ISSN 1816-6075 (Print), 1818-0523 (Online)
Journal of System and Management Sciences
Vol. 14 (2024) No. 7, pp. 122-144
DOI:10.33168/JSMS.2024.0707

Renewable Energy in Indonesia: A Critical Review of Sources, Technologies, and Strategies for Clean Energy Transition

Nicholas Pranata, Fahmy Rinanda Saputri

Engineering Physics Department, Universitas Multimedia Nusantara, Tangerang, Indonesia

fahmy.rinanda@umn.ac.id

Abstract. This paper reviews renewable, and non-renewable energy sources, and analyzes their potential role in Indonesia's energy future. With declining fossil fuel reserves and environmental impacts, Indonesia needs to transition to renewable energy. However, economic, technical, and social barriers must be addressed. We provide an overview of key energy sources - coal, oil, gas, nuclear, solar, wind, geothermal, hydropower, ocean, tidal, wave, and biomass. For each source, we summarize the technology, advantages, and disadvantages. Key comparative parameters like carbon footprints are analyzed. Indonesia's energy use tilted heavily toward fossil fuels is outlined along with projections. The results show Indonesia has abundant renewable energy potential, especially solar, geothermal, hydro, and biomass. However material issues remain around economic viability, grid integration, environmental sustainability, and social acceptance. Targeted policies, facilitated investment, technological innovation, and public engagement are needed to realize Indonesia's renewable energy goals.

Keywords: Indonesia, energy sources, technology, advantages, disadvantages, renewable energy potential

1. Introduction

Since long ago, the use of energy has become significant for human lives. Undoubtedly, any terrestrial civilization depends on the Sun energy both directly, and indirectly as the environmental cycle formation, and maintenance (food production, water cycle, wind flow, etc.) (Smil, 2017; Zou, et al., 2016). The use of energy since the primitive era, in this case heat, and light from the fire became one the important tools to support hunting, and other simple purposes (Boserup, 1976; Zou, et al., 2016). Before the industrial revolution, the use of energy had evolved from an agricultural focus to the use for transportation such as using wind for sailing, and animal muscles for transportation rides (Smil, 2017). During the industrial era, the invention of the steam engine, which was more convenient, and effective from animal labor, water, and wind, was preferable and soon improved tremendously (Frenken 2003; Smil, 2017; Forrester, 2019). This invention helped humanity in easing their overall job as it became the energy source for machines, and vehicles (Chassignet, 2014). However, the use of coal has started to increase since these engines became widely implemented (Linsten, 2018). This became the beginning in which the use of fossil fuels source became increasingly exceeding.

On the side of fossil fuels historical use, in the form of petroleum, bitumen was discovered in ancient civilizations for construction, and waterproofing (Burclaff, 2022). This was followed by the discoveries of oils for lighting, and burning, natural gas for heating, and lighting, asphalt to glue, and coal for heating (Kool, 2020; Smil, 2017). By the time of the Industrial Revolution in Britain, these three sources had become the main key for energy in industry, and households (Kool, 2020). This can be seen in the case of the steam engine mentioned which used coal as the fuel. The steam engine was the first key to the revolution of mover technology as it was more practical, economical, and reliable than coal (from chemical to mechanical energy) (Smil, 2017). The use of fossil fuel since then has become dependent in the last decades whilst causing damage, and impact negatively to the environment (Rajest, 2021). The use of fossil fuels can be seen in the last decades which increased along the need for energy for human activities due to the growing population (Wambui et al 2023). Moreover, the reserves of fossil fuels are declining along with the global industrialization (Wambui, et al., 2022). The effect of using fossil fuels is negatively impactful on the environment, raising concerns about climate change, greenhouse gas emission, pollution, flora, and fauna extinction, deforestation, soil degradation, urban sprawl, and many more (Moosavi et al., 2018 Wambui, et al., 2022; Holechek, *et al*, 2022). Therefore, renewable energy becomes one of the solutions to provide an additional source of energy, specifically for electricity in terms of environmental impact (Wisatesajja, et al., 2021).

Indonesia is one of the countries that is facing the crisis of fossil fuels. With the decline of fossil fuel resources, Indonesia may not preserve its energy supply for future generations. Economic growth may also be halted within the moment energy usage is stopped. The sustained fluctuations in energy prices demand the need for solid macroeconomic policy planning to maintain the economic stability of each country. The greater a country's dependence on fossil energy supplies from abroad, the more important it is for that country to be prepared to face the dynamics of global economic turmoil. Considering this situation, especially in the context of Indonesia's economy, authorities should seriously consider the implementation of renewable energy sources as an alternative to reduce dependence on fossil energy. Diversifying energy sources toward sustainable development can help mitigate risks associated with global energy price fluctuations and enhance domestic energy resilience. Thus, strategic measures to promote and integrate renewable energy into economic policies can have a positive impact not only on economic stability but also on the environment and the sustainability of natural resources (IESR, 2022).

Renewable energy usage in Indonesia is far less than its tremendous potential. According to the IRENA report, the potential of Indonesia is 3692 GW whereas the energy generated is still 12 GW (IRENA, 2022). Whereas, the use of renewable energy in Indonesia has been regulated in Presidential Regulation Number 112 of 2022 concerning the Acceleration of Renewable Energy Development for Electricity Supply. Thus, in this article, a review of fossil fuels, and renewable energy will be shown,

compared, and discussed to provide, and conclude the most suitable energy type for this era especially in Indonesia.

The paper's outline is designed to provide a comprehensive exploration of the intricate facets within the realm of energy consumption and sources. The introduction serves as a gateway, briefly highlighting the topic's significance in the context of contemporary challenges. The subsequent sections navigate through the landscape of energy trends, uncovering patterns and shifts over time, followed by an exploration of reserves in the third section, shedding light on the availability and potential limitations of various energy sources. Section four conducts a thorough analysis of the advantages and disadvantages associated with different energy sources, offering a nuanced understanding of their inherent strengths and weaknesses. The fifth section scrutinizes the environmental impact through the lens of carbon footprints, elucidating the ecological consequences tied to energy production and consumption. Anticipating the future, the sixth section speculates on emerging trends, innovations, and potential solutions, delving into sustainable practices and technological advancements. The concluding section synthesizes the paper's key findings, offering a concise summary and suggesting potential avenues for further research or policy considerations.

2. Energy Consumption Trend

Population and economic growth in this era have increased global energy consumption. The demand for global energy is estimated to increase by 1.3% annually until 2040 (Megia, *et al*¸2021). With these, fossil fuels have been predicted to be the dominant source until 2050, which can be shown in Fig. 1a (Megia, *et* al, 2021). Prior, the consumption of fossil fuels showed tremendous escalation from 1800-2021 (shown in Fig. 1b).

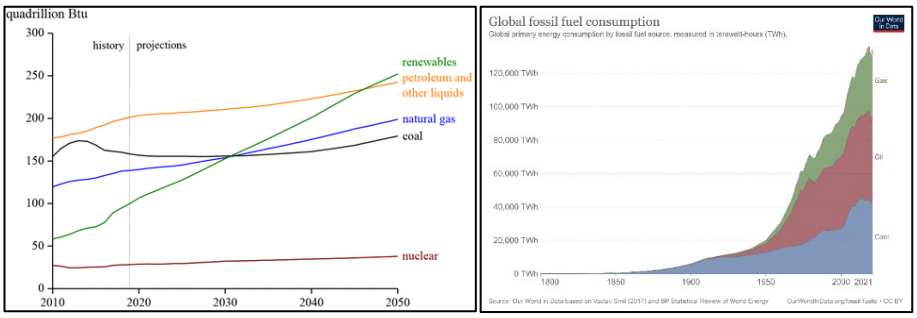

Fig. 1: a) Global energy consumption based on sources (EIA), and b) Global Fossil Fuels Consumption by Type (Our World in Data)

Many countries are facing the crisis of fossil fuels while still highly relying on it, such as Indonesia. In the ASEAN region, Indonesia become one of the largest consumers of energy with a 36% share (IRENA, 2022). Indonesia's total energy consumption is approximated at 923 million BOE at the end of 2020 with the transportation, and industry sectors being the dominant factor (IRENA, 2022). Energy consumption based on the type in Indonesia from 2012 to 2021 (seen in Fig. 3) is mostly dominated by fuel, about 33 million TOE (26.8%) followed by biofuel (biogas, and biogas oil) about 27 million TOE (DEN, 2022). Electricity and LPG consumption reached 23.6 million TOE, and 10.2 E respectively (DEN, 2022).

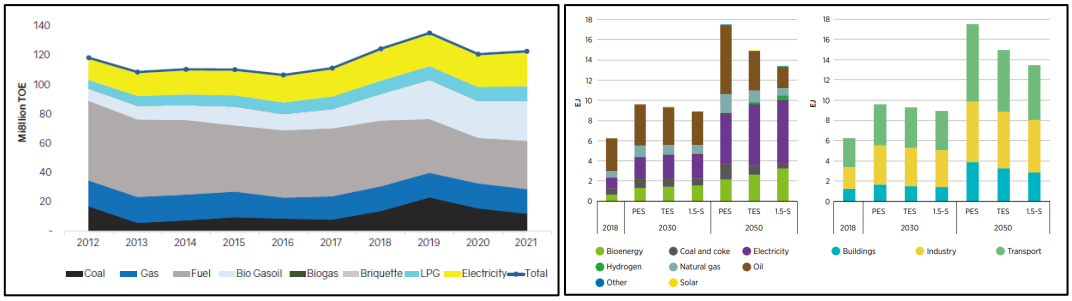

Fig. 2: Indonesia Energy Consumption by Type in 2012-2021 (HEESI)

Based on the Planned Energy Scenario (PES), Indonesia's total final energy consumption (TFEC) will rise by three times in 2050 which is shown in Fig. 3 (IRENA, 2022). Driven by population, and economic growth, Indonesia's energy demand grows by 3.3% annually (IRENA, 2022). Thus, it can be depicted that energy consumption both globally, and in Indonesia has the tendency to increase which is mostly dominated by fossil fuels. This is due to the requirement for transportation, industry, household, commercial, and others. Hence, there is a need to observe the reserve of these energy sources to find out how long will it last for future generations.

