentives	0,05	3	0,15
O5 Increasing Energy Demand	0,05	3	0,15
07 Energy Transition and Decarbonization	0,05	3	0,15
010 Expansion of Renewable Energy	0,05	3	0,15
O15 Decarbonization Efforts	0,05	3	0,15
T13 Economic Viability	0,05	4	0,2
T15 Financing and Investment	0,05	4	0,2
Total Scores	1,00		**3,54**

Table 5 IFE/EFE of Geothermal Energy[30]



IFAS/EFAS Strategic Factors Nuclear	**Weight**	**Rating**	**Weighted Score**
S1 Clean and Renewable	0,05	4	0,2
S4 Long Lifespan	0,05	4	0,2
S5 Distributed Generation	0,04	4	0,16
S6 Mature Technology	0,04	4	0,16
S7 Energy Independence	0,04	4	0,16
S8 Job Creation and Economic Benefits	0,05	3	0,15
S11 Large-Scale Power Generation	0,04	4	0,16
W2 Upfront Costs	0,05	4	0,2
W14 Technological Challenges	0,04	4	0,16
O2 Declining Costs	0,04	2	0,08
O3 Energy Access and Electrification	0,04	3	0,12
O4 Policy Support and Incentives	0,05	3	0,15
O5 Increasing Energy Demand	0,04	3	0,12
07 Energy Transition and Decarbonization	0,05	3	0,15
010 Expansion of Renewable Energy	0,05	3	0,15
O15 Decarbonization Efforts	0,05	3	0,15
T2 Regulatory and Permitting Challenges	0,05	3	0,15
T3 Market and Policy Uncertainty	0,04	3	0,12
T6 Public Opposition	0,04	4	0,16
T13 Economic Viability	0,05	3	0,15
T14 Safety Concerns	0,05	4	0,2
T15 Financing and Investment	0,05	3	0,15
Total Scores	1,00		**3,4**

Table 6 IFE/EFE of Nuclear Energy[31]

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[30] The author

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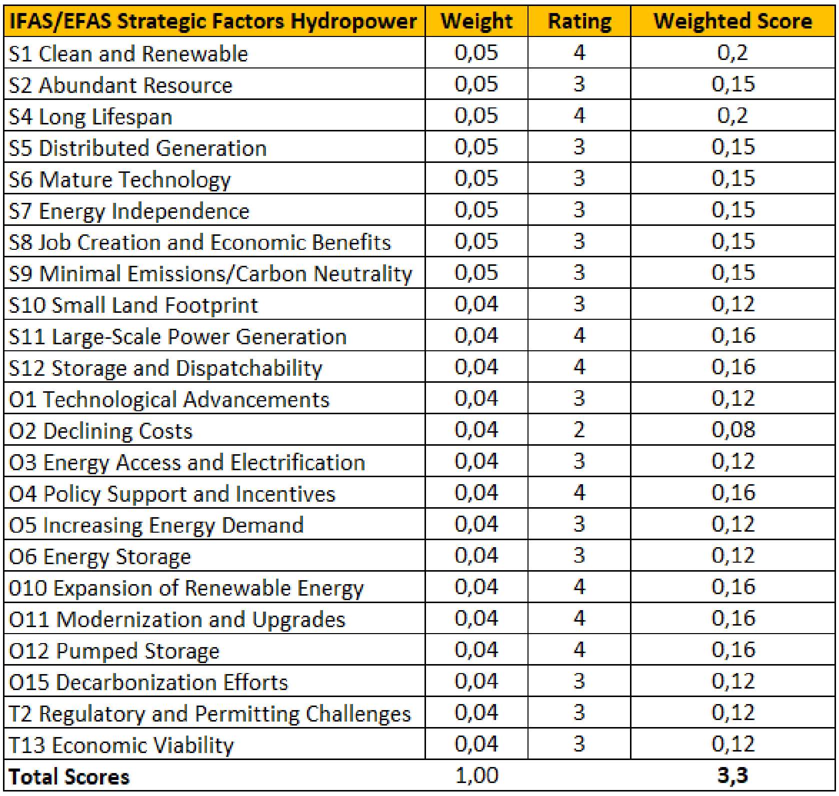
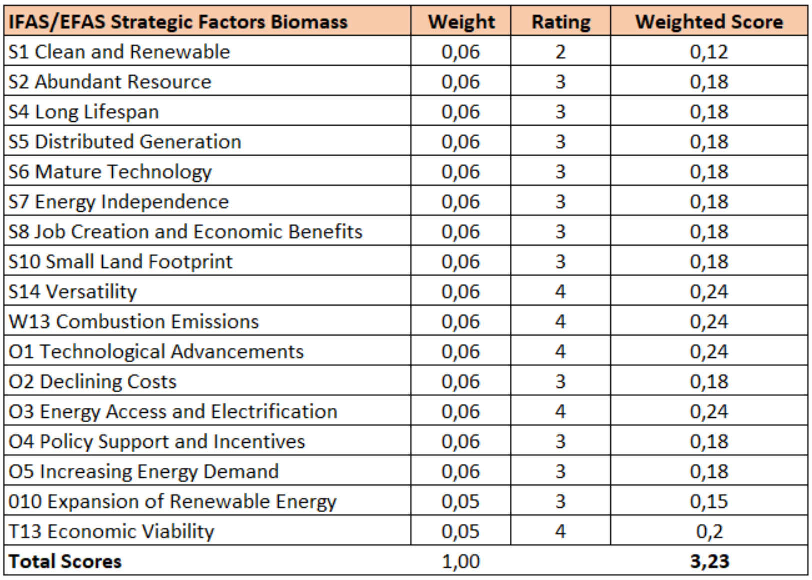


