

Projection of Coal-Fired Power Plant (CFPP) Towards Net Zero Emission 2060 in Indonesia

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Abstract— Electricity is a strategic commodity in the country and the supply of electricity is one of the factors of national energy security. The supply of electricity is carried out with various sources, fossil energy and renewable energy sources. Global politics has focused on sustainability schemes so environmental issues have become a hot issue. The environmental issue has created a long-term target, namely Net Zero Emission 2060 and has led to the need for an energy transition that was formerly oriented to fossil energy to new and renewable energy (NRE). Coal-Fired Power Plants (CFPP) contribute emissions that are not environmentally friendly so they are not suitable for this purpose. Retirement of CFPP with 2 scenarios: 1) innovation in storage technology that is more economical to replace CFPP with NRE generators, 2) innovation in Carbon Capture, Usage, and Storage (CCUS) technology. The transition in the energy sector does not only affect technology but also has impacts on other sectors. Economic and social challenges arise along with the energy transition. This paper uses a qualitative method with literature studies.

Keywords— Coal, Electricity, CFPP, NZE, Renewable Energy

I. INTRODUCTION

Today, the concern of every country globally over the sovereignty and security of electricity is a priority for the nation, in general electricity is a commodity that cannot be separated from all human activities so it dominates the lives of many people. The demand for electricity will continue to increase according to world developments so it can be said that electricity is a strategic commodity [1]. In this case, electricity is present as a wheel of development of a country in all sectors. The country's ability to provide electricity will be an important factor in how a country achieves its energy security. By inhibiting the use of electricity, it will cause problems in the development of a country, leading to not achieving people's welfare. Therefore, the state is responsible for ensuring the availability of electricity. [2].

Indonesia's policy regarding the availability of electricity is contained in Presidential regulations (Peraturan Presiden or Perpres) No. 14 of 2017 namely "Electricity development aims to ensure the availability of electricity in sufficient quantities, good quality, and reasonable prices in order to increase the welfare and prosperity of the people in a fair and equitable manner and to realize sustainable development" [25]. The word sustainability here will be a challenge for every country because there must be harmony between the economy, the environment, and society. The power plants used by Indonesia were previously dominated by fossil

energy-based generators. However, after environmental issues have become a concern and global politics, renewable energy (RE) innovation is the hope to achieve this sustainable scheme. [3].

Environmental issues have been raised to global attention, starting with Rio Convention in 1992, the establishment of The United Nations Framework Convention on Climate Change (UNFCCC), and increasingly being clarified by the inclusion of environmental issues in sustainable development goals [4]. The Paris Agreement resulted in a joint commitment to seek emission reductions to reach the threshold for increasing the earth's temperature below 2°C and reducing it to 1.5°C. Indonesia confirmed its position by ratifying the Paris Agreement and committing to reduce emissions below business as usual (BAU) by 2030 (National Determined Contribution (NDC)) and the long-term target of Net Zero Emission 2060 (NZE) [5]. Efforts to support this condition by closing the opening of licenses for power plants that use coal fuel.

The plan for reducing greenhouse gas (GHG) emissions has been submitted by the Government of Indonesia at the UNFCCC Conference and has been witnessed by representatives of other countries [7]. Electrification from fossil-based power plants such as Coal-fired Power Plants (CFPP) produces emissions that are not environmentally friendly and are not in line with the NZE 2060 plan [6]. Indonesia must be prepared for an energy transition that used to be dominated by fossil energy sources to renewable energy [8].

Based on the description of the background and problems, this work aims to provide a projection of the possibility of utilizing coal-fired power plants. However, what will happen to the power plant in the national target and the challenges to achieving the net-zero emission in 2060. Therefore, this paper attempts to examine the technology and policy of CFPP in the step of achieving Net Zero Emission 2060 in Indonesia. This paper uses a qualitative method by studying literature from journal articles, printed books, official publications from the relevant Ministries and media writings related to the issue.

