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Scenario Insight of Energy Transition: A Lesson Learned from European Union to Indonesia

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Abstract

Almost all countries committed to tackling climate change as agreed in the Paris Agreement in 2015. In developed countries, the European Union (EU) issued the European Green Deal (EGD) with a target of 55% emissions reductions by 2030 and net zero emissions by 2050. Among developing countries, Indonesia has similar targets, which are 29% to 41% emission reductions by 2030 and net zero emissions by 2060 or sooner. EU countries and Indonesia also aim to implement energy transitions by increasing renewable energy shares, especially in the electricity sector, to reduce their emissions. Nevertheless, the EU countries have state-of-art research related to technologies and clean energy policies, allowing the EU as the first continent to commit to net-zero emissions by 2050. Our study aims to take lessons from recommendations in EGD and analyze their fitness for implementation in Indonesia. The research was conducted through a qualitative approach using secondary information and relevant references. We found that almost all recommendations for the energy transition in the EU electricity sector are relevant to Indonesia, except nuclear power plants and electricity tariff policies.

Keywords:
energy transition, renewable energy, climate change, European Union, Indonesia

1. Introduction

The issue of climate change is increasingly becoming a global concern. All countries under the United Nations (UN) committed to reducing emissions to tackle climate change through the Paris Agreement that was declared during the United Nations Framework on Climate Change Conference (UNFCCC) or the 21st Conference of Parties (COP21) in Paris in 2015 (Kuyper et al., 2018). Those countries are committed to maintaining the average global temperature increase below 2 °C and keeping the best effort to reach 1.5 °C above the temperature of the pre-industrial period (Allen et al., 2019).

One of the leading countries in climate change commitment is the European Union (EU), which issued the European Green Deal (EGD) in 2019. The EGD contains the EU's vision to reduce emissions by 55% in 2030 and achieve net-zero emissions in 2050 (Andreucci & Marvuglia, 2021; European Commission [EC], 2019, 2021a). The primary measure adopted globally to mitigate the environmental impacts of the increasing greenhouse gas (GHG) emissions is to maintain the quality of electricity supply from renewables (Esmaeili-Shayan et al., 2022). Similarly, the EU already prioritizes its energy transition as a decarbonization strategy; it switches fossil energy into renewable energy utilization. Currently, EU countries mainly used fossil energy for 71% of total energy consumption in 2020; meanwhile, renewable energy share was only 29% (British Petroleum [BP], 2021). The EU roadmap planned to increase renewable energy share by more than 80% in power generation to net-zero emission by 2050 (EC, 2018b).

Various studies provided policies and strategies supporting EU countries in achieving EGD targets. Hainsch et al. (2022) reviewed at least 23 studies of energy transition scenarios in the EU. In a nutshell, Hainsch et al. (2022) recommended the implementation of the EU transition energy scenarios from three aspects, namely policy, technology, and social. However, Hainsch et al. (2022) did not discuss the economic aspect, such as renewable energy electricity production cost and the electricity tariff, which are essential factors in achieving clean energy transitions (Blazquez et al., 2020; Breetz et al., 2018; Ćetković & Buzogány, 2016; Qadir et al., 2021). Developed and developing countries have implemented various incentives, including premium electricity tariffs, to accelerate the decarbonization of the energy sector (Anggono et al., 2021; Drosos et al., 2021; REN21, 2015).

Energy transition research in the EU provides excellent lessons to developing countries, especially Indonesia. The government committed to reducing emissions by 29% in 2030 with its efforts and 41% with international support (Government of Indonesia [GOI], 2016b). Moreover, during COP26 2021 in Glasgow, Indonesia committed to achieving net-zero emissions by 2060 or sooner (GOI, 2021a). In this light, our study aims to take lessons from the recommendations by Hainsch et al. (2022) and then evaluate the feasibility of adopting the recommendations in Indonesia.