IFAS/EFAS Strategic Factors Hydropower	Weight	Rating	Weighted Score
S1 Clean and Renewable	0,05	4	0,2
S2 Abundant Resource	0,05	3	0,15
S4 Long Lifespan	0,05	4	0,2
S5 Distributed Generation	0,05	3	0,15
S6 Mature Technology	0,05	3	0,15
S7 Energy Independence	0,05	3	0,15
S8 Job Creation and Economic Benefits	0,05	3	0,15
S9 Minimal Emissions/Carbon Neutrality	0,05	3	0,15
S10 Small Land Footprint	0,04	3	0,12
S11 Large-Scale Power Generation	0,04	4	0,16
S12 Storage and Dispatchability	0,04	4	0,16
O1 Technological Advancements	0,04	3	0,12
O2 Declining Costs	0,04	2	0,08
O3 Energy Access and Electrification	0,04	3	0,12
O4 Policy Support and Incentives	0,04	4	0,16
O5 Increasing Energy Demand	0,04	3	0,12
O6 Energy Storage	0,04	3	0,12
O10 Expansion of Renewable Energy	0,04	4	0,16
O11 Modernization and Upgrades	0,04	4	0,16
O12 Pumped Storage	0,04	4	0,16
O15 Decarbonization Efforts	0,04	3	0,12
T2 Regulatory and Permitting Challenges	0,04	3	0,12
T13 Economic Viability	0,04	3	0,12
Total Scores	1,00		**3,3**

Table 7 IFE/EFE of Hydropower[32]



IFAS/EFAS Strategic Factors Biomass	Weight	Rating	Weighted Score
S1 Clean and Renewable	0,06	2	0,12
S2 Abundant Resource	0,06	3	0,18
S4 Long Lifespan	0,06	3	0,18
S5 Distributed Generation	0,06	3	0,18
S6 Mature Technology	0,06	3	0,18
S7 Energy Independence	0,06	3	0,18
S8 Job Creation and Economic Benefits	0,06	3	0,18
S10 Small Land Footprint	0,06	3	0,18
S14 Versatility	0,06	4	0,24
W13 Combustion Emissions	0,06	4	0,24
O1 Technological Advancements	0,06	4	0,24
O2 Declining Costs	0,06	3	0,18
O3 Energy Access and Electrification	0,06	4	0,24
O4 Policy Support and Incentives	0,06	3	0,18
O5 Increasing Energy Demand	0,06	3	0,18
O10 Expansion of Renewable Energy	0,05	3	0,15
T13 Economic Viability	0,05	4	0,2
Total Scores	1,00		**3,23**

Table 8 IFE/EFE of Biomass[33]