II. RESEARCH METHOD

A research method is an approach taken to solve a problem [9], especially in this study using qualitative research methods that focus on unravelling problems by utilizing a

literature review. The literature review is the most important step of the research process, especially in qualitative research studies because it will influence decision making [10]. A thorough and innovative literature review (synthesizing and corroborating the various shortcomings of the literature that has been done by previous researchers) is the basis and inspiration for substantial and fruitful research [10]. Qualitative research intends to understand the phenomenon of what is experienced by research subjects such as actors, motivations, perceptions, actions and the form of language in a special scientific context.

Data collection techniques by utilizing various sources of information that can be validated and the reliability of the information can be measured (Literature Study). A limited search was conducted using the terms “Coal Power Plant”, “Net-zero emission in 2060”, “Energy Security”, “Energy Transition”, “National Resilience”. The search results used include research, reviews, anecdotes, proceedings and opinion pieces by authorities with a good scientific background [24].

III. RESULT AND DISCUSSIONS

The demand for energy continues to increase following the growing population and changing lifestyles. In order to achieve energy security, almost all sectors of Indonesian life still depend on fossil energy. In 2018, 99.9% of transportation used fuel oil, the industrial sector was dominated by fossil energy with 35% coal and 33% gas, and the commercial and household sectors used electricity (60%) dominated by coal energy sources [5]. Not only domestically, but Indonesia's coal wealth is also often the answer to the inability of other countries to guarantee their energy supply. In the Handbook of Energy and Economy Statistics of Indonesia 2020, Indonesia exports 127.79 million tons of coal or around 32% of China's supply and India occupies the 2nd position with 97.51 million tons with an estimated 24% of India's supply [12]. This figure indicates that coal is not only influential for the country but is a pillar of life for other countries. The great need for coal and the abundance of Indonesia's wealth should provide a good position for Indonesia itself and Indonesia is projected to become a major power in the world economy. [13].

Large reserves, economical prices, and relatively simple exploitation technology make coal a promising commodity [13]. Indonesia's proven coal reserves reach 70 years and when combined with resource reserves, it is possible to increase reserves to 120-200 years [5]. This can provide an explanation that coal is the right choice in fulfilling energy. In short, CFPP uses coal as boiler fuel and heats water which then produces steam. The steam serves to drive the turbine and the turbine will drive a generator to produce electricity. Problems arise from CFPP which can cause acid rain and contribute to CO₂, NO₂ and SO₂ emissions, as well as toxic fine particles [14]. The criticism came and became a special concern for Indonesia regarding how to utilize the backbone of the national energy supply which is not in line with the targets that have been made in Indonesia.

This target was born from Indonesia's activeness in global politics as reflected by Indonesia's commitment to NDC 2030 and the long-term target of NZE 2060 (Environmental issues). In this case, climate change requires synergistic steps from all countries. If the state does not commit to it, the design will not develop better. India, one of the top 5 countries with the largest carbon emissions in the world, is still not committed to this [15]. India's unpreparedness to commit indicates that this transition is indeed a very difficult thing and proves how strong a country's national resilience is in following the currents of global politics. Therefore, the achievement of NZE 2060 can be proof of Indonesia's national resilience and its able to follow the dynamics of global politics.

Further descriptions regarding the overall emission reduction and energy transition scenarios are described in Figures 1 and 2. The scenarios were born from the ratification as outlined in Presidential Regulation Number 98 of 2021. In Article 3 of the Presidential Regulation, it is noted that the regulation refers to the BAU/GHG Emissions baseline wherein 2030 GHG emissions are calculated at 2,869 million tons of CO₂e. In addition, climate resilience projections and climate resilience targets are important in this regulation. Emission reduction targets are divided into two: independent efforts and assistance through international cooperation. With independent efforts, Indonesia is committed to reducing emissions by 29% or 834 millions ton CO₂e equivalent to 314 million tons CO₂e (19% of BAU) in the energy sector. On the other hand, relying on international assistance, emission reductions are targeted to reach 41% or 1.185 million tons of CO₂e equivalent to 398 million tons of CO₂e (24% of BAU) for the energy sector [26]. If we look at the share of decline with international assistance, it is higher than confidence in the results of one's own efforts. This can be evidence that environmental issues can be solved by cooperation and integration between nations for solutions ranging from investment to policy. The graph of Indonesia's sectoral emissions roadmap for 2030 is shown in Figure 1.