Our research aims to identify gaps in clean energy transition strategies in developed and developing countries. Al Irsyad et al. (2017) argued that the two economies have contrasting energy systems and opt for different policies. We choose Indonesia as a developing country since Indonesia and the EU have similar goals to switch from fossil energy dominance to new and renewable energy. In this light, our study will also help the Indonesian government sharpen the clean energy transition strategies in the electricity sector.

2. Energy Transition Scenarios in EU Countries

The EGD contains targets and leading strategies for energy transitions in EU countries. Strategies in the electricity sector include the phasing out of coal and gas-fueled power plants. The new power plants must be renewable energy. In addition, EGD emphasizes the development of offshore wind power plants and the strong cooperation between EU countries.

Hainsch et al. (2022) reviewed EGD and other 23 other studies on energy transition in the EU. Based on the review results, Hainsch et al. (2022) created a simulation model for the proposed energy transition scenarios. The scenarios considered policy, technological and social aspects. The technological aspect is suggested as the most decisive factor for successfully achieving the decarbonization scenario in the EU (Hainsch et al., 2022). Furthermore, Hainsch et al. (2022) advised that the most crucial technologies in various energy transition scenarios are solar and wind power plants onshore and offshore. The finding is based on an assumption of declining investment costs of the variable renewables. The simulation results also concluded that new energies and technologies, such as nuclear power plants, carbon capture and storage (CCS), and hydrogen, will emerge in 2050. However, simulations involving social aspects will exclude the role of a nuclear power plant in clean energy transitions. Several simulated scenarios predicted new CCS investments because fossil energy is still in use in the future. Several scenarios suggested using hydrogen in power plants, industry, and transportation. However, the volume of hydrogen usage will be small because of its relatively high investment and operational costs.

In conclusion, EGD, combined with Hainsch et al. (2022), provided eight recommendations related to policy, technological, and social aspects of implementing energy transition in power generation successfully. The first recommendation is massive renewable energy development as the primary strategy to reduce emissions in the policy and technological aspects. Secondly, renewable energy development should be accompanied by the phasing out of coal- and gas-fired power plants. The third recommendation is to prioritize offshore wind turbines among other renewable energies. Consequently, as the fourth recommendation, renewable energy development should be backed up with energy storage to maintain the stability of electricity systems. The fifth recommendation is to pull up immense investments in renewable energy power plants supplying the increasing electricity demand. The last recommendation is to anticipate potentially neglected gas infrastructures in the future while renewable energy will play a dominant role.

Recommendations on social aspects concern multiplier effects and social acceptance (Hainsch et al., 2022). The growing renewable energy investments will open new jobs and shift labor forces from fossil energy to renewable energy industries. Consequently, EU countries should prepare high-qualified human resources to support clean energy transitions. The last recommendation is to manage the social acceptance issues because the massive renewable energy investments may change land and sea zone uses and, consequently, affect public perceptions.

3. Methodology

The qualitative method compares strategies implementation in the EU vs Indonesia using the framework defined by Hainsch et al. (2022). Strategies in Indonesia are based on planning document drafts, presentation materials, intensive discussions, and meeting series in the Ministry of Energy and Mineral Resources. The comparison analysis focuses on the electricity sector, one of the largest emitters in the EU and Indonesia (European Environment Agency [EEA], 2021; GOI, 2021a).

4. Adopting the EU Policy Recommendations for Indonesia

The EU and Indonesia are committed to tackling climate change through the 2015 Paris Agreement. Table 1 compares the emission reduction targets and commitment documents in the EU and Indonesia. The EU EGD expects a 55% emission reduction in 2030 and net zero emissions by 2050 (EC, 2019, 2021a). Meanwhile, the First Indonesia National Determined Contributions (NDC) in 2016 (GOI, 2016a) intends to reduce emissions in 2030 by 29% with its efforts and 41% with international support. Moreover, Indonesia also has a vision of net-zero emissions by 2060 or sooner (GOI, 2021a).

Table 1. The comparisons of targets and commitment documents related to climate changes in the EU and Indonesia.