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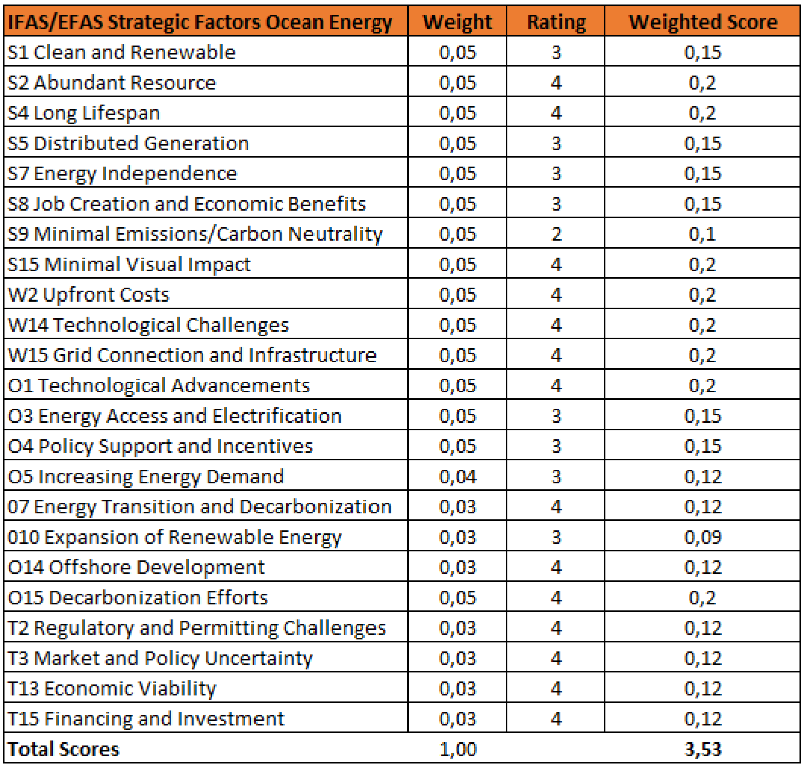
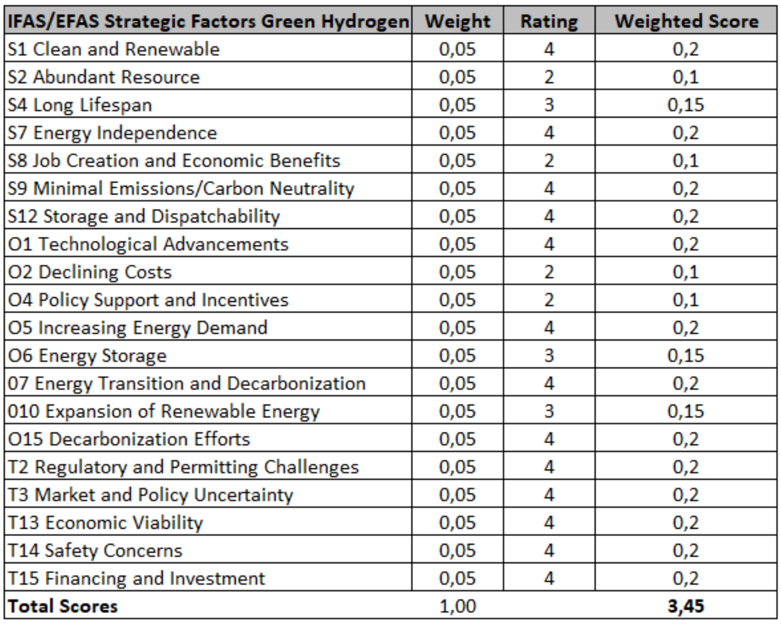
[32] The author
[33] The author



IFAS/EFAS Strategic Factors Ocean Energy	Weight	Rating	Weighted Score
S1 Clean and Renewable	0,05	3	0,15
S2 Abundant Resource	0,05	4	0,2
S4 Long Lifespan	0,05	4	0,2
S5 Distributed Generation	0,05	3	0,15
S7 Energy Independence	0,05	3	0,15
S8 Job Creation and Economic Benefits	0,05	3	0,15
S9 Minimal Emissions/Carbon Neutrality	0,05	2	0,1
S15 Minimal Visual Impact	0,05	4	0,2
W2 Upfront Costs	0,05	4	0,2
W14 Technological Challenges	0,05	4	0,2
W15 Grid Connection and Infrastructure	0,05	4	0,2
O1 Technological Advancements	0,05	4	0,2
O3 Energy Access and Electrification	0,05	3	0,15
O4 Policy Support and Incentives	0,05	3	0,15
O5 Increasing Energy Demand	0,04	3	0,12
07 Energy Transition and Decarbonization	0,03	4	0,12
010 Expansion of Renewable Energy	0,03	3	0,09
O14 Offshore Development	0,03	4	0,12
O15 Decarbonization Efforts	0,05	4	0,2
T2 Regulatory and Permitting Challenges	0,03	4	0,12
T3 Market and Policy Uncertainty	0,03	4	0,12
T13 Economic Viability	0,03	4	0,12
T15 Financing and Investment	0,03	4	0,12
Total Scores	1,00		**3,53**

Table 9 IFE/EFE of Ocean Energy[34]