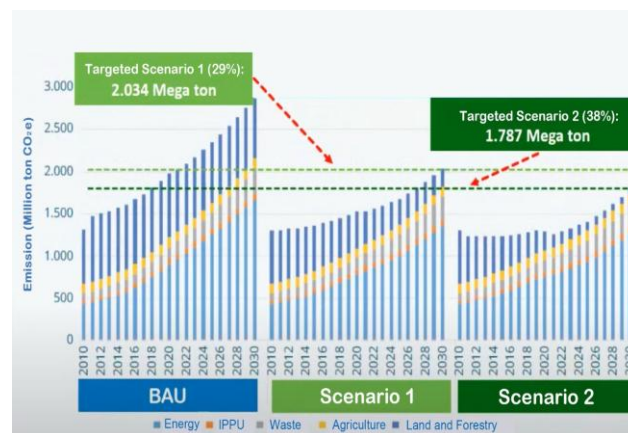


Figure 1 Sectoral Emissions Road Map 2030 Chart by Ministry of Environment and Forestry of Indonesia (2019)

Figure 1 explains that starting in 2010 the GHG/BAU emission baseline is no longer dominated by land and forestry, but the energy sector has begun so it can be said that energy sector activities contribute greatly to increasing emissions and reducing emissions in the future. This is driven by an increase in population and the issue of community welfare. Energy itself plays a role of 58% as a source of emissions in 2030. The figure also explains the difference in emissions from the two scenarios in 2030. The target with self-employment is 29% or equivalent to 1.787 million tons of CO₂e while the target with international assistance is 38% or equivalent to 2,034 million tons CO₂e. The number of emissions in the energy sector is not only in Indonesia, the United Nations Environment Program (UNEP) in 2020 stated that the world is facing the same problem, namely emissions from fossil energy reaching 38 Gigatonnes (64%) and 2019 global emissions have exceeded the target. The target is not to exceed 24-25 Gigatonnes to keep the earth's temperature from increasing by no more than 1.5°C but in reality, 2019 global emissions have penetrated to 59.1 Gigatonnes [16].

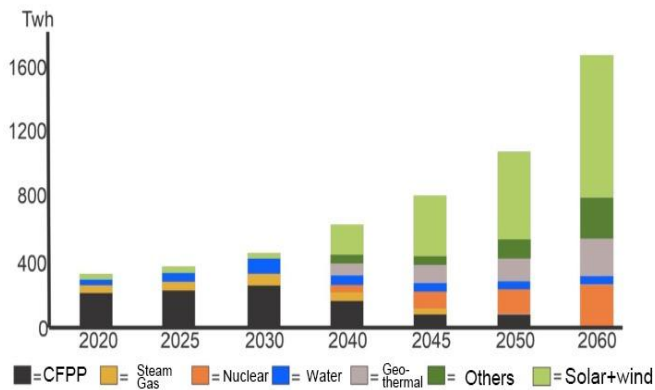


Figure 2 Net-Zero Emission Scheme by PT. PLN (Persero) [17].

Presidential Regulation Number 98 of 2021 serves as a guideline for reducing emissions and with this regulation it is agreed that it can be interpreted that reducing emissions is one of the national goals. CFPP with supercritical and ultra-supercritical boiler technology innovation is indeed low in carbon but still produces carbon, so a backup plan is needed if Indonesia's ambition of zero-emission in 2060 is to be achieved. To achieve the NZE 2060 scheme, the State Electricity Company (PT. PLN (Persero)) plans two scenarios. The First Innovation in storage technology is more economical to replace CFPP with NRE generators. Gradually, the first replacement of CFPP with biomass co-firing was followed by NRE generators which were centered on solar and wind power plant [5]. From 2020 to 2030, the portion of CFPP is still operating and dominant, then the number will decrease significantly in 2040 in accordance with the agreed power plant contract period.