3. Energy Sources Reserves

Reserves and resources are two different terms. All reserves are resources (Nguyen, et al, 2023) whilst resources become reserves when they are identified and recorded, and can be economically accessed, and extracted (Ngyuen, et al, 2023; Perez, 2022). Reserves of energy sources are mostly directed to non-renewable energy such as fossil fuels. However, in the context of considering other factors, the term is modified and called the Reasonably Assured Recoverable Reserve or RARs (Perez, 2022). Fig. 3 represents the RAR of each type of energy according to Perez's research (2022). In specific, according to his research in consideration for the term 'reasonable' (by technology, and price-point conditions), renewable energy sources have a much larger reserve than fossil fuels specifically compared with solar, and wind energy.

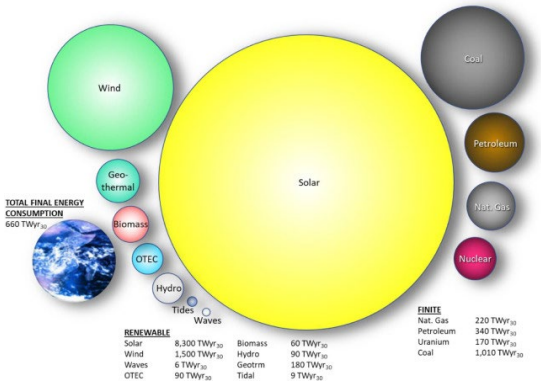

Fig. 3: Global Reasonably Assured Recoverable Reserve (Perez)

On the other hand, Indonesia's energy reserves stand at an almost similar trend compared to the global energy reserves. A report for fossil fuels reserves in Indonesia is presented below (DEN, 2022; HEESI, 2021):

1. Oil reserves amount to about 0.1% according to BP Statistic Review which declined to 2.2 billion barrels in 2021 from 7.4 billion barrels in 2012.
2. Gas reserves declined from 103 TSCF (Trillions of Standard Cubic Feet) in 2012 to 42 TSCF in 2021.
3. Coal reserves increased from 2012 to 2021 reaching 36 billion tons due to exploration in the last decade. Production, and exports of coal increase along the reserve's exploration.

As for another "considered" finite resource which is nuclear energy, based on BRIN data, Indonesia has the potential of 89,498 tons of uranium, and 143,234 tons of thorium (DEN, 2022). On the other side, renewable energy sources according to DEN (2022) can be represented below.

Table 1. Indonesia Renewable Potential, and Power Plant Capacity in 2021

NRE Commodity	Total Potential 2021 (GW)	Power Plant Capacity (GW)	%Utilization
Tidal	17.9	-	-
Geothermal	23.9	2.3	9.6%
Bioenergy	56.9	2.3	4.0%
Wind	154.9	0.2	0.1%
Hydro	95.0	6.6	6.9%
Solar	3,294.4	0.2	0.01%
Total	3,643	11.2	0.3%

Based on Table 1, solar energy dominates the share for potential by 3,294.4 GW although the utilization is the smallest (0.01%) compared to geothermal energy, and hydropower. Wind energy also shows the same tendency with only 0.1% utilization whereas its potential reaches 154.9 GW. For the case of ocean energy, no specific potential nor power capacity data is given by this report nor another similar report in Indonesia although locations have been identified by several experts. This means that the use of these renewable energy can be fostered, and accelerated to reach its maximum potential along the way. However, there should be many considerations that involve many aspects of utilizing these sources, mainly based on their advantages, and disadvantages.

4. Advantages, and Disadvantages of Energy Sources

4.1. Coal

Coal is a type of energy source that consists of carbon, and hydrocarbons, and has become the most important source for humans (Casau, et al, 2021; Gasporatto, et al, 2020). Initially, it was used as a solid fuel which now shifted to electricity generation and industrial purposes. The energy conversion of coal starts from combustion (chemical energy) to produce steam which drives the turbines, and the generator to produce electricity (Casau, et al, 2021; Kaushika, et al, 2016; Smil, 2017). The advantages, and disadvantages of coal are:

- Advantages = As mentioned before, aside from heating, and lighting, coal has been useful for industries to manufacture products such as chemical production, cement, fertilizer, textile, paper, brick, and other purposes such as metallurgical process, gasification, bioconversion, etc. (Casau, et al, 2021; Dai, et al, 2020, Li, et al, 2017; Qaisar, et al, 2014, Keboletse, et al, 2021; Li, et al, 2017). Moreover, coal creates job opportunities, and employment (Blankeship, et al, 2022).
- Disadvantages = Coal caused health issues for the lungs, immune system, heart, brain, reproductive system, DNA, and comorbidities (Gasparotto, et al, 2021). Aside from health problems, it leads to climate change, greenhouse gas emissions (CO2, SO2, and NOx), resource decrease as well as social instability (Manhberger, 2021; Lebre, et al, 2020; Medunic, et al, 2018).

According to the given information, coal is noted as a harmful potential source both to humans and the environment although it has many advantages. Therefore, it should be considered not to be the primary choice for Indonesia's future.

4.2. Oil

Oil, aside from coal, has become a source that has been needed by countries since long ago. In America by the 1800s, oil becomes significant for the production, and distribution of tools, and machines as well as shipments (Smil, 2017). Oil, popularly referred to as petroleum can be classified into three categories gaseous, liquid, and solid fuels through combustion (Kaushika, et al, 2016). This fuel in the form of steam will be used to generate electricity through a turbine, and generator (Kaushika, et al, 2016). The advantages, and disadvantages of oil can be shown below:

- Advantages = Just like other fossil fuel sources, oil is used for energy supply from the earliest human civilization (Smil, 2017). It is also used for industrial purposes such as tire manufacturing, pharmaceuticals, health care, agriculture purposes, etc. (Ambaye, et al, 2022; Hess, et al, 2011, Nasruddin, and Susanto, 2018). It also has a higher density than other energy sources, especially renewable energy (Tursi, 2019).
- Disadvantages = Oil, poses a threat to the environment, and health sufficiently. Many impacts from exploring sources, extracting, processing, shipping, and utilizing this hydrocarbon have caused severe damage such as oil spills which have greatly affected marine life ecosystems as well as burdening additional cost to solve this problem (Asif, et al, 2022). It is also associated with health problems either from gas flaring or oil spills (Oghenetega, et al, 2020).

The use of oil is still dependent in Indonesia although the reserves have started to decline. With many benefits and impacts, considerations should be made as to whether to choose oil as the dominant energy share or shift to other more environmentally friendly resources for Indonesia.

4.3. Natural Gas

Natural gas, seemingly the same as the previous sources has become a heating, and lighting source since long ago (Smil, 2017, Faramawy, et al, 2016). This source is the cleanest fossil fuel, resulting in lesser to negligible sulfur dioxide, nitrous oxide, and carbon dioxide emission by combustions which help in reducing greenhouse gases, and other problems such as acid rain (Mohammad, et al, 2021; Faramawy, et al, 2016; Smil, 2017). It is combustible and maintains a state of colorless, shapeless, and odorless (Faramawy, et al, 2016). Natural gas is conventionally burned directly in the combustion chamber to produce energy (electricity). However, many newer methods that increase efficiency have been proposed, and used, such as the Solid Oxide Fuel Cell-Hybrid System that uses natural gas (Zhu, et al, 2020). Its advantages and disadvantages are shown below:

- Advantages = Aside from being the cleanest fossil fuels, its processes such as extraction, storing, and transporting are more environmentally friendly (Thalassinos, et al, 2022). It is also used for many purposes, mainly for heating, and electricity generation as well as industrial objectives such as in the petrochemical industry, fertilizer industry as well and chemical production (Faramawy, et al, 2016).
- Disadvantages = It should be noted that although carbon dioxide and other pollutants are lesser by combustion, methane is higher in production which has a greater potential for global warming (Thalassinos, et al, 2022). It also causes health problems through air pollution that contains carcinogens from the hydraulic fracturing liquid (one of the production processes) which can also affect ground quality when injected (Thalassinos, et al, 2022). This technology also consumes a large amount of freshwater for its operations which impacts to local water system (Thalassinos, et al, 2022).

Even though it is well known for its variety of uses in industries, heating purposes, and electricity generation, many aspects such as its impact should be reviewed before deciding the potential share of this source for Indonesia's future.

4.4. Nuclear Energy

Nuclear energy is a form of energy that is produced by the nuclear reaction that releases heat to turn water into steam that will rotate the turbine to generate electricity (Arefin, et al, 2021). This reaction can be categorized into fusion, fission, and nuclear decay (Arefin, et al, 2021). It is considered a renewable energy that will help in reducing greenhouse gases and mitigating climate change (Alweli, and Mannheim, 2022; Arefin, et al, 2021). However, this energy has become a controversial topic due to its historical impact (schematic history of nuclear energy shown in Fig. 14). This is such as The Three Mile Island (1979), Chernobyl (1986), and Fukushima (2011) incidents that released radioactive components to the surrounding due to inadequate safety analysis, design flaws, and systemic management issues (Arefin, et al, 2021; Duffey, and D'Auria, 2020). Four issues according to Duffey, and D'Auria (2020) for nuclear challenges are public acceptance (due to historical incidents), sales (market competition in which fossil fuels are relatively cheaper), investment (political, and financial support retainment, technology development, research demonstration, managing, and recycling), and innovation (advancement on technology). Until today, nuclear energy does not show significant growth since many barriers limit its development. Its advantages and disadvantages counterbalance each other, which can be explained briefly below:

- Advantages = As mentioned, nuclear energy is expected to replace fossil fuels. This is shown that over the past two decades, the world's energy was shared by nuclear energy about 11-20% (Alwaeli, and Manheim, 2022). Other benefits of nuclear power are such as it consumes less energy, is high-efficiency, and creates deployment (Alwaeli, and Manheim, 2022). Moreover, fusion technology for higher efficiency in electricity generation (Horvath, and Rachlew, 2016).
- Disadvantages = This includes the adverse impact on marine life through thermal pollution, and proliferation risks (Pearce 2012; Huang, et al, 2019). Aside from the environmental threat, this energy source is still responsible for CO_2 emissions from processes such as milling, mining, and transporting of uranium (Pearce 2012; Parker, et al, 2016; Hassan, et al, 2021). Finally, safety measurement, and procedures as well as nuclear waste management, and storage are still unresolved (Pearce, 2012; Horvath, and Rachlew, 2016; Duffey, and D'Auria, 2020).