	European Union	**Indonesia**
Emission reduction target	**2030**: 55% emission reductions compared to emission level in 1990.	**2030**: 29% emission reductions by own efforts, and 41% emission reductions by international supports, compared to emission level by 2010 level.
	2050: Net-zero emission	**2060 or sooner**: Net-zero emission
Commitment documents	The European Green Deal (EGD) (EC, 2019, 2021a).	The Long-Terms strategy for Low Carbon and Climate Resilience 2050 (GOI, 2021a) and the first NDC (GOI, 2016a).

The first recommendation of Hainsch et al. (2022) to rapidly develop renewable energy is in line with strategies in Indonesia. Table 2 shows that the renewable energy share in the EU (i.e., 29%) is already higher than the global average (i.e., 16.8%). Meanwhile, renewable energy share in Indonesia was 11.3% of total primary energy consumption in 2020. The National Energy General Plan of Indonesia (GOI, 2017) aims to increase renewable energy share to 23% of the total energy supply in 2025 and 27% in 2030. Moreover, the long-term clean energy transition policy aims to have 100% renewable energy shares in electricity production to achieve net-zero emission by 2060 or sooner (GOI, 2021a; Ministry of Energy and Mineral Resources [MEMR], 2022b). In Indonesia, all new power plants must be renewable energy starting in 2030 (MEMR, 2022b). Figure 1 shows that coal power plants will have the highest accumulated capacity in 2030. Therefore, the transformation from coal to renewables will be very challenging. As a starting policy, Indonesia has banned new coal power plants except if it is under construction or already contracted.

Table 2 . The shares of primary energy consumption in 2020 (BP, 2021 & MEMR, 2021a).

	World	EU	Indonesia
Oil	31.3%	33.4%	32.8%
Gas	24.7%	25.9%	17.4%
Coal	27.2%	11.7%	38.5%
New & renewable energies	16.8%	29.0%	11.3%

In Indonesia, new and renewable energy potentials reached 3,686 GigaWatt (GW), while the installed capacity in 2021 was 10.88 GW, as shown in Table 3 (MEMR, 2021d). Therefore, achieving the renewable energy share target in 2025 must increase the share of renewable energy utilization by more than two times.

Table 3. Potentials and utilization of renewable energy in Indonesia in 2021 (MEMR, 2021d).

Energy sources	Unit: Giga Watt	
	Potential	Utilizations
Solar	3,295	0.19
Wind	155	0.15
Hydro	95	6.43
Bioenergy	57	1.92
Ocean	60	-
Geothermal	24	2.19
Total	3,686	10.88

MEMR (2022b) presented power plant expansions from 2022 to 2060, as in Figure 1, which are the simulation results of the Balmorel and LEAP energy models. 100% of the electricity supply in 2060 will be generated from new and renewable energies. The total power plant capacity will reach 587 GW, dominated by solar energy for 361 GW or 61% of total power plant capacity in 2060. MEMR (2022b) will give nuclear power plants a vital long-term role. The first nuclear power plant will operate in 2049, and the capacity will continuously increase over the years. In contrast, the EU gradually abandon nuclear power plants and, accordingly, the nuclear power plant capacity will decline significantly in the medium term (Jäger-Waldau et al., 2020).