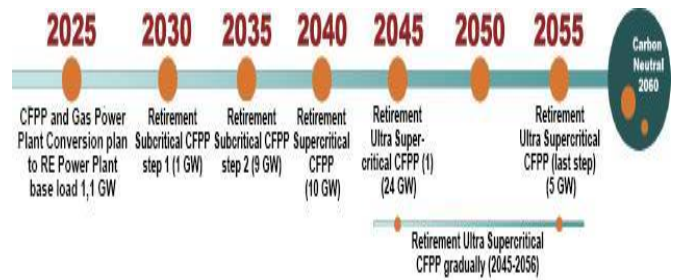


Fig. 3 CFPP Retirement Plan Towards Carbon Neutral 2060 [17]

The plan to retire the CFPP has been running since 2025 and is slowly but surely stopping the use of the last ultra-supercritical CFPP in 2056. The gradual discontinuation of the CFPP is followed by the development of a baseload NRE generator so that it can replace the national energy backbone and guarantee the country's electricity supply by increasing massively in 2028 [17]. This scenario is also followed by a policy of prohibiting contract extensions and the construction of new CFPPs.

The second planned scenario is the innovation of Carbon Capture, Usage, and Storage (CCUS) technology so that the utilization of CFPP can still be done without contributing to the increase in greenhouse gases with clean coal technology, this is in accordance with the results of Zhou, H. L., et al. (2021) [18]. In simple terms, this technology captures CO₂ from flue gas with a system and distributes it to storage by the pipes. Unfortunately, the technical and economic feasibility of this innovation poses a challenge for Indonesia. The existing technology to date causes a derating of the generator by 30-40%. In addition, on the storage side, the gas is generally distributed to depleted gas fields which are not necessarily located around the generating area. This will relate to the cost of transporting CO₂ to storage. CFPP with a more established and more economical CCUS is planned to operate starting in 2035 so that Indonesia only needs a retirement old subcritical CFPP of around 1 GW in 2030 [17].

Both scenarios have something in common, namely the need for an established technology. Indonesia is often faced with several challenges. Such as the contradiction of globalization and interdependence. The initial concept of globalization should have made it easier for countries to meet their national needs but ended up becoming a dependency concept. To realize these two scenarios, good technology development is needed. It is undeniable that the technology of high-income countries is leading so that the possibility of low-income countries depends. With global politics that leads to the use of low-carbon energy, countries that have not been able to maximize their domestic technology will rely on energy that has been transformed by low-carbon energy-producing countries [19]. Based on the technological gap, dependent countries are used as energy markets and it will be difficult to achieve energy independence. However, on the other hand, it will be a great opportunity for NRE exports to foreign countries.

On the community side, Maslow's state illustrates that the simplest needs must be met so that the higher needs can be met. To strive to ensure clothing, food, and shelter [20]. Humans generally look for the fastest, simple, and economical way so that they will tend to use conventional energy with the perspective of NRE which is still underdeveloped and the need for adaptation to new technologies. Not only limited to policies, humans as users can also help achieve NZE 2060 by conserving energy. The use of electricity as efficiently as possible will have an effect on the amount of electricity issued [21]. This will also relate to the amount of coal that is processed, and how much the emission contribution will make so that the electricity used is not wasted.

From an economic point of view, the price of NRE is relatively cheap but still cannot compete with fossil energy, so it will be related to investment. The hype "cheap NRE" does not cover all types of NRE, solar and wind power are indeed cheap, but unlike other energy sources such as geothermal energy, it is difficult to say that it is economical energy [22]. The energy transition will be related to the economy, such as understanding green energy will produce a green economy. National Development Planning Board of Indonesia (BAPPENAS) in 2019 states that the average GDP growth rate through a low-carbon economy will reach 6% until 2045. To support it, the financial services industry has changed the principle that was originally oriented to conventional to a green sector and has the task of ensuring funding for this sector [23]. Indonesia's position as a producer or consumer will be influenced by how technology and how ready Indonesia is to carry out this transition.