The use of nuclear energy is still debated in world societies because its benefits and impact counterbalance each other, resulting in lesser interest in developing this technology. Moreover, this energy is also associated with military purposes, which tends to give a negative image. With Indonesia's current situation, the use of nuclear energy is not recommended until its technology is objectively safe.

4.5. Solar Energy

Solar energy is a form of energy that uses radiation to produce heat, electricity, or other usable from using various solar conversion technologies (Ravi, et al, 2021; Kaushika, et al, 2016). This energy can be classified into solar photovoltaic or PV (grid-connected or off-grid), and thermal solar energy (Kaushika, et al, 2016; Pang, et al, 2022; Maka, and Alabid, 2022; Saleh, et al, 2021). A better explanation of both types can be shown below.

Table 3. Photovoltaic, and Thermal Conversion of Solar Energy

Solar Type	Photovoltaic	Thermal
Conversion	Uses solar cells (semiconductor material) to absorb light that moves the electron to produce electricity for further usage (Kaushika, et al, 2016; Pang, et al, 2022; Maka, and Alabid, 2022; Saleh, et al, 2021).	Uses solar collectors (direct normal irradiance), and transports thermal energy (by fluid for further utilization) to storage by pump/blower in which there are two types of collectors, namely non-focusing (example flat plate collector), and focusing collectors (parabolic linear/point focus

		collectors) (Kaushika, et al, 2016; Blanc, et al, 2014).
Cost	The cost itself depends on the technology, weather/climate, and national policies (Osman, et al, 2022). In general, it is relatively cheaper when used since it has low running costs, and maintenance costs (Adelakun, and Olanipekun, 2019).	
Usage	Relatively for electricity generation. Variations of this technology can be seen such as PV desalination technology (removing salt from the sea), PV-thermal technology, building-integrated PV (BIPV), PV water-pumping system, PV-powered cathodic protection, concentrated PV, and many more (Maka, and Alabid, 2022).	Solar energy conversion to thermal utilizes solar collectors, and thermal energy storage systems to collect heat for various purposes (Tian, and Zhao, 2013; Alnaimat, and Rashid, 2019; Ravi, et al, 2021). These purposes include heating, and cooling spaces, water heating, power generation, drying, washing, pasteurization, sterilization, distillation, bleaching, food processing, refrigeration, desalination, etc (Ravi, et al, 2020; Ramaiah, and Shekar, 2018).
Advantages	Clean energy that reduces greenhouse gas emissions, mitigates climate change, increases deployment, etc.	
Disadvantages	Weather, and land/latitude dependent, space requirement, environmental impact, high initial investment, etc. (Saleh, et al, 2021; Maka, and Alabid, 2022; Osman, et al, 2022, Ravi, et al, 2020, Tian, and Zhao, 2013; Alnaimat, and Rashid, 2019; Ramaiah, and Shekar, 2018).	
	It has low efficiency even compared to solar thermal technology (Saleh, et al, 2021; Maka, and Alabid, 2022; Osman, et al, 2022).	Lack of awareness towards simulation, the requirement of life cycle cost analysis, effective economic evaluation, complex integration to existing heating streams, inadequate policy, and regulations, etc. (Ramaiah, and Shekar, 2018)

Therefore, it should be noted that many aspects need to be considered, analyzed, and evaluated before proceeding with the installation of these systems due to economic, environmental, and technical downsides. Nevertheless, this can be a great opportunity to conduct further studies while implementing solar energy in Indonesia, given the fact that it has tremendous potential to supply energy.

Indonesia has already implemented Solar Power Plants (PLTS) to harness the existing potential. On August 2, 2021, the Floating Solar Power Plant (PLTS) in Cirata, Indonesia, with a capacity of 145 Mega Watts AC (MWAc), successfully secured funding. This PLTS project, projected to be the largest floating solar power plant in Southeast Asia, is estimated to require an investment of around US$145 million or approximately Rp2.1 trillion (assuming an exchange rate of Rp14,500 per US$). It is noteworthy that each 1 MW is estimated to require an investment of around US$1 million. The initial investment estimate for this project was around US$129 million (Umah, 2021).

4.6. Wind Energy

Wind energy comes from the motion of air that moves from higher to lower temperature locations because of pressure differences (Kaushika, *et al*, 2016; Murniati, *et al*, 2022). Its electricity conversion can be classified through the use of horizontal-axis or vertical-axis wind turbines shown in Fig. 16 (Kaushika, *et al*, 2016; Wisatesajja, *et al*, 2021). The horizontal-axis wind turbine has a rotating blade parallel to wind flow, and the system is operated based on the sensor to rotate the blade whereas the vertical-axis wind turbine rotates perpendicular to wind flow, and the system operates based on any wind direction without a sensor (Wisatesajja, *et al*, 2021). Wind energy is categorized as renewable energy which means it reduces the use of fossil fuels along with greenhouse gas emissions, and

environmental impact (Wisatesajja, *et al*, 2021 from Kondili, and Kaldellis, 2012). The advantages, and disadvantages of wind energy can be shown below:

1. Advantages = Creation of job opportunities, and market growth can be stimulated since jobs for manufacturing, installing, maintaining, and others are needed (Wisatesajja, *et al*, 2021). The development in the territory is also encouraged (Wisatesajja, *et al*, 2021). Based on the location type, wind energy can be classified into onshore, and offshore in which the offshore has given many benefits including higher wind velocity, less turbulence, and stability of wind flow (Waewsak, *et al*, 2015). In addition, the reduction of noise, and visual drawbacks as well as increasing power output can be achieved based on offshore type (Wisatesajja, *et al*, 2021).
2. Disadvantages = Wind energy has several drawbacks which are high cost as well as the complexity of maintaining the system (Wisatesajja, *et al*, 2021). The transportation of the components using helicopters or boats is obligated, and transmission lines are necessary for onshore type (which causes losses of power). The noise and visual drawbacks should not be overlooked since they hinder the movement of aircraft, and sea transport (Osman, *et al*, 2022). The climate also greatly impacts the wind flow because of its instability which will decide its power output (Preethi, *et al*, 2021). Moreover, although wind energy reduces emissions, it makes the surrounding temperature warmer (Miller, and Keith, 2018). Finally, the biggest impact is on wildlife since their habitual changes, and large death occurred to many species of bats, and birds either by the blade or other factors (noise, etc) (Perold, *et al*, 2020; Sekker, *et al*, 2022; Osman, *et al*, 2022; Zimmerling, and Francis, 2016).

Whereas there are advantages and disadvantages, some hydropower plants have been built in Indonesia. In example is the Sidrap Wind Power Plant (PLTB Sidrap) that is already established. There is an issue regarding the planned expansion and development of PLTB Sidrap, with an estimated investment of around USD 1.8 million per megawatt (MW). The expansion aims to utilize the most modern and advanced wind power technology, incorporating battery storage into the system (EBTKE, 2019).

4.7. Geothermal Energy

Geothermal energy is a natural energy that is derived from the Earth's core in the form of thermal energy (Sharmin, *et al*, 2023; Syivarulli, 2020; Igwe, 2021; Sui, *et al*, 2019; Aliyu, and Garba, 2019; Osman, *et al*, 2022). The process of obtaining geothermal energy starts with exploring, extracting (conventionally by drilling, extracting, distributing fluids, and Enhanced Geothermal Systems method), and finally implementing (based on temperature range) (Sharmin, *et al*, 2023; Igwe, 2021). In power plant usage, geothermal power systems can be classified into flash steam power plants (using heat from extracted geothermal wells to flash into steam), dry steam power plants (using steam of 100% vapor from underground), and binary cycle power plant (using two cycles in which the lower-temperature of hot water heat a fluid which will power the system) (Sharmin, *et al*, 2023; Igwe, 2021; Aliyu, and Garba, 2019). This energy is a renewable, and environmentally friendly source with a minimum carbon footprint and huge potential. The advantages, and disadvantages of geothermal energy can be seen below:

1. Advantages = Geothermal energy is used in varied applications such as directly for hot springs (bathing), space heating, cooking, agriculture, industrial processes such as drying, washing, fur treatment, space cooling, canning, refrigeration, chemical production; and finally, power production (Sharmin, *et al*, 2023; Igwe, 2021; Osman, *et al*, 2022). It is also a stable energy, and weather independent as well as can be stored for further applications (Sharmin, *et al*, 2023). It is also considered to be cheaper than other energy sources, yet, it depends on the technology used (Sharmin, *et al*, 2023; Igwe, 2021; Osman, *et al*, 2022).

2. Disadvantages = Challenges in implementing this energy are the high capital investment, geothermal good drilling issues (corrosions, fractures, and mechanical failures due to the high temperature), geological changes (seismic disruptions, surface instability/earthquakes, land subsidence, and hydrothermal eruptions), noise pollution, and environmental, and health impact (sulfur dioxide, and silica emissions as well as heavy metals pollution to the air, and water body as well as a human, and surrounding organism) (Sharmin, *et al*, 2023; Igwe, 2021; Osman, *et al*, 2022).

Thus, aligned with Indonesia's potential for geothermal, the use of this energy is most likely dependable to supply energy, however, it must be done with precautions, procedures, and considerations. As additional information, Indonesia already has several geothermal power plants. For example, there are the Dieng and Patuha Geothermal Power Plants (PLTP) Unit II, with a project investment value of US$300 million (Prima, 2019).