IFAS/EFAS Strategic Factors Green Hydrogen	Weight	Rating	Weighted Score
S1 Clean and Renewable	0,05	4	0,2
S2 Abundant Resource	0,05	2	0,1
S4 Long Lifespan	0,05	3	0,15
S7 Energy Independence	0,05	4	0,2
S8 Job Creation and Economic Benefits	0,05	2	0,1
S9 Minimal Emissions/Carbon Neutrality	0,05	4	0,2
S12 Storage and Dispatchability	0,05	4	0,2
O1 Technological Advancements	0,05	4	0,2
O2 Declining Costs	0,05	2	0,1
O4 Policy Support and Incentives	0,05	2	0,1
O5 Increasing Energy Demand	0,05	4	0,2
O6 Energy Storage	0,05	3	0,15
07 Energy Transition and Decarbonization	0,05	4	0,2
010 Expansion of Renewable Energy	0,05	3	0,15
O15 Decarbonization Efforts	0,05	4	0,2
T2 Regulatory and Permitting Challenges	0,05	4	0,2
T3 Market and Policy Uncertainty	0,05	4	0,2
T13 Economic Viability	0,05	4	0,2
T14 Safety Concerns	0,05	4	0,2
T15 Financing and Investment	0,05	4	0,2
Total Scores	1,00		**3,45**

Table 10 IFE/EFE of Green Hydrogen[35]

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After receiving the scores from the IFE (Internal Factor Evaluation) and EFE (External Factor Evaluation) matrices, we can analyze and use information in the following ways:

- **Interpret the Scores**: Examine the scores from both matrices to understand your internal factor's relative strengths, weaknesses, opportunities, and threats in the external environment. Identify the elements with the highest scores, as they indicate areas of significant importance or impact.
- **Analyze the Findings**: Consider the relationships between the internal and external factors. Look for patterns or correlations that emerge from the scores. For example, high inner strengths coupled with favorable external opportunities could indicate areas of strategic advantage. In contrast, high internal weaknesses and external threats might highlight areas requiring immediate attention or mitigation.
- **Identify Strategic Implications**: Based on the analysis, identify strategic implications for the situation, business, or project. This could involve capitalizing on strengths, addressing weaknesses, leveraging opportunities, or mitigating threats. Prioritize actions and strategies that align with the goals and objectives.
- **Develop Action Plans**: Convert the strategic implications into actionable plans. Determine the specific initiatives, projects, or actions needed to address the identified factors. Assign responsibilities, set timelines, and establish performance indicators to track progress.
- **Implement and Monitor**: Execute the action plans and closely monitor the progress. Regularly assess the effectiveness of the strategies and adjust them as needed. Continuously review and update the internal and external factors to ensure they remain relevant and reflect the changing circumstances.

From the table above, the top three technologies are Geothermal Energy, Ocean Energy, and Green Hydrogen. The result of criterion weightings is shown below:

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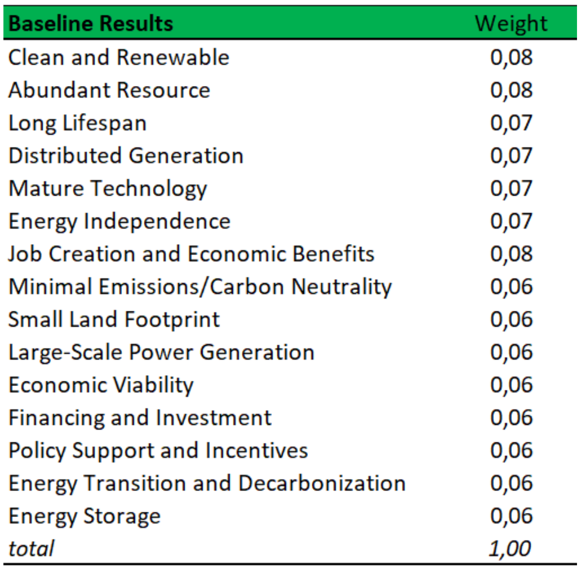
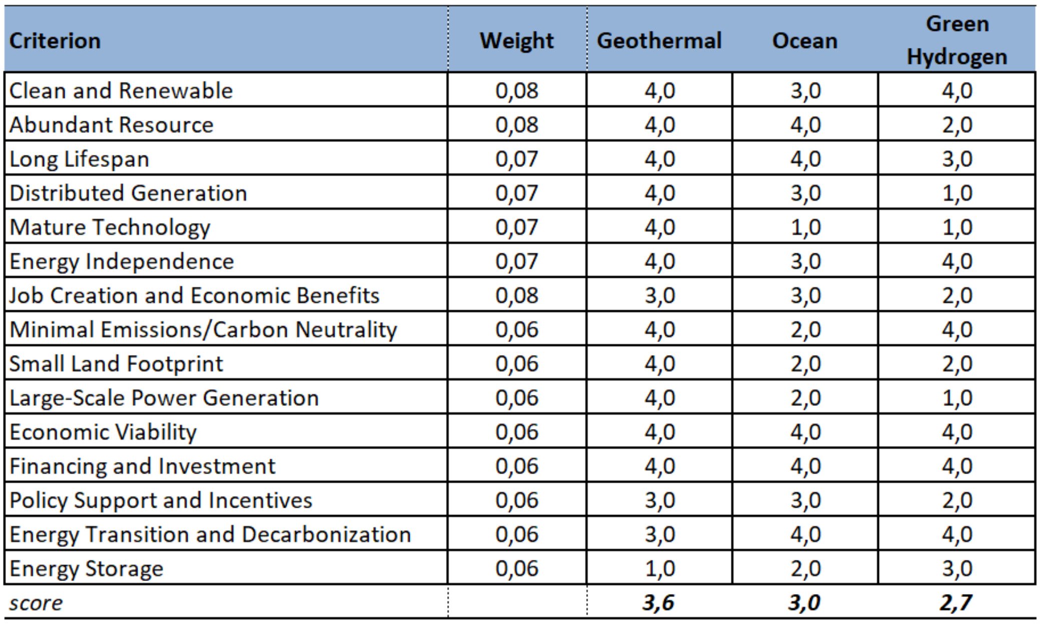