Accelerating the retirement of CFPP requires large funds to switch to renewable energy technology so that a definite financial plan is needed from within the country or through foreign cooperation. According to the NDC Road Map by the Ministry of Environment and Forestry (2019), the energy sector mitigation investment reaches Rp. 3.500 Trillion of which Rp. 1.688 trillion for NRE-based generators and Rp. 1619 Trillion for low carbon CFPP [16]. This investment is estimated for 2030 and to achieve NZE 2060, a larger investment is needed and this is a challenge for all parties.

Future projections of the sustainability of coal-fired power plants (CFPP) must pass and consider various conditions because the majority of coal-fired power plants in Indonesia currently still play an important role as base load buffering energy. Therefore, based on the studies and opinions of the authors, Ministries and policy-making institutions synergize with state-owned enterprises engaged in the energy sector. Accelerated adaptation of coal-biomass co-firing technology combined with Carbon Capture Storage (CCS). The development of coal-biomass co-firing technology at least contributes to the use of coal (clean energy).

Based on the economic side, the utilization of conventional coal-fired power plants that have been transferred to a Co-firing coal-biomass power plant equipped with CCS can reduce the cost of generating electricity when

compared to renewable energy plants built from scratch. The development of renewable energy in supporting the national energy base load (Republic of Indonesia) is still very difficult.

In the 2040s, Vietnam promised to phase out coal. This includes not constructing or investing in coal-fired power plants and new coal-fired power plants. Authorities added that coal will be phased out by 30% by 2030 and the lost energy will be replaced by gas and renewable energy sources. This is great news for reducing greenhouse gas emissions and fossil fuel consumption, as well as other environmental and economic benefits. Remember that coal is the dirtiest of all fossil fuels. Vietnam is the ninth largest coal consumer in the world, so this is a step in the right direction for a clean energy transition. Neighbouring countries such as South Korea and Indonesia have also announced the phasing out of coal by the 2030s and 2040s, respectively [27].

Based on a report from J.Kou et al (2022) [28], China still cannot clearly declare a "coal abolition", because coal is likely to occupy an important position in China's energy system in the short term. Faced with this reality, China must increase investment in scientific and technological innovation to achieve further breakthroughs in the clean and efficient use of coal technology. China needs to focus on the coal use process, and improve the efficiency of coal utilization, mandatory carbon capture and storage devices. This will encourage the use of technology for coal cleaning, to achieve the standard "zero discharge" target and maximize the reduction in the share of carbon emissions caused by coal use.

China's efforts to achieve the goals of "peak emissions" in the medium term and "carbon neutrality" in the long term, China needs to significantly reduce coal production and consumption until it is completely phased out. However, this does not mean that China should be overly influenced by the global trend towards "coal elimination"; in other words, he must maintain his independent judgment. China is still a developing country with uneven internal development. based on China's Declaration on "coal elimination" is not a short-term immediate step, but not impossible to achieve. It should be planned according to the actual situation, to achieve the following conditions while maintaining stable GDP growth [28].

China is a country with the largest population so the volume of energy use is very large. As China can achieve economies of scale with clean energy, the cost of domestic renewable energy can be comparable to, or even comparable to, the cost of coal. Through subsidies and incentives, governments can balance the national income of coal companies with the cost of public spending and gradually receive support from both. China needs to fully prepare a set of practical implementation plans to overcome the regional recession, unemployment and social unrest in the coal industry [28].

Strategies and policies to follow up on opportunities that will occur in the future, starting from the use of waste as

biomass fuel, Adaptation and acceleration of research on Carbon Capture Storage (CCS) technology so that co-firing technology will support Net Zero Emission conditions and have the potential to achieve carbon neutrality but it is necessary tree replanting/reforestation. The development of a Biomass-coal power plant with high technology has the potential to overcome the energy base load gradually with a certain ratio so that coal-fired power plants that produce high emissions on a regular basis can be reduced. Furthermore, Equitable adaptation of Co-firing + CCS (clean energy) technology to coal-fired power plants on a regular basis. The development of coal-biomass Co-firing in the future will provide a large NDC contribution to Indonesia in facing the Net Zero Emission Condition in 2060.