4.8. Hydropower

Hydropower allows water motion to generate electricity using turbines (such as Pelton, Kaplan, etc) (Kaushika, *et al*, 2016). Hydropower has been used for over a century which resulted in a sophisticated technological development compared to other renewable energy sources (Kougias, *et* al, 2019; Osman, *et al*, 2022). The four types of the facility for hydropower consist of Run-of-River or RoR (generate power from flowing streams throughout the year at any rate), Storage/Reservoir (generation from a relatively steady stream of water stored behind a dam), Pumped Storage Hydro Power Plants or HPPs (water pumped from lower to the upper repository), and In-stream Hydropower (uses turbine in the dam, and the stream is not redirected) (Karre, *et al*, 2022). Based on the capacity it can be classified into large (100 MW+), medium (10MW-100MW), small (1MW-10MW), mini (100kW-1MW), micro (5kW – 100kW), and pico (0kW- 5kW) (Karre, *et al*, 2022; Kaushika, *et al*, 2016). With many installations and technological implementations, hydropower shows significant results in generating power while having its advantages, and disadvantages. This is such as:

1. Advantages = It has a robust system, relatively predictable power generation, and huge sources of water (Chala, *et al*, 2019). Its construction, operation, and maintenance cost are low which also create deployments (Chala, *et al*, 2019; Osman, *et al*, 2022). Aside from energy source, hydropower provides facilities for flood control, mitigate the risks from climate change (droughts, etc), provides means of managing freshwater as well as drive investment, and creates tourism/recreational/fisheries place (Silva, and Castillo, 2021). For industries, hydropower can be directly utilized to mill grain, charge batteries, etc (Chala, *et al*, 2019). Mini/micro hydropower, it is reported to be more efficient, and competitive than solar, and wind energy (Chala, *et al*, 2019).
2. Disadvantages = It has expensive investment cost, long construction duration, geographical changes (divides the river into sections, removing flow for natural irrigation, and erosion from downstream flows), health issues (respiratory, and eye problems from the dust of construction), immigration/displacement, soil decomposition, eutrophication, suspending sediments, deforestation, damaging/altering aquatic life as well as changing water quality, and temperature (Silva, and Castillo, 2021; Osman, *et al*, 2022). The creation of reservoirs also replaces homes, natural areas, agricultural land, and archaeological sites as well as altering physical, chemical as well as biological ways of the environment (Silva, and Castillo, 2021; Osman, *et al*, 2022). Finally, greenhouse gas emissions can still be seen by the reduced oxygen from obstructed water of dams (Silva, and Castillo, 2021).

Since Indonesia is a country with many water stream sources, it is highly recommended to install this energy type with many considerations, planning, and technological aid to prevent damage, especially to the environment. In reality, there are already several Hydropower Plants (PLTA) that have been built and are currently under construction. An example is the construction of the Mentarang Hydropower Plant with a capacity of 1,375 MW. This hydropower plant is projected to be completed

in 7 years or by 2030, with an investment value of US$2.7 billion (DESDM Provinsi Kalimantan Utara, 2023).

4.9. Ocean Thermal Energy

Ocean thermal energy conversion is one of the renewable energy sources produced by the ocean aside from waves, and tides that temperature gradients based on the depth of the ocean, and surface difference (Abbas, *et al*, 2022; Herrera, *et al*, 2021; Xiao, and Gulfam, 2023; Mane, and Patil, 2020). The thermal energy mainly comes from the absorption of solar radiation, making this system the most effective energy storage system (Abbas, *et al*, 2022; Herrera, *et al*, 2021; Mane, and Patil, 2020). Its working principle is based on the surface water that is used to heat liquid into steam to generate electricity through turbines with three types of cycles (open, closed, and hybrid cycles) (Herrera, *et al*, 2021). OTEC systems can be made in three types of construction which are onshore, offshore, and floating (Herrera, *et al*, 2021). The advantages, and disadvantages of OTEC can be depicted:

1. Advantages = It can produce energy 24 hours a day while also providing other benefits such as producing desalinated water, refrigerated soil agriculture implementation (cooling soil), aquaculture systems advantages (feeding deep water to aqua life), cold-water agricultures (using cold water for crops such as strawberries), and as a refrigerant fluid for air conditioner (Herrera, *et al*, 2021; Xiao, and Gulfam, 2023; Mane, and Patil, 2020). Marine life can also be attracted to the systems since it emit seawater with nutrients, giving positive impacts. Finally, it has the potential to serve as a tourist location (Herrera, *et al*, 2021).
2. Disadvantages = By the system that is directly involved in the oceanic ecosystem, technical safety must be ensured such as producing pipes, and pumps with specified properties (Herrera, *et al*, 2021). Thermodynamics cycle efficiency must also be increased since losses have occurred by gravitational energy, friction, density difference, piping, pump, etc. (Herrera, *et al*, 2021). From an environmental perspective, potential ammonia exposure to workers as well as carbon dioxide emission from open cycle systems are still presented (Herrera, *et al*, 2021). In addition, marine life is damaged by eutrophication potentials, proliferations, and decreasing oxygen levels (Rivera, *et al*, 2020). The viability of this system is also not suitable for many locations (geographical limitations due to temperature) combined with expensive infrastructure, and implementation costs (Suprijo, et al, 2021; Mane, and Patil, 2020)

Therefore, this renewable energy must be further analyzed before being carried out in Indonesia's implementation.

4.10. Tidal Energy

Tidal energy is one of the sources from the ocean that depends on tide range (vertical rise), and currents (horizontal flow), resulting in converting the energy using two ways which are tidal range power plants (potential energy to electricity), and tidal stream turbines (kinetic energy to electricity) (Mendi, *et al*, 2016; Khare, and Bhuiyan, 2022; Shetty, and Priyam, 2022; Neili, 2021). Although this energy is considered effective, there is least development, and construction in the last 25 years since it still reaching in Research, and Development stages (Neili, *et al*, 2021). In designing the tidal system power plants, complex procedures must be made such as resource allocation, modeling of the system, constructing control system, reliability assessment as well optimization (Khare, and Bhujyan, 2022). The advantages, and disadvantages of tidal energy are shown below (Mendi, *et al*, 2016; Khare, and Bhuiyan, 2022; Shetty, and Priyam, 2022; Neili, 2021, Rivera, *et al*, 2022):

1. Advantages = It is a great source since it can be found worldwide, and the energy obtained is more efficient than wind turbines. Aside from that, tidal currents are predictable, and reliable

as well as weather independent. The life of a tidal power plant is also very long, and its turbines are more compact than wind turbines.

2. Disadvantages = Like others, tidal energy has high construction, installation, generation, and maintenance costs. It must be set up at a very suitable location. In addition, the transmission of electricity from the system to the target destination is usually far away which contributes to losses. It also affects the environment by its barrage, disrupting natural migratory routes for aquatic life. Turbines have also created noise which causes stress while also causing collisions that lead to species of fish death. The decrease in water quality and sediment erosion may also occur.

Hence, tidal energy is not suitable for Indonesia's choice of energy sources since not much has been made in the development of this energy system.

4.11. Wave Energy

Wave energy is the other form of energy from the sea/ocean that is also categorized as renewable energy (Guo, and Ringwood, 2021). This energy is driven by sources of forces such as wind, Coriolis, tidal, and other phenomena (Curto, *et al*, 2021; Yuxin, and Zhemin, 2020). This source has high energy density, and availability as well as the suitability to be integrated with solar, and wind technology. (Guo, and Ringwood, 2021; Curto*, et al*, 2021; Yan*, et al*, 2022). Wave energy generation can be divided based on the location such as coastal, nearshore, and offshore (Yan, *et al*, 2022; Curto*, et al*, 2021). It also can be classified into a float, pendulum duck, raft, squat, clam, point absorption, water column, etc. based on the collection method (Yan, *et al*, 2022; Yuxin, and Zhemin, 2020; Guo, and Ringwood, 2021; Curto, *et al*, 2021). The advantages, and disadvantages of wave energy can be shown below (Guo, and Ringwood, 2021; Yuxin, and Zhemin, 2020; Yan*, et al*, 2022):

1. Advantages = The availability of wave energy as well as energy density is higher than solar, and wind. It is also more predictable, resulting in advancement towards planning, and managing energy. The technology has matured, and can even be integrated with other sources (solar/wind). Not to mention that wave energy is renewable energy that has little impact on the environment and reduces carbon emissions. Finally, it promotes deep-sea development, aquaculture, hydrogen production, desalination, and other utilization of seawater.
2. Disadvantages = Wave energy technology has a high maintenance cost, low efficiency (specifically on traditional technology), technical issues (such as in wave energy converter which is not fully commercialized, and difficulties in generating electricity at low frequency). In addition, this source is dependent on wave conditions (height, direction, spectrum, etc). Some of its technologies are also at research, and development state since it is still uncertain with high risks.

The potential for wave energy in Indonesia as a maritime country can be beneficial, yet, with many considerations of its impact as well as cost, this should be analyzed and studied before being implemented.

4.12. Biomass

Biomass is an energy that comes from living things through plants or animals' residue (Kaushika, *et al*, 2016; Luthfi, *et al*, 2020). These may include crop residues (hay, rice husk, and straw), forest residues (branches, and leaves), plantation residue (coconut, and coffee), industrial waste (wood chips), municipal solid waste, aquatic biomass, and sanitary waste (Kaushika, *et al*, 2016; Luthfi, *et al*, 2020; Primadita*, et al*, 2020). This energy conversion can be categorized into thermo-chemical (combustion, gasification, and pyrolysis), biological (fermentation, and anaerobic digestion such as hydrolysis, methanogenesis, etc), and physio-chemical (esterification) (Kaushika, *et al*, 2016; Luthfi, *et al*, 2020; Athala, *et al*, 2022; Primadita*, et al*, 2020; Tursi, 2019; Sivabalan, *et al*, 2021). In thermo-chemical conversion, the energy produced depends on heat, and chemical reaction (Tursi, 2019). For biochemical

conversion, biomass sources are decomposed to carbohydrates which will be converted to biofuel, and biogas (Tursi, 2019). Whereas physio-chemical conversion converts sources to biofuels with high density (Tursi, 2019). The advantages, and disadvantages of biomass (Tursi, 2019; Sivabalan, *et al*, 2021):

1. Advantages = This source is available in various types based on its origin (municipal waste, crops, sewages, forest residues, etc). As it is also considered renewable energy, it helps in reducing greenhouse emissions, creates job opportunities in rural areas, helps farmers economically, and aids health sustainability, and many technologies are lower in cost compared to fossil fuels.
2. Disadvantages = Biomass has several drawbacks such as deforestation potential (Jagger, and Kittner, 2017), slagging, and fouling by the combustion system, the technical constraints on the gasification system (temperature, pressure, and catalyst), the complex requirement (densification, briquette, etc), limitation in power generation, and low efficiency of boiler (due to high moisture from lignocellulosic material). This source is also debated and is considered controversial due to its uncertainty.