Baseline Results	Weight
Clean and Renewable	0,08
Abundant Resource	0,08
Long Lifespan	0,07
Distributed Generation	0,07
Mature Technology	0,07
Energy Independence	0,07
Job Creation and Economic Benefits	0,08
Minimal Emissions/Carbon Neutrality	0,06
Small Land Footprint	0,06
Large-Scale Power Generation	0,06
Economic Viability	0,06
Financing and Investment	0,06
Policy Support and Incentives	0,06
Energy Transition and Decarbonization	0,06
Energy Storage	0,06
total	*1,00*

Table 11 Criterion weightings baseline[36]

The final step involves the multiplication of the ratings by the relevant criterion weights. This calculation is shown in Table 12.



Criterion	**Weight**	**Geothermal**	**Ocean**	**Green Hydrogen**
Clean and Renewable	0,08	4,0	3,0	4,0
Abundant Resource	0,08	4,0	4,0	2,0
Long Lifespan	0,07	4,0	4,0	3,0
Distributed Generation	0,07	4,0	3,0	1,0
Mature Technology	0,07	4,0	1,0	1,0
Energy Independence	0,07	4,0	3,0	4,0
Job Creation and Economic Benefits	0,08	3,0	3,0	2,0
Minimal Emissions/Carbon Neutrality	0,06	4,0	2,0	4,0
Small Land Footprint	0,06	4,0	2,0	2,0
Large-Scale Power Generation	0,06	4,0	2,0	1,0
Economic Viability	0,06	4,0	4,0	4,0
Financing and Investment	0,06	4,0	4,0	4,0
Policy Support and Incentives	0,06	3,0	3,0	2,0
Energy Transition and Decarbonization	0,06	3,0	4,0	4,0
Energy Storage	0,06	1,0	2,0	3,0
score		***3,6***	***3,0***	***2,7***

Table 12 Overall scores of the top three technologies[37]

Taking the baseline example from Table 12, six sensitivity tests are carried out on the baseline weighting scores, where the three most important criteria (Clean and renewable,

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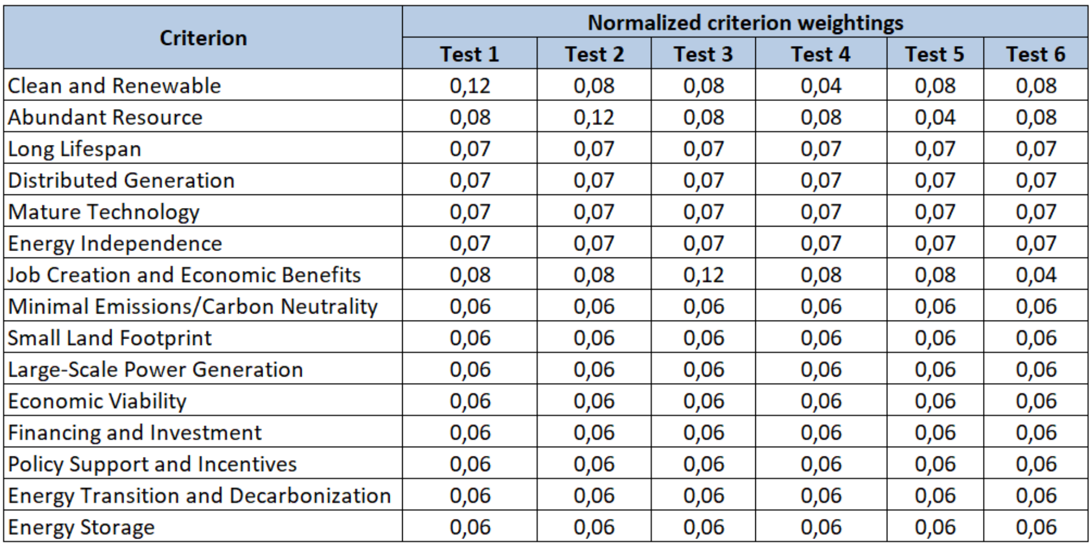
[37] The author