Change in the energy sector is a very huge plan. Indonesia's national resilience is tested by whether it can follow global politics. Countries that can adapt quickly are likely to lead this action. Therefore, Indonesia must be able to adapt so as not to be left behind and hamper the activities of other sectors.

IV. CONCLUSIONS

The demand for energy continues to increase following the growing population and changing lifestyles. Large reserves, economic prices, and relatively simple exploitation technology make coal a promising commodity. This can provide an explanation that coal is the right choice in fulfilling energy. The great need for coal and the abundance of Indonesia's wealth should provide a good position for Indonesia itself and Indonesia is projected to become a major power in the world economy. made in Indonesia.

The amount of emissions in the energy sector is not only faced by Indonesia, the UNFCCC in 2020 states that the world is facing the same problem, namely emissions from fossil energy reaching 38 Gigatonnes and 2019 global emissions exceeding the target. The targeted emission is not to exceed 24-25 Gigatonnes to keep the earth's temperature from increasing by no more than 1.5°C, but in reality, 2019 global emissions have penetrated to 59.1 Gigatonnes.

The State Electricity Company (PT. PLN (Persero)) plans 2 scenarios for CFPP in the NZE 2060 plan. First, is innovation in storage technology that is more economical to replace CFPP with EBT generators. Second, the innovation of Carbon Capture, Usage, and Storage (CCUS) technology so that the utilization of CFPP can still be done without contributing to the increase in greenhouse gases.

First, The innovation in storage technology that is more economical to replace CFPP with RE generators. Gradually, the replacement of the CFPP was first with biomass co-firing, followed by the RE power plant which became entrenched in solar and wind power plants. In 2020 to 2030, the portion of CFPP is still operating and dominant, then the number will decrease significantly in 2040 in accordance with the agreed power plant contract period.

The second planned scenario is the innovation of Carbon Capture, Usage, and Storage technology so that the utilization of CFPP can still be carried out without contributing to the increase in greenhouse gases with clean coal technology. The existing technology to date causes a derating of the generator by 30-40%. In addition, on the storage side, the gas is generally distributed to depleted gas fields which are not necessarily located around the generating area. CFPP with a more established and more economical CCUS is planned to operate from 2035 so Indonesia only needs a retirement old subcritical CCPP of around 1 GW in 2030.

Both scenarios have something in common, namely the need for an established technology. To realize these two scenarios, it is necessary to develop good technology. With global politics leading to the use of low-carbon energy, countries that have not been able to maximize their domestic technology will rely on energy that has been transformed by low-carbon energy-producing countries. Based on this technological gap, dependent countries are used as energy markets and it will be difficult to achieve energy independence.

On the community side, in general, people are looking for the fastest, simple, and most affordable way so they will tend to use conventional energy with the perspective of RE which is still underdeveloped and the need for adaptation to new technologies. The use of electricity as efficiently as possible will have an effect on the amount of electricity issued. This will also relate to the amount of coal that is processed, and how much the emission contribution will make so that the electricity used is not wasted.

The buzz of "cheap NRE" does not cover all types of NRE, solar and wind power are cheap, but unlike other energy sources such as geothermal energy, it is difficult to say that it is economical energy. To support this, the financial services industry has changed its principles from being conventional to a green sector and has the task of ensuring funding for this sector. Accelerating the retirement of CFPP requires large funds to switch to renewable energy technology so that a definite financial plan is needed from within the country or through foreign cooperation. This investment is estimated for 2030 and to achieve NZE 2060, a larger investment is needed and this is a challenge for all parties.

Based on the economic side, the utilization of conventional coal-fired power plants that have been transferred to a Co-firing coal-biomass power plant equipped with CCS can reduce the cost of generating electricity when compared to renewable energy plants built from scratch. The development of renewable energy in supporting the national energy base load (Republic of Indonesia) is still very difficult.