In Indonesia, the use of biomass is still integrated with coal burning at some ratio, a term called co-firing method (Primadita*, et al*, 2020; Sugiyono, *et al*, 2021). This method is popular and has been researched, and used by many practitioners. However, it lacks the implementation of sustainability principles, not to mention the greenhouse gas emissions from its other processes such as transportation. However, it is also true that many levels of Indonesian society have utilized biomass significantly due to its tremendous resources. PLTBm Siantan is the first biomass power plant in West Kalimantan, Indonesia. This biomass power plant generates electricity of 75,000 MWh per year and is equivalent to a potential reduction of greenhouse gas emissions by 25,000 tons of CO_2e per year (ESDM, 2023).

5. Carbon Footprints

Based on the explanation of the advantages, and disadvantages of each energy source, the interconnection of those sources lies in the global issue which is greenhouse gas emissions. In a more specific context, the term called carbon footprint is introduced. Carbon footprint is defined as the production quantity of carbon dioxide, and other greenhouse gases during the entire life cycle that is used to measure the impact of human activities on the environment based on climate change effects (Kerem, 2021). In the energy sector, this term is highly associated with effectiveness and becomes the parameter to measure the benefits, and drawbacks of each type of energy source. As an example, fossil fuels are undoubtedly contributing to a large amount of greenhouse gases directly from their operation/combustion (Kerem, 2021). All renewable energy sources present a carbon footprint mostly in indirect form mainly from **extraction, material manufacturing, construction, transportation, installation/building, maintenance, and decommissioning** although it is not significant compared to fossil fuels (Kerem, 2021; ÓhAiseadha; 2020). A summary of carbon footprint factors for each energy aside from the mentioned can be shown below:

Table 4. Carbon Footprints Based on Energy Sources

Energy Reserves Based on Sources	Carbon Footprints Findings
Coal	Combustion (dominantly), and other mentioned processed.
Oil/Petroleum	
Natural Gas	
Nuclear Energy	Waste management, and waste deposition as well as a small amount of emission from operation (Wagner, 2021).

Solar Energy	Based on lithium, glass manufacturing, and high-purity silicon manufacturing as the material based on coal usage (Colum, and Booth, 2023; Liberatore, 2023) as well as other processes mentioned.
Wind Energy	Waste disposal, recycling, local microclimate, and as mentioned (Fonseca, and Carvalho, 2022).
Geothermal Energy	Natural occurrence (magmatic events that result in a temporary influx of CO_2 which increase emission), and through the life cycle (drilling, completion of wells, etc.) (Fridriksson, *et al*, 2017).
Hydropower	As mentioned (Räsänen, 2018**)**
Ocean Thermal Energy Conversion (OTEC)	OTEC emission can occur by, short-term release during electricity generation, long-term release from carbon dioxide discharged from the power plant, and as mentioned (Green, and Guenther, 1990).
Tidal Energy	As mentioned (Walker, and Thies, 2021)
Wave Energy	As mentioned (Uihlein, 2016).
Biomass	Waste feedstock sourcing, removal of material's impurities, hydrogen production, hydro treatment, cracking, fractionation, polymerization, incineration of resin, etc. (Kikuchi, et al, 2022)

In the case of Indonesia, greenhouse gas emissions are still dominated by fossil fuels. This can be seen in Fig. 4 below.

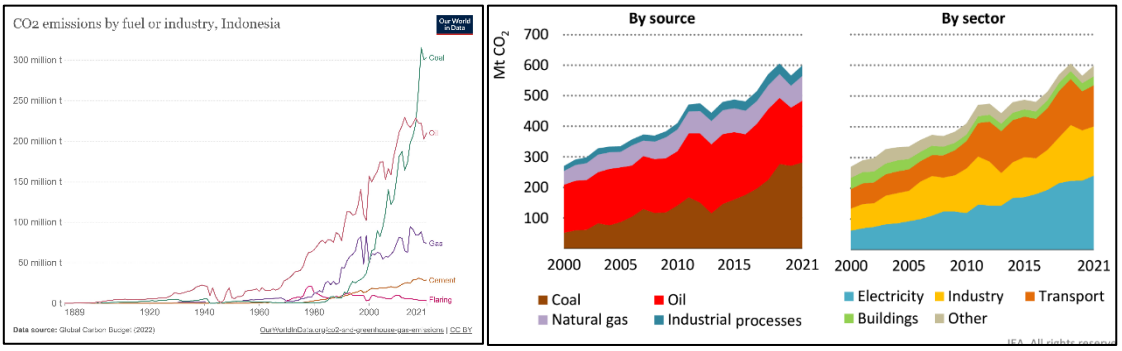

Fig. 4: Indonesia CO_2 Emissions a) by Fuel Type from 1890 to 2021 (Our World in Data), and b) by Source, and Sector from 2000 to 2021 (IEA)

Both graphs depict that there is an increase in CO_2 emissions (although a short reduction occurred due to the Pandemic COVID-19 in 2019-2020). This graph clearly shows how dependent Indonesia towards fossil fuels. The impact of this dependency is oblivious which is the main issue nowadays, such as temperature rise (shown in Fig. 23). With this still occurring alongside other mentioned issues, there must be an immediate solution to counter this problem. The use of renewable energy become one of the proposed recommendations. However, these sources are not entirely free from environmental impact since it can be seen by the greenhouse gas emissions from their life cycle stage, ecosystem alteration, etc. On top of that, many considerations must be taken due to many disadvantages that may counterbalance the advantages presented by these sources. Thus, before further implementations are done for Indonesia, analysis, and research must be done to avoid unwanted impacts on environmental, economic, and social aspects.

6. Towards The Future

Indonesia in the use of energy still faces many complex problems. On the one side, the use of fossil fuels is still dependent on many purposes, and activities, making renewable energy utilization fall behind. On the other side, the impact of climate change, pollution, global warming, greenhouse gas

emissions, and others have tremendously affected these activities, resulting in the global scale shifting to renewable energy to reduce these problems. Then, what can be done? Based on the analysis of the advantages, and the disadvantages of each energy sector (non-renewable, and renewable energy sources), many aspects must be considered, as an example for renewable energy still results in environmental impact (though greenhouse gas emissions may be reduced, but it needs a long time after installation whereas other impacts to the ecosystem, and social acceptance are unavoidable). Then, should Indonesia still rely on fossil fuels as both non-renewable and renewable energy causes negative impacts? This answer should not be narrowed down only according to the impacts. If fossil fuel reserves are taken into consideration, these source's consumption will be stopped at some point soon due to excessive depletion. With these conditions, no other choice can be made aside to rely on renewable energy technologies. To this prediction, renewable energy's negative impacts should be quickly studied and researched to reduce environmental damage, social acceptance, and cost as optimal as possible by developing its technologies to a higher level with better efficiency, more environmentally friendly impact as well, and lower investment. From the perspective of civilians, energy usage should also be considered. This can be done by slowly reducing the use of energy from fossil fuels such as transportation fuels, electricity, and other forms. This is followed by the shifting to renewable energy usage steadily, and readily which has been done now, however still at a slower pace due to several factors (mainly economic, and geographic). Those actions should also be followed by awareness that the dominant energy based on fossil fuels has become scarce. It is important to be aware that the excessive use of energy will greatly impact the reserves, and accelerate global issues (climate change, pollution, global warming, etc). The use of renewable energy, although it is not a perfect alternative, at least can help in reducing those problems

7. Conclusion

In conclusion, Indonesia faces a complex energy landscape with surging demand currently met mostly by polluting, and finite fossil fuel reserves. This review indicates Indonesia has vast renewable energy potential to chart a sustainable path. Solar, wind, geothermal, and hydropower resources are world-class. However economic, technical, and social barriers persist. Transitioning will require a concerted strategy encompassing supportive policies like transparent licensing, stable tariffs, and incentives; regulation holding suppliers accountable for sustainability; large-scale facilities with modern technologies; integrated grid management; and active public participation. With targeted initiatives, Indonesia can tap into its rich renewables to expand energy access equitably while safeguarding the environment - ultimately powering a just, resilient, and prosperous society.