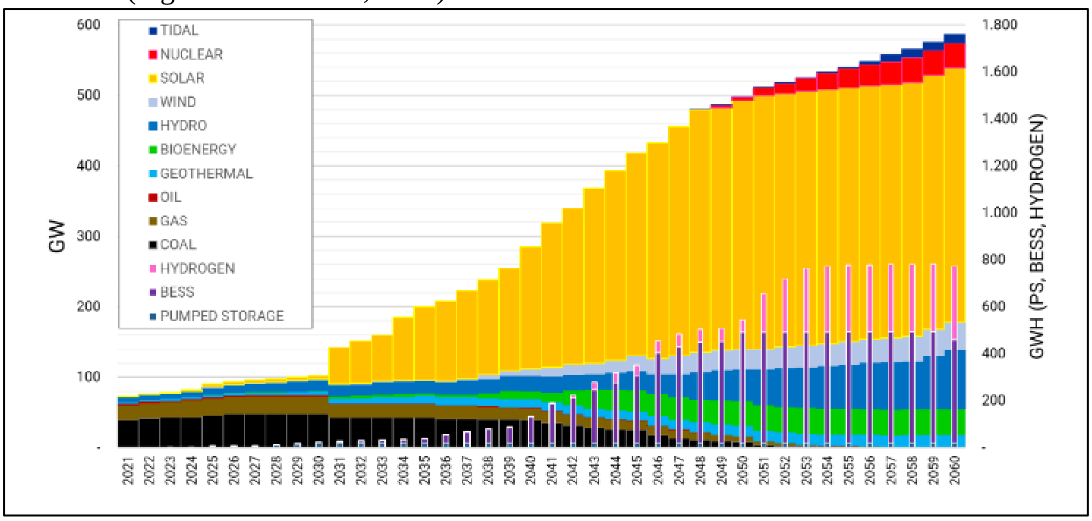

Figure 1. Net zero emission transition plan in the electricity sector (MEMR, 2022b).

The aspect not analyzed by Hainsch et al. (2022) is the challenge of relatively expensive electricity production costs from renewable energies. This economic aspect is the most critical in determining Indonesia's most optimal renewable energy technology (Tasri & Susilawati, 2014). Tagliapietra et al. (2019) argued that one of the critical priorities for the EU's energy transition to 2024 is the massive renewable energy development at an acceptable level of production costs without compromising security. In other words, the first recommendation by Hainsch et al. (2022) related to electricity from renewables was incomplete without considering the low-carbon electricity production cost.

In the economic criteria context, most renewable energy technologies have electricity production costs higher than the average electricity supply cost in Indonesia. As an example, electricity supply costs from solar farms in 2015 reached USD 25 ¢/kWh. Therefore, the higher share of renewable-based electricity supply will increase the average electricity cost of production. The consequence of this situation is to increase either electricity subsidies or electricity tariffs. Increasing the electricity subsidy will burden the state budget, while increasing the electricity tariffs will cause political pressures.

Energy subsidies have burdened Indonesia's national budget year after year. In 2015, Indonesia succeeded in carrying out energy subsidy reform, so the total energy subsidy in 2014 decreased by more than half from USD 23.74 billion to USD 8.27 billion in 2015, as shown in Figure 2. The Indonesian government successfully maintains the energy subsidy level from 2016 to 2021. Therefore, increasing the energy subsidy will be a policy setback. Moreover, increasing the energy subsidy budget will be difficult, especially since the country needs a large budget to overcome the impacts of the COVID-19 pandemic and the national economic recovery.

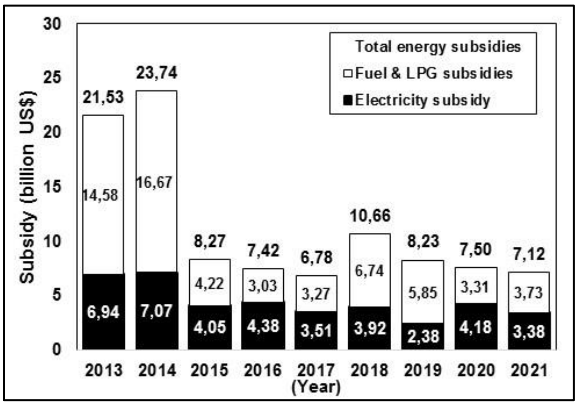

Figure 2. Realization of electricity subsidy and Fuel & LPG subsidies (MEMR, 2022).