Plans to solve global problems related to CFPP are also carried out by several countries. In the 2040s, Vietnam promised to phase out coal. Authorities added that coal will be phased out by 30% by 2030 and lost energy will be replaced by gas and renewable energy sources. Based on the report of

J.Kou et al, China still cannot clearly state “coal elimination”, because coal is likely to occupy an important position in China's energy system in the short term. Faced with this reality, China must increase investment in scientific and technological innovation to achieve further breakthroughs in the clean and efficient use of coal technology. This will encourage the use of technology for coal cleaning, to achieve the standard “zero discharge” target and maximize the reduction of the share of carbon emissions caused by coal use.

China's efforts to achieve the goals of “peak emission” in the medium term and «carbon neutrality” in the long term, China needs to significantly reduce coal production and consumption until it is completely phased out. Through subsidies and incentives, the government can balance the national income of coal companies with the costs of public spending and gradually gain support from both. China needs to fully prepare a series of practical implementation plans to tackle the regional recession, unemployment and social unrest in the coal industry. The construction of biomass-coal power plants with high technology has the potential to gradually overcome the energy base load with a certain ratio so that coal-fired power plants that produce high emissions on a regular basis can be reduced.

Furthermore, uniform adaptation of Co-firing + CCS technology to coal-fired power plants on a regular basis. The development of coal-biomass Co-firing in the future will provide a large NDC contribution for Indonesia in facing the Net Zero Emission Condition in 2060. Change in the energy sector is a very big plan. Countries that can adapt quickly are likely to lead this action.

From the discussion above, the author gives recommendations to review the draft law on renewable energy and need to be ratified soon, Development of environmentally friendly technology and socialization of RE with integrated energy conservation. For the education, human resources need to be introduced to this issue because education is the first step so as to produce improvements in future research. Reflecting on China, the Indonesian government should be able to provide incentives so that RE prices can compete with coal.

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REFERENCES

- [1] Said, A. (2018). ASEAN Power Grid Cooperation in Improving Electricity Security in Indonesia. *JOM FISIP*, 5, 1-11.
- [2] Kumar, A., Kumar, K., Kaushik, N., Sharma, S., & Mishra, S. (2010). Renewable energy in India: current status and future potentials. *Renewable and sustainable energy reviews*, 14(8), 2434-2442.
- [3] Maulidia, M., Dargusch, P., Ashworth, P., & Ardiansyah, F. (2019). Rethinking renewable energy targets and electricity sector reform in Indonesia: A private sector perspective. *Renewable and Sustainable Energy Reviews*, 101, 231-247.