Acknowledgements

We extend our heartfelt appreciation to Universitas Multimedia Nusantara for the support provided in the research process for this journal article. Both in terms of facilities, and funding, we truly appreciate it

References

Asif, Z., Chen, Z., An, C., and Dong, J. (2022). Environmental Impacts, and Challenges Associated with Oil Spills on Shorelines. *Journal of Marine Environmental Science, and Engineering*. https://www.mdpi.com/2077-1312/10/6/762

Abbas, S. M., Alhassany, H. D. S., and Vera. D., Jurado, F. (2022). Review of enhancement for ocean thermal energy conversion system. *Journal of Ocean Engineering, and Science, 8(5), 553-545*. https://www.sciencedirect.com/science/article/pii/S2468013322000572

Adelakun, N. O., and Olanipekun, B. A. (2019). A Review of Solar Energy. *Journal of Multidisciplinary Engineering Science, and Technology, 6(12)*. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3579939

Aliyu, S., and Garba, M. M. (2019). Review on Current Global Geothermal Energy Potentials, and the Future Prospects. *International Journal of Advances in Scientific Research, and Engineering, 5(4)*. https://ijasre.net/index.php/ijasre/article/view/182/220

Alnaimat, F., and Rashid. Y. (2019). Thermal Energy Storage in Solar Power Plants: A Review of the Materials, Associated Limitations, and Proposed Solutions. *Energies, 12(21)*. https://www.mdpi.com/1996-1073/12/21/4164

Alweli, M., and Mannheim, V. (2022). Investigation into the Current State of Nuclear Energy, and Nuclear Waste Management – A State-of-the-Art Review. *Energies*, *15*(*12*). https://www.mdpi.com/1996-1073/15/12/4275

Ambaye, T. G., Chebbi, A., Formicola, F., Prasad, S., Gomez, F. H., Franzetti, A., and Vaccari, M. (2022). Remediation of soil polluted with petroleum hydrocarbons, and its reuse for agriculture: Recent progress, challenges, and perspectives. *Chemosphere, 293*. https://www.sciencedirect.com/science/article/pii/S0045653522000613

Arefin, M. A., Islam, M. T., Rashid, F., Mostakim, K., Masuk, N. I. M., and Islam, M. H. I. (2021). A Comprehensive Review of Nuclear-Renewable Hybrid Energy Systems: Status, Operation, Configuration, Benefit, and Feasibility. *Frontiers in Sustainable Cities*. https://www.frontiersin.org/articles/10.3389/frsc.2021.723910/full

Athala, A. P., Fitri, Y., Meka, W., Ridwan, A., Mahendra, R. A., Rezeki, T. N., Widara, L. S., and Hamzah, M. (2022). Experimental analysis on distribution of co-pyrolysis products from medical glove waste, and biomass waste. *Jurnal Teknik Kimia, 28(3), 116-125*. http://ejournal.ft.unsri.ac.id/index.php/JTK/article/view/1283/743

Blanc, P., Epsinar, B., Geuder, N., Gueymard, C., Meyer, R., Pitz-Paal, R., Reinhardt, B., Renne, D., Sengputa, M., Wald, L., and Wilbert, S. (2014). Direct normal irradiance related definitions, and applications: The circumsolar issue. *Solar Energy, 110, 561-577*. https://www.nrel.gov/docs/fy15osti/63177.pdf

Blankeship, B., Aklin, M., Urpelainen, J., and Nandan, V. (2022). Jobs for a just transition: Evidence on coal job preferences from India. *Energy Policy, 165*. https://www.sciencedirect.com/science/article/abs/pii/S0301421522001355

Boserup, E. (1976). Environment, Population, and Technology in Primitive Societies. *Population, and Development Review, 2(1), 21*. https://doi.org/10.2307/1971529

Burclaff, N. (2022). Oil, and Gas Industry: A Research Guide. Library of Congress. https://guides.loc.gov/oil-and-gas-industry#1

Casau, M., Cancela, D. C. M., Matias, J. C. O., Dias, M. F. Nunes, L. J. R. (2021). Coal to Biomass Conversion as a Path to Sustainability: A Hypothetical Scenario at Pego Power Plant (Abrantes, Portugal). *Assessment of Biomass for Bioenergy 10(8)*. https://doi.org/10.3390/resources10080084

Chala, G. T., Ma'Arof, M. I. N., and Sharma, R. (2019). Trends in an increased dependence towards hydropower energy utilization – a short review. *Cogent Engineering, 6(1)*. https://www.tandfonline.com/doi/full/10.1080/23311916.2019.1631541

Chassignet, M. P. (2014). The Steam Engine. Environmental, and Society Portal, Multimedia Library. http://www.environmentandsociety.org/node/6627/

Colum, C. P., and Booth Lea. (2023). *Solar Panels are Three Times More Carbon-Intensive Than IPCC Claims*. https://environmentalprogress.org/big-news/2023/7/3/solar-panels-are-more-carbon-intensive-than-experts-will-admit

Curto, D., Franzitta, V., and Guercio, A. (2021). Sea Wave Energy. A Review of the Current Technologies, and Perspectives. *Energies, 14 (20)*. https://www.mdpi.com/1996-1073/14/20/6604

DEN. (2022). Indonesia Energy Outlook 2022. *ESDM, Indonesia*. https://den.go.id/index.php/publikasi/download/136

Dinas ESDM Provinsi Kalimantan Utara. (2023). "PEMBANGUNAN KIPI DAN PLTA SUDAH ON THE TRACK". desdm.kaltaprov.go.id. https://desdm.kaltaraprov.go.id/berita/pembangunan-kipi-dan-plta-sudah-on-the-track.html

Duffey, R., and D'Auria, F. (2020). Nuclear Energy, and Its History: Past Consequences, Present Inadequacies, and a Perspective for Success. *Energy, and Power Engineering, 12(6)*. https://www.scirp.org/journal/paperinformation.aspx?paperid=100612

ESDM. (2023). "Perkembangan Proyek PLT Bioenergy di Indonesia". etbke.esdm.go.id. https://ebtke.esdm.go.id/lintas/id/investasi-ebtke/sektor-bioenergi/perkembangan-proyek

ETBKE. (2019). "PLTS Sidrap; Proyek Energi Untuk Masyarakat, Pemerintah dan Investor". ebtke.esdm.go.id. https://ebtke.esdm.go.id/post/2019/09/02/2326/pltb.sidrap.proyek.energi.untuk.masyarakat.%20pemerintah.dan.investor#:~:text=PLTB%20Sidrap%20I%20dikembangkan%20oleh,dan%205%25%20Tenaga%20Kerja%20Asing

EIA. (2019). International Energy Outlook 2019. EIA, Washington. http://scholar.google.com/scholar_lookup?hl=en&publication_year=2019&author=U.S.+Energy+Information+Administration%0A%28EIA%29&title=International+Energy+Outlook%0A2019+%28IEO2019%29

Enerdata. (2022). World Energy, and Climate Statistics-Yearbook 2022. *Enerdata, France*. https://yearbook.enerdata.net/total-energy/world-consumption-statistics.html

ESDM. (2021). Handbook of Energy, and Economic Statistics of Indonesia/HEESI 2021. *ESDM*. https://www.esdm.go.id/assets/media/content/content-handbook-of-energy-and-economic-statistics-of-indonesia-2021.pdf

Faramawy, S., Zaki, T., and Sakr, A. A. E. (2016). Natural gas origin, composition, and processing: A review. *Journal of Natural Gas Science, and Engineering*. https://www.sciencedirect.com/science/article/abs/pii/S1875510016304139

Fonseca, L. F. S., and Carvalho, M. (2022). Greenhouse gas, and energy payback times for a wind turbine installed in the Brazilian Northeast. *Frontiers in Sustainability, 3*. https://www.frontiersin.org/articles/10.3389/frsus.2022.1060130/full

Forrester, R. (2019). The Invention of the Steam Engine. https://doi.org/10.31235/osf.io/fvs74

Frenken, K, and Nuvolari, A. (2003). The Early Development of the Steam Engine: An Evolutionary Interpretation using Complexity Theory. *Industrial, and Corporate Change, 13(2)*. DOI:10.1093/icc/dth017

Fridriksson, T., Merino, A. M., Orucu, Y., and Audinet, P. (2017). Greenhouse Gas Emissions from Geothermal Power Production. *PROCEEDINGS, 42nd Workshop on Geothermal Reservoir Engineering*. https://openknowledge.worldbank.org/handle/10986/24691

Gasparotto, J., and Martinello, K. D. B. (2020). Coal as an energy source, and its impacts on human health. *Energy Geoscience*, *vol 2(2), pp 113-120.* https://www.sciencedirect.com/science/article/pii/S2666759220300500

Green, H. J., and Guenther, P. R. (1990). Carbon Dioxide Release from OTEC Cycles. *International Conference on Ocean Energy Recovery*. https://www.nrel.gov/docs/legosti/old/3594.pdf

Guo, B., and Ringwood, J. V. (2021). A review of wave energy technology from a research, and commercial perspective. *IET Renewable Power Generation, 15(14), 3065-3090*. https://ietresearch.onlinelibrary.wiley.com/doi/10.1049/rpg2.12302

Hassan, S. T., Khan, D., Zhu, B., and Batool, B. (2021). Is public service transportation increase environmental contamination in China? The role of nuclear energy consumption, and technological change. *Energy , 238*. https://www.sciencedirect.com/science/article/abs/pii/S0360544221021381

Herrera, J., Sierra. S., Ibeas, A. (2021). Ocean Thermal Energy Conversion, and Other Uses of Deep-Sea Water: A Review. *Journal of Marine Science, and Engineering, 9(4)*. https://www.mdpi.com/2077-1312/9/4/356#metrics

Hess, J., Bednarz, D., Bae, J., and Pierce, J. (2011). Petroleum, and Health Care: Evaluating, and Managing Health Care's Vulnerability to Petroleum Supply Shifts. *Am J Public Health, 101(9)*. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3154246/

Holechek, J. L., Geli, H. M. E, Sawalhah, M. N., and Valdez, R. (2022). A Global Assessment: Can

Huang, F., Lin, J., and Zheng, B. (2019). Effects of Thermal Discharge from Coastal Nuclear Power Plants, and Thermal Power Plants on the Thermocline Characteristics in Sea Areas with Different Tidal Dynamics. *Water, 11(12)*. https://www.mdpi.com/2073-4441/11/12/2577

Renewable Energy Replace Fossil Fuels by 2050. *Sustainability, 14(8)*. https://www.mdpi.com/2071-1050/14/8/4792

IEA. (2023). An Energy Sector Roadmap to Net Zero Emissions in Indonesia. *IEA*. https://www.iea.org/reports/an-energy-sector-roadmap-to-net-zero-emissions-in-indonesia/executive-summary

Igwe, C. I. (2021). Geothermal Energy: A Review. *International Journal of Engineering Research, and Technology, 10(3)*. https://www.researchgate.net/publication/350823763_Geothermal_Energy_A_Review

IRENA. (2022). Indonesia energy transition outlook. *International Renewable Energy, Abu Dhabi*. https://www.irena.org/publications/2022/Oct/Indonesia-Energy-Transition-Outlook