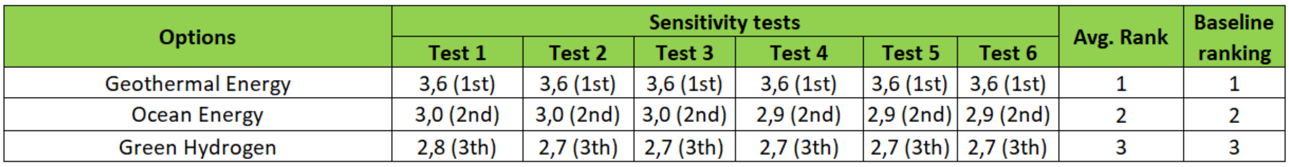
abundant resource, and Job creation and economic benefits) are subjected to a ±50% variation. The effect of these variations on the overall ranking is assessed. Table 13 details the weighting system derived from these adjustments as follows:



Criterion	Normalized criterion weightings					
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
Clean and Renewable	0,12	0,08	0,08	0,04	0,08	0,08
Abundant Resource	0,08	0,12	0,08	0,08	0,04	0,08
Long Lifespan	0,07	0,07	0,07	0,07	0,07	0,07
Distributed Generation	0,07	0,07	0,07	0,07	0,07	0,07
Mature Technology	0,07	0,07	0,07	0,07	0,07	0,07
Energy Independence	0,07	0,07	0,07	0,07	0,07	0,07
Job Creation and Economic Benefits	0,08	0,08	0,12	0,08	0,08	0,04
Minimal Emissions/Carbon Neutrality	0,06	0,06	0,06	0,06	0,06	0,06
Small Land Footprint	0,06	0,06	0,06	0,06	0,06	0,06
Large-Scale Power Generation	0,06	0,06	0,06	0,06	0,06	0,06
Economic Viability	0,06	0,06	0,06	0,06	0,06	0,06
Financing and Investment	0,06	0,06	0,06	0,06	0,06	0,06
Policy Support and Incentives	0,06	0,06	0,06	0,06	0,06	0,06
Energy Transition and Decarbonization	0,06	0,06	0,06	0,06	0,06	0,06
Energy Storage	0,06	0,06	0,06	0,06	0,06	0,06

Table 13 Criterion weightings within the six sensitivity tests[38]

While Table 14 shows the overall scores and rankings for each option on the six sensitivity tests.



Options	Sensitivity tests						Avg. Rank	Baseline ranking
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6		
Geothermal Energy	3,6 (1st)	3,6 (1st)	3,6 (1st)	3,6 (1st)	3,6 (1st)	3,6 (1st)	1	1
Ocean Energy	3,0 (2nd)	3,0 (2nd)	3,0 (2nd)	2,9 (2nd)	2,9 (2nd)	2,9 (2nd)	2	2
Green Hydrogen	2,8 (3th)	2,7 (3th)	2,7 (3th)	2,7 (3th)	2,7 (3th)	2,7 (3th)	3	3

Table 14 Results of sensitivity tests[39]

Step 6 - Indonesian Energy Business Selection

The sensitivity analysis confirms that geothermal energy can be the priority for developing New and Renewable Energy in Indonesia Region. Particular attention may also be paid to criterion scores that involve a high degree of uncertainty and subjectivity. A competent decision-maker should identify such criteria and analyze the effect of their variation on the overall ranking.

Step 7 – Performance Monitoring

This decision model is particularly relevant to the appraisal process for public sector-based energy projects or policies where environmental and social criteria must be

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assessed equal to the economic considerations. Using a method based on an ability to include all possible factors rather than one that leads to the exclusions or marginalization of certain attribute classes is much more likely to lead to public acceptance of whatever the appraisal reveals. The SAW model requires criteria of evaluation, measured initially on different scales, to be evaluated on a typical basis and permits multiple weighting systems reflecting the view of other decision-making groups to be input into the process. Sensitivity analysis plays a significant role within this technique, allowing the robustness of the baseline results to be engaged.