- [4] Thew, H. (2018). Youth participation and agency in the United Nations framework convention on climate change. *International Environmental Agreements: Politics, Law and Economics*, 18(3), 369-389.
- [5] Yusgiantoro, P. (2021, Juli 2). Energy Transition and Financing: Indonesia's Contribution Towards Global Net Zero Emission 2050. Retrieved from Environment Institute: <https://www.youtube.com/watch?v=o2-GhwOt4bo&t=3493s>
- [6] Sadhukhan, J. (2022). Net zero electricity systems in global economies by life cycle assessment (LCA) considering ecosystem, health, monetization, and soil CO₂ sequestration impacts. *Renewable Energy*, 184, 960-974.
- [7] Resosudarmo, B. P., Ardiansyah, F., & Napitupulu, L. (2013). The dynamics of climate change governance in Indonesia. *Climate governance in the developing world*, 72-90.
- [8] Nugroho, H., Rustandi, D., & Widyastuti, N. L. (2021). What Position Should Indonesia Have in Placing Its Renewable Energy Development and Energy Transition Plan?. *Bappenas Working Papers*, 4(2), 239-254.
- [9] Singh, Y. K. (2006). *Fundamental of research methodology and statistics*. New Age International.
- [10] Govindan, K., Rajendran, S., Sarkis, J., & Murugesan, P. (2015). Multi criteria decision making approaches for green supplier evaluation and selection: a literature review. *Journal of Cleaner Production*, 98, 66-83.
- [11] Boote, D. N., & Beile, P. (2005). Scholars before researchers: On the centrality of the dissertation literature review in research preparation. *Educational researcher*, 34(6), 3-15.
- [12] ESDM. (2020). *Handbook Of Energy & Economic Statistics Of Indonesia*. Retrieved from [esdm.go.id: https://www.esdm.go.id/id/publikasi/handbook-of-energy-economic-statistics-of-indonesia](https://www.esdm.go.id/id/publikasi/handbook-of-energy-economic-statistics-of-indonesia)
- [13] Nugroho, H. (2017, April). Coal As the National Energy Supplier Forward: What are Policies to be Prepared? *The Indonesian Journal of Dev. Planning*, 1(1), 1-13.
- [14] Course Material : Energy Conversion Technology by Dr. Ir. Imam Supriyadi, MM.
- [15] ZOU Caineng, XIONG Bo, XUE Huaqing, ZHENG Dewen, GE Zhixin, WANG Ying, JIANG Luyang, PAN Songqi, WU Songtao. (2021, April). The role of new energy in carbon neutral. *PETROLEUM EXPLORATION AND DEVELOPMENT*, 48(2), 480-491
- [16] Karuniasa, D. M. (2021, Juli 2). Indonesia's Contribution Towards Global Net Zero Emission 2050. Retrieved from Enviroment Institute: <https://www.youtube.com/watch?v=o2-GhwOt4bo&t=6563s>
- [17] PLN. (2021, Juli 30). Strategy and readiness of the Indonesian State Electricity Company for the global trend of "coal phase out" and future plans for coal-fired power plants. Retrieved from Youtube [ditjenminerbaTV: https://www.youtube.com/watch?v=Zx3MNwMSYTE&t=782s](https://www.youtube.com/watch?v=Zx3MNwMSYTE&t=782s)
- [18] Zhou, H. L., Silveira, S., Tang, B. J., & Qu, S. (2021). Optimal timing for carbon capture retrofitting in biomass-coal combined heat and power plants in China. *Journal of Cleaner Production*, 293, 126134.
- [19] Paroussos, L., Fragkos, P., Capros, P., Fragkiadakis, K. (2014). Assessment of carbon leakage through the industry channel: The EU perspective, *Technological Forecasting and Social Change*, In press
- [20] Ozguner, Z., & Ozguner, M. (2014). A managerial point of view on the relationship between of Maslow's hierarchy of needs and Herzberg's dual factor theory. *International Journal of Business and Social Science*, 5(7).
- [21] Zhang, S., Worrell, E., & Crijns-Graus, W. (2015). Evaluating co-benefits of energy efficiency and air pollution abatement in China's cement industry. *Applied Energy*, 147, 192-213.
- [22] Course Material: The Dynamics of Indonesia's Energy Transition System by Dr. Ir. Saleh Abdurrahman, MSc
- [23] Maftuchah, I. (2021, Juli 2). Implementation of Sustainable Finance for Supporting Low Carbon Development. Retrieved from Environment Institute: <https://www.youtube.com/watch?v=o2->

- GhwOt4bo&t=7624s
- [24] Zohrabi, M. (2013). Mixed Method Research: Instruments, Validity, Reliability and Reporting Findings. *Theory & practice in language studies*, 3(2).
- [25] Presidential Regulation of The Republic of Indonesia Number 14 of 2017
- [26] Presidential Regulation of The Republic of Indonesia Number 98 of 2021
- [27] Madani, D. H., & Morisset, J. (2022). No Time to Waste: The Challenges and Opportunities of Cleaner Trade for Vietnam.
- [28] Kou, J., Sun, F., Li, W., & Jin, J. (2022). Could China Declare a “Coal Phase-Out”? An Evolutionary Game and Empirical Analysis Involving the Government, Enterprises, and the Public. *Energies*, 15(2), 531.