Indonesia Energy Transition Outlook 2023. (2022). Tracking Progress of Energy Transition in Indonesia: Pursuing Energy Security in the Time of Transition. IESR. https://iesr.or.id/wp-content/uploads/2022/12/Indonesia-Energy-Transition-Outlook_2023.pdf

Jagger, P., and Kittner, N. (2017). Deforestation, and biomass fuel dynamics in Uganda. *Biomass, and Bioenergy, 105, 1-9*. https://www.sciencedirect.com/science/article/abs/pii/S0961953417301915

Karre, R. K., Srinivas, K., Manna, K., Prashanth, B., and Prasad, Ch. R. (2022). A Review on Hydropower Plants, and Turbines. *International Conference on Research in Sciences, Engineering, and Technology*. https://www.researchgate.net/publication/360839120_A_review_on_hydro_power_plants_and_turbines

Kaushika, N. D, Reddy, K. S., Kaushik, K. (2016). Sustainable Energy, and the Environment: A Clean Technology Approach. *Springer*

Keboletse, K. P., Ntuli, F., and Oladijo, O. P. (2021) Influence of coal properties on coal conversion processes-coal carbonization, carbon fiber production, gasification, and liquefaction technologies: a review. *International Journal of Coal Science, and Technology, 8, 817-843*. https://link.springer.com/article/10.1007/s40789-020-00401-5

Kerem, A. (2021). Investigation of carbon footprint effect of renewable power plants regarding energy production: A case study of a city in Turkey. *Journal of the Air, and Waste Management Association*, *72(3)*. https://www.tandfonline.com/doi/full/10.1080/10962247.2022.2028690

Khare, V., and Bhujyan, M. A. (2022). Tidal energy-path towards sustainable energy: A technical review. *Cleaner Energy Systems*. https://www.sciencedirect.com/science/article/pii/S2772783122000395#abs0001

Kikuchi, Y., Torizaki, N., Tahkamo, L., Enstrom, A., and Kuusisto, S. (2022). Life cycle greenhouse gas emissions of biomass-, and waste-derived hydrocarbons considering uncertainties in available feedstocks. *Process Safety, and Environmental Protection, 166*. https://www.sciencedirect.com/science/article/pii/S0957582022007443

Kool, T. (2020). The Complete History of Fossil Fuels. https://oilprice.com/Energy/Energy-General/The-Complete-History-Of-Fossil-Fuels.html. Accessed 17 September 2023.

Kougias, I., Aggidis, G., Avellan, F., Deniz, S., Lundin, U., Moro, A., Muntean, S., Novara, D., Perez-Diaz, J. I., Quaranta, E., Schild, P., and Theodossiou, N. (2019). Analysis of emerging technologies in the hydropower sector. *Renewable, and Sustainable Energy Reviews, 113*. https://www.sciencedirect.com/science/article/pii/S1364032119304575

Lebre, E., Stringer, M., Svobodova, K., Owen, J. R., Kemp, D., Cote, C., Arratia-Solar, A., Valenta, R. K. (2020). The social, and environmental complexities of extracting energy transition metals. *Nat Commun, 11*. https://doi.org/10.1038/s41467-020-18661-9

Li, J., and Hu, Shanying. (2017). History, and future of the coal, and coal chemistry industry in China. *Resources, Conservation, and Recycling, 124, 13-24*. https://www.sciencedirect.com/science/article/abs/pii/S092134491730085X

Liberatore, S. (2023). *The big eco lie: Solar panels produce five TIMES more carbon dioxide than previously thought, report claims*. https://www.dailymail.co.uk/sciencetech/article-12356901/The-big-eco-lie-Solar-panels-produce-five-TIMES-carbon-dioxide-previously-thought-report-claims.html

Linsten, H. (2018). Energy: A Revolution with Steam. *Well-being, Sustainability, and Social Development pp 201-15*. https://link.springer.com/chapter/10.1007/978-3-319-76696-6_10

Luthfi, P., and Parinduri, T. (2020). Biomassa Sebagai Sumber Energi Terbarukan. *Journal of Electrical Technology, 5*. https://core.ac.uk/download/pdf/329070577.pdf

Maka, A. O. M, and Alabid, J. M. (2022). Solar energy technology, and its roles in sustainable development. *Clean Energy, 6(3), 473-483*. https://academic.oup.com/ce/article/6/3/476/6606003

Mane, V., and Patil S. S. (2020). Ocean Thermal Energy Conversion: A Review. *Journal of Emerging Technologies, and Innovative Research, 7(9)*. https://www.researchgate.net/publication/362516795_Ocean_Thermal_Energy_Conversion_A_Review

Mawad, M. M. (2020). Origin of Petroleum: A New Theory of Its Formulation. *Journal of Power, and Energy Engineering, 8(8)*. https://www.scirp.org/journal/paperinformation.aspx?paperid=102438

Medunic, G., Mondol, D., Radenovic, A., and Nazir, S. (2018). Review of the latest research on coal environment, and clean technologies. *The Mining-Geology-Petroleum Engineering Bulletin*.

https://www.researchgate.net/publication/322245450_Review_of_the_latest_research_on_coal_environment_and_clean_technologies

Mendi, V., Rao. S., and Seelam, J. K. (2016). Tidal Energy: A Review. *Conference on Hydraulics, Water Resources, and Coastal Engineering*. https://www.researchgate.net/publication/310795127_Tidal_Energy_A_Review

Miller, L. M, and Keith, D. W. (2018). Climatic Impacts of Wind Power. *Joule, 2(12), 2618-2632*. https://www.sciencedirect.com/science/article/pii/S254243511830446X

Mohammad, N., Ishak, W. W. M., Mustapa, S. I., and Ayodele, B. V. (2021). Natural Gas a Key Alternative Energy Source in Sustainable Renewable Energy Transition: A Mini Review. *Advanced Clean Fuel Technologies*. https://www.frontiersin.org/articles/10.3389/fenrg.2021.625023/full

Moosavi, S.A., Aghaalikhani, M. Ghobadian, B., and Fayyazi, E. (2018). Okra: A potential future bioenergy crop in Iran. *Renewable, and Sustainable Energy Reviews*, *93, 517-524*. https://www.sciencedirect.com/science/article/abs/pii/S1364032118302466

Murniati, M. E., and Sudarti. (2022). Analisis Potensi Energi Angin Sebagai Pembangkit Listrik Tenaga Angin di Daerah Banyuwangi Kota Menggunakan Databas Online-BMKG. *Jurnal Surya Energy, 6(1), 9-16*. https://jurnal.um-palembang.ac.id/senergi/article/download/3364/2863

Nasruddin, and Susanto, T. (2018). The Effect of Natural Based Oil as Plasticizer towards Physics-Mechanical Properties of NR-SBR Blending for Solid Tyres. *The 6th International Conference of Indonesian Chemical Society*. https://iopscience.iop.org/article/10.1088/1742-6596/1095/1/012027

Neill, S. P., Haas, K. A., Thiebot, J., and Yang Z. (2021). A review of tidal energy-Resources, feedbacks, and environmental interactions. *Journal of Renewable Sustainable Energy, 13*. https://pubs.aip.org/aip/jrse/article/13/6/062702/285164/A-review-of-tidal-energy-Resource-feedbacks-and

Nguyen, V. G., Pham, M. T., Nguyen, V. L. L., Le, H. C., Truong, T. H., and Cao, D. N. (2023). A Comprehensive review on the use of biodiesel for diesel engines. *International Journal of Renewable Energy Development*. https://ejournal.undip.ac.id/index.php/ijred/article/view/54612/pdf

Oghenetega, O. B., Ana, G. R. E. E, Okunlola, M. A, and Ojegngbede, O. A. (2020). Oil Spills, Gas Flaring, and Adverse Pregnancy Outcomes: A Systematic Review. *Journal of Obstetrics, and Gynecology*. https://www.scirp.org/journal/paperinformation.aspx?paperid=97894

ÓhAiseadha, Quinn, and Connolly. (2020). Energy, and Climate Policy – An Evaluation of Global Climate Change Expenditure 2011-2018. *Energies 13(18)*. https://www.researchgate.net/publication/344270001_Energy_and_Climate_Policy-An_Evaluation_of_Global_Climate_Change_Expenditure_2011-2018

Osman, A. I., Chen, L., Yang, M., Msigwa, G., Farghali, M., Fawzy, S., Rooney, D. W., and Yap, P. S. (2022.) Cost, Environmental impact, and resilience of renewable energy under a changing climate: a review. *Environmental Chemistry Latters vol 21, pp 741-764.* https://link.springer.com/article/10.1007/s10311-022-01532-8

Ozturk, M., and Ibrahim, D. (2021). Geothermal Energy Systems. https://doi.org/10.1016/B978-0-12-820775-8.00012-X

Pang, P., Pan, L., Zhang, J. M., Chen, J. W., Dong, Y., Sun, H. X. (2022). Integrated sizing, and scheduling of an off-grid integrated energy system for an isolated renewable energy hydrogen refuelling station. *Applied Energy, 323*. https://www.sciencedirect.com/science/article/abs/pii/S0306261922008832?via%3Dihub

Parker, D. J., McNaughton, C. S., and Sparks, G. A. (2016). Life Cycle Greenhouse Gas Emissions from Uranium Mining, and Milling in Canada. *Environmental Science, and Technology, 50(17)*. https://pubs.acs.org/doi/10.1021/acs.est.5b06072

Pearce, J. (2012). Limitations of Nuclear Power as a Sustainable Energy Source. *Sustainability, 4(6), 1173-1187*. https://www.mdpi.com/2071-1050/4/6/1173

Perez, M., and Perez, P. (2022). Update 2022 – A fundamental look at supply side energy reserves for the planet. *Solar Energy Advances*, *2*. https://www.sciencedirect.com/science/article/pii/S266711312200002X

Perold, V., Ralston-Paton, S., and Ryan, P. (2020). On a collision course? The large diversity of birds killed by wind turbines in South Africa. *Journal of African Ornithology, 91(3), 228-239*. https://www.tandfonline.com/doi/abs/10.2989/00306525.2020.1770889