CONCLUSION

1. Determining the optimal technologies for new and renewable energy implementation in Indonesia requires a comprehensive and systematic approach. It involves considering factors such as the country's energy needs, available resources, policy environment, technological maturity, economic viability, and environmental impact. Here is a step-by-step guide to help with the process:

    - Energy Demand Assessment: Analyze Indonesia's current and projected energy demand. Consider population growth, economic development, industrialization, and urbanization trends.
    - Renewable Energy Resource Mapping: Identify and assess the availability of renewable energy resources in Indonesia, such as solar, wind, geothermal, hydro, ocean, green hydrogen, and biomass. Use data from government agencies, research institutions, and relevant international organizations.
    - Technological Assessment: Evaluate different renewable energy technologies' technical potential and maturity. Consider efficiency, scalability, reliability, and integration with the existing energy infrastructure.
    - Cost-Benefit Analysis: Conduct a comprehensive cost-benefit analysis for each renewable energy technology. Include the capital costs, operational expenses, expected lifespan, and potential revenue streams (e.g., feed-in tariffs, carbon credits).
    - Policy and Regulatory Framework: Review Indonesia's energy policies, regulations, and incentives related to renewable energy. Assess their support of different technologies and whether they encourage private investments in renewable projects.
    - Environmental Impact: Consider the environmental impacts of each technology, including greenhouse gas emissions (GHGs), land use, water consumption, and waste generation. Identify technologies that have low ecological footprints.
    - Grid Integration and Storage: Analyze the existing energy infrastructure and grid capacity. Evaluate the feasibility and cost-effectiveness of integrating renewable

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energy sources into the grid. Also, consider energy storage options to manage intermittent energy supply.

- Local Community Engagement: Involve local communities in decision-making, especially in areas where renewable energy projects might be implemented. Address their concerns, consider their needs, and foster community ownership to ensure project success and sustainability.
- Long-Term Planning: Develop a long-term energy roadmap that outlines the phased implementation of different renewable energy technologies. Consider the potential for technology advancements and evolving energy demand patterns.
- Pilot Projects and Monitoring: Start with pilot projects to test the feasibility and performance of chosen technologies in real-world conditions. Monitor the results and learn from the experiences to refine the implementation strategy.
- Collaboration and Partnerships: Engage with international organizations, NGOs, research institutions, and private sector partners with expertise in renewable energy. Collaborate on research, knowledge sharing, and capacity building.
- Continuous Evaluation and Adaptation: Regularly evaluate the progress of renewable energy implementation and be prepared to adapt strategies based on new information, technological advancements, and changing circumstances.

Remember that the optimal mix of renewable energy technologies may vary by region within Indonesia, depending on the availability of resources and local energy demands. It is essential to tailor the approach based on the specific conditions of each area. Nevertheless, from the above analysis, geothermal energy is the top priority of Indonesia's new and renewable energy technologies that can be implemented significantly to chase the target of 23% installed capacity of new and renewable energy in 2025.

2. Implementing renewable energy and energy efficiency projects and policies in Indonesia faces several obstacles and difficulties. Some of the key challenges include:
    1. **Lack of Financial Resources:** Financing renewable energy projects can be a significant barrier, especially for smaller projects and early-stage technologies. Limited access to affordable financing and high upfront costs can deter potential investors and developers.
    2. **Inadequate Infrastructure:** The existing energy infrastructure in Indonesia might need to be optimized for integrating renewable energy sources. Upgrading and adapting the grid to handle variable and distributed energy generation can be costly and time-consuming.

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3. **Policy and Regulatory Uncertainty:** Inconsistent or unclear policies and regulations regarding renewable energy can create uncertainty for investors and developers. Frequent regulation changes or ambiguous implementation guidelines can hinder long-term planning and investment.

4. **Bureaucratic Red Tape:** Complex and time-consuming bureaucratic processes can delay project approvals and hinder project development. Streamlining administrative procedures could accelerate project implementation.

5. **Limited Technological Expertise:** A need for more skilled professionals and experts in renewable energy technologies may limit the ability to design, install, and maintain renewable energy systems effectively.

6. **Land Acquisition and Permitting:** Securing land for renewable energy projects, particularly large-scale installations, can be challenging due to land-use conflicts and permitting issues.

7. **Intermittency and Energy Storage:** Numerous renewable energy sources, including solar and wind, are intermittent, necessitating energy storage solutions to ensure a stable and reliable energy supply.

8. **Dependency on Fossil Fuels:** Indonesia relies heavily on fossil fuels, specifically coal. The fossil fuel industry's biases may oppose the transition to renewable energy.

9. **Social and Cultural Factors:** Local communities might have reservations or concerns about introducing renewable energy projects in their regions, mainly if it affects their livelihoods or traditional practices.

10. **Access to Market and Off-take Agreements:** For independent power producers, securing power purchase agreements (PPAs) with utilities or off-takers is crucial to ensure a stable revenue stream. However, negotiating these agreements can be challenging.