Preethi, S., Prithika, H., Pramila, M., and Birundha, S. (2021). Predicting the Wind Turbine Power Generation based on Weather Conditions. *5th International Conference on Electronics, Communication, and Aerospace Technology, 132-139*. https://ieeexplore.ieee.org/document/9676051

Prima, B. (2019). "Nilai investasi proyek PLTP unit II Dieng dan Patuha mencapai US$300 juta". Industri.kontan.co.id. https://industri.kontan.co.id/news/geo-dipa-energi-gelontorkan-us-300-juta-untuk-proyek-pltp-unit-ii-dieng-dan-patuha

Primadita, D. S., Kumara, I. N. S., and Ariastina, W. G. (2020). A Review on Biomass for Electricity in Indonesia. *Journal of Electrical, Electronics, and Informatics, 4(1)*. https://ojs.unud.ac.id/index.php/JEEI/article/view/57188/34849

Qaisar, S. H., and Ahmad, M. A. (2014). Production, Consumption, and Future Challenges of Coal in India. *International Journal of Current Engineering, and Technology, 4(5)*. http://inpressco.com/production-consumption-and-future-challenges-of-coal-in-india/

Ramaiah, R., and Shekar, K. S. S. (2018). Thermal Energy Utilization for Medium Temperature Industrial Process Heat Applications – A Review. *Materials Science, and Engineering, 376*. https://iopscience.iop.org/article/10.1088/1757-899X/376/1/012035

Räsänen, T. A., Varis, O., Scherer, L., and Kummu, M. (2018). Greenhouse gas emissions of hydropower in the Mekong River Basin. *Environmental Research Letters, 13(3)*. https://iopscience.iop.org/article/10.1088/1748-9326/aaa817

Ravi, K. K., Chaitanya, K. N. V. V., and Natarajan, S. K. (2021). Solar Solar thermal energy technologies, and its applications for process heating, and power generation – A review. *Journal of Cleaner Production, 282*. https://www.sciencedirect.com/science/article/abs/pii/S0959652620353415

Ritchie, H a., Rosado, P., and Roser, M. (2021). Fossil Fuels. *Our World in Data.* https://ourworldindata.org/fossil-fuels

Ritchie, H b., and Roser, M. (2021). Indonesia: CO_2 Country Profile. *Our World in Data*. https://ourworldindata.org/co2/country/indonesia

Rivera, G., Felix, A., and Mendoza, E. (2020). A Review on Environmental, and Social Impacts of Thermal Gradient, and Tidal Currents Energy Conversion, and Applications to the Case of Chiapas, Mexico. *International Journal of Environmental Research, and Public Health, 17(21)*. https://www.mdpi.com/1660-4601/17/21/7791

Saleh, U. A., Johar, M. A., Jumaat, S. A., Rejab, M. N., Jamaludin, and W. A. W. (2021). Evaluation of a PV-TEG Hybrid System Configuration for Improved Energy Output: A Review. *International Journal of Renewable Energy Development, 10(2), 385-400*. https://ejournal.undip.ac.id/index.php/ijred/article/view/33917/pdf

Sekker, Y. T., Berger-Tal, O., Lehnardt, Y., and Teschner, N. (2022). Noise Pollution from wind turbines, and its effects on wildlife: A cross-national analysis of current policies, and planning regulations. *Renewable, and sustainable Energy Reviews, 168*. https://www.sciencedirect.com/science/article/pii/S1364032122006852

Sharma, R., Shabhaz, M., Kautish, P., and Vo, V. X. (2021). Does energy consumption reinforce environmental pollution? Evidence from emerging Asian economies. *Journal of Environmental Management,* vol 297. https://doi.org/10.1016/j.jenvman.2021.113272

Sharmin, T., Khan, N. R., Akram, M. S., Ehsan, M. M. (2023). A State-of-the-Art Review on Geothermal Energy Extraction, Utilization, and Improvement Strategies: Conventional Hybridized, and Enhanced Geothermal Systems. *International Journal of Thermofluids, 18*. https://www.sciencedirect.com/science/article/pii/S2666202723000423

Shetty, C., and Priyam, A. (2022). A review on tidal energy technologies. *Materials Today: Proceedings, 56(5), 2774-2779*. https://www.sciencedirect.com/science/article/abs/pii/S2214785321064993

Silva, S. N., and Castillo, J. A. (2021). An Approach of the Hydropower: Advantages, and Impacts. A Review. *Journal of Energy Research, and Reviews*. https://www.researchgate.net/publication/352563300_An_Approach_of_the_Hydropower_Advantages_and_Impacts_A_Review

Sivabalan, K., Hassan, S., Ya, H., and Pasupuleti, J. (2021). A review on the characteristic of biomass, and classification of bioenergy through direct combustion, and gasification as an alternative power supply. *International Conference on Robotic, and Artificial Intelligence*. https://iopscience.iop.org/article/10.1088/1742-6596/1831/1/012033

Smil, V. (2017). Energy in Prehistory in Energy, and Civilization: A History. The MIT Press. https://www.jstor.org/stable/j.ctt1pwt6jj

Sugiyono, A., Febijanto, I., Hilmawan, E., and Adiarso. (2021). Potential of biomass, and coal co-firing power plants in Indonesia: a PESTEL analysis. *Earth, and Environmental Science, 963*. https://iopscience.iop.org/article/10.1088/1755-1315/963/1/012007

Sui, D., Witorski, E., Roksland, M., and Basmoen, T. A. (2019). Review, and Investigations on geothermal energy extraction from abandoned petroleum wells. *Journal of Petroleum Exploration, and Production Technology, 9, 1135-1147*. https://link.springer.com/article/10.1007/s13202-018-0535-3

Syivarulli, R. (2020). Public Acceptance in Geothermal Energy. *Journal of Mechanical Engineering, and Vocational Education*. https://jurnal.uns.ac.id/jomeve/article/view/38574/31327

Tian, Y, and Zhao, C. Y. (2013). A Review of Solar Collectors, and Thermal Energy Storage in Solar Thermal Applications. *Applied Energy, 104, 538-553. https://ideas.repec.org/a/eee/appene/v104y2013icp538-553.html*

Tursi, A. (2019). A review on biomass: importance, chemistry, classification, and conversion. *Biofuel Research Journal, 22*. https://www.biofueljournal.com/article_88067.html

Uihlein, A. (2016). Life cycle assessment of ocean energy technologies. *LCA For Energy Systems, and Food Products, 24, 1425-1437*. https://link.springer.com/article/10.1007/s11367-016-1120-y

Umah, A. (2021). "Dana PLTS Terapung Cirata Rp 2 T Aman, Ini Pesan Pemerintah". cnbcindonesia.com. https://www.cnbcindonesia.com/news/20210803194915-4-265875/dana-plts-terapung-cirata-rp2-t-aman-ini-pesan-pemerintah

Waewsak, J., Laundry, M., and Ganon, Y. (2015). Offshore Wind Power Potential of the Gulf of Thailand. *Renewable Energy, 81, 609-626,* https://www.sciencedirect.com/science/article/abs/pii/S0960148115002517

Wagner, F. (2021). CO_2 emissions of nuclear power, and renewable energies: a statistical analysis of European, and global data. *The European Physical Journal Plus, 136*. https://link.springer.com/article/10.1140/epjp/s13360-021-01508-7

Walker, S. R. J., and Thies, P. R. (2021). A life cycle assessment comparison of materials for a tidal stream turbine blade. *Applied Energy, 309(1)*. https://www.sciencedirect.com/science/article/pii/S0306261921015993

Wambui, T., Hawi, M., Njoka, F., and Kamau, J. (2023). Performance enhancement, and emissions reduction in a diesel engine using oleander, and croton biodiesel doped with graphene nanoparticles. *International Journal of Renewable Energy Development vol 12(3)*. https://ejournal.undip.ac.id/index.php/ijred/article/view/51785/pdf

Wisatesajja, W., Roynarin, W., and Intholo, D. (2021). Analysis of Influence of Tilt Angle on Variable-Speed Fixed-Pitch Floating Offshore Wind Turbines for Optimizing Power Coefficient Using Experimental, and CFD Models. *International Journal of Renewable Energy Development vol 10(2)*. https://ejournal.undip.ac.id/index.php/ijred/article/view/33195/pdf

Xiao, C., and Gulfam, R. (2023). Opinion on ocean thermal energy conversion. *Process, and Energy Systems Engineering, 11*. https://www.frontiersin.org/articles/10.3389/fenrg.2023.1115695/full

Yan, J., Mei, N., Zhang, D. P., Zhong, Y., and Wang, C. (2022). Review of wave power system development, and research on triboelectric nano power systems. *Fronters in Energy Research*. https://ietresearch.onlinelibrary.wiley.com/doi/10.1049/rpg2.12302

Yuxin, Y., and Zhemin, Jin. (2020). Research on Wave Energy Generation Technology. *E3S Web of Conferences, 165*. https://www.e3s-conferences.org/articles/e3sconf/pdf/2020/25/e3sconf_caes2020_01021.pdf

Zhu, P., Yao, J., Qian, C., Yang, F., Porpatham, E., Zhang, Z., and Wu, Z. (2020). High-Efficiency conversion of natural gas fuel to power by an integrated system of SOFC, HCCI engine, and waste heat recovery: Thermodynamic, and thermo-economic analyses. *Fuel*, *275*, https://www.sciencedirect.com/science/article/abs/pii/S0016236120308796

Zimmerling, J. R., and Francis, C. M. (2016). Bat mortality due to wind turbines in Canada. *The Journal of Wildlife Management, 8(8), 1360-1369*. https://wildlife.onlinelibrary.wiley.com/doi/abs/10.1002/jwmg.21128

Zou, C., Zhao, Q., Zhang, G., Xiong, B. (2016). Energy Revolution: From a fossil energy era to new energy era. *Natural Gas Industry B, 3(1), 1-11.* https://doi.org/10.1016/j.ngib.2016.02.001.