11. **Inadequate Awareness and Education:** A lack of awareness and understanding of the benefits of renewable energy and energy efficiency measures can slow the adoption of these technologies.

12. **Environmental Considerations:** Despite being renewable, some energy sources, such as large-scale hydropower, can have significant environmental impacts, raising concerns among environmentalists and local communities.

13. **Geographical and Resource Constraints:** The availability and distribution of renewable energy resources might vary across different regions in Indonesia, making some technologies more suitable in certain areas than others.

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Addressing these obstacles requires a comprehensive approach involving collaboration between the government, private sector, communities, and international partners. Clear and consistent policies, financial incentives, capacity building, and public awareness campaigns can help overcome these challenges and accelerate the adoption of renewable energy and energy efficiency in Indonesia.

FUTURE RESEARCH

Future research on implementing renewable energy technologies in Indonesia should address the existing challenges and explore opportunities for scaling up renewable energy adoption.

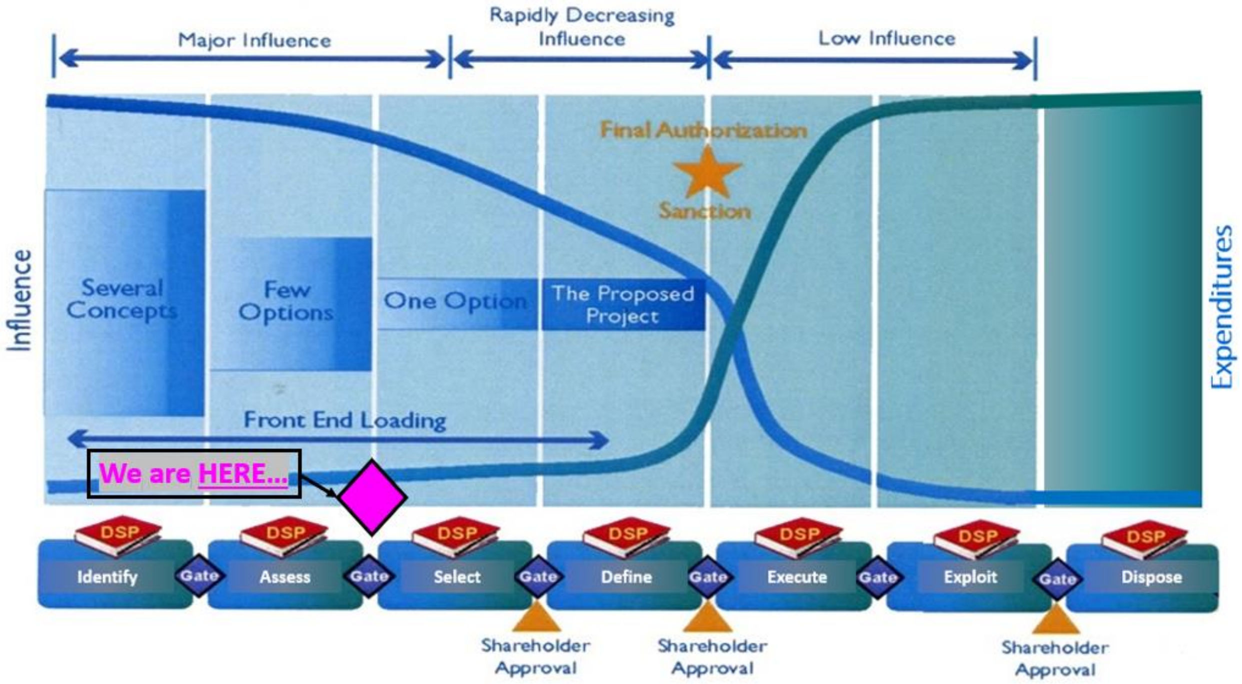

Figure 15 The Boehm, MacCleamy, or Paulson Curve[40]

According to the above curve, we can conclude that this paper is already in the second stage, "assess," and for future research, can move into the next third stage, "select," before approval of the shareholder with critical areas including:

1. **Technological Advancements:** Research and development efforts should focus on improving the efficiency, reliability, and cost-effectiveness of renewable energy technologies in a small-scale pilot project, particularly for geothermal, ocean, green hydrogen, nuclear, and energy storage solutions.

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2. **Energy Storage Solutions:** Investigate and develop advanced energy storage technologies to efficiently store excess renewable energy and provide a stable and reliable power supply, especially in remote areas or off-grid communities.
3. **Grid Integration and Smart Grids:** Research ways to enhance the integration of renewable energy into the existing grid infrastructure, including smart-grid technologies, demand response mechanisms, and grid management strategies to accommodate intermittent energy sources.

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