On the other side, increasing the electricity tariffs is also not an option, especially the subsidized electricity tariffs for the underprivileged. Data from MEMR (2021b) in Figure 3 shows that the average electricity production cost for low voltage customers (i.e., households) is USD 11.02 ¢ per kWh, while the subsidized electricity tariffs range from USD 0.96 to 7.64 cents per kWh. Even the electricity tariff for non-subsidized customers (i.e., USD 10.03 ¢ per kWh) is still lower than the average production cost. The government then uses a term of compensation to cover the price and cost gap for the non-subsidized electricity customers. The compensation is a subsidy but given to customer groups that are not entitled to be subsidized. Avoiding these two impacts requires innovation to reduce the electricity production costs of renewable energy. In the future, solar energy will be competitive with coal-fired power plants. International Renewable Energy Agency [IRENA] (2021) predicted that electricity from solar panels installed in high solar irradiance areas will have the lowest cost in 2050. Renewable energy projects in Indonesia have started to have low generation costs. For example, the 145 MW Cirata floating solar farm has a power purchasing agreement for USD 5.82 ¢/kWh, which is lower than the average electricity supply cost (i.e., USD 7.05 ¢/kWh (MEMR, 2021c)). The solar farm construction started in September 2021, and the commercial operation date is at the end of 2022.

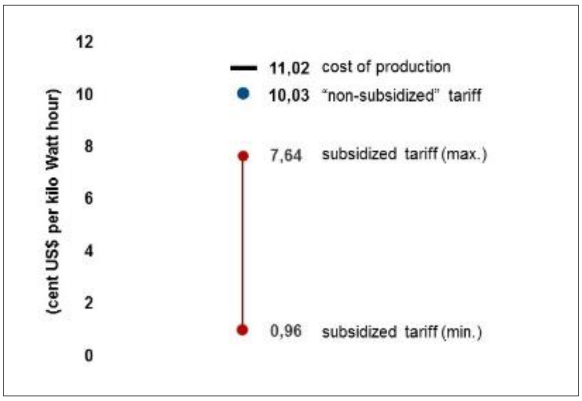

Figure 3. Low voltage electricity cost of production and household tariff (MEMR, 2021b).

Related to the second recommendation, Indonesia and the state-owned electricity company (PLN) commited to phasing out coal-fired power plants starting in 2030. MEMR (2022b) prohibits new coal-fired power plants, except if they are under construction or already have a power purchase agreement. Therefore, the accumulated capacity of coal-fired power plants reaches its peak in 2029 and will gradually diminish to zero in 2060 or sooner. Similarly, this trend also applies to gas-fired power plants. Those coal-fired power plants will be phased-out naturally, considering their lifespan and the carbon tax policy. Law Number 7 of 2021 on the Harmonization of Tax Regulation (GOI, 2021b) mandates the government to implement the carbon tax that will be initially applied to coal-fired power plants for USD 2 per ton of CO_2 on April 1st, 2022. The tax is a disincentive for fossil energy and an incentive for renewable energy. Faster phasing-out of coal-fired power plants requires replacement costs to compensate the power plant owners. This option is only feasible with financial support from international assistance. Another financing option is the carbon tax which should be increased and expanded to other polluting sectors. Revenues from the carbon taxes also can be used to incentive renewable energy development.

Indonesia will also develop offshore wind farms, which is the third recommendation. The total capacity of wind power plants will be the third-largest renewable energy capacity in 2060 after solar and hydro energies. In 2060, the capacity of wind power plants will be 39 GW and the total renewable energy capacity will be 587 GW (MEMR, 2022b). Currently, the wind energy potential in Indonesia has reached 155 GW, and the installed capacity of wind power plants is only 154 MW (MEMR, 2021d). The installed capacities are from two onshore wind farms, i.e., the 75 MW Sidrap wind farm and the 72 MW Tolo wind farm. The electricity price from wind farms is around USD 11 ¢/kWh, higher than the national average generation cost (i.e., USD 7.05 ¢/kWh). MEMR (2022b) proposed that the first offshore wind farm construction will begin in 2030. Offshore wind farms have higher investment costs and, consequently, higher generation costs than onshore wind farms. Therefore, the development of offshore wind farms should be supported by fiscal policies, which potentially burden the state budget. In this light, technological innovations are essential to reduce the investment costs of wind energy.

The fourth recommendation, i.e., energy storage, is indispensable for both the EU and Indonesia to maintain the reliability of electricity grids. Energy storage and smart grid technologies are the solutions for the intermittency nature of variable renewable energies with very high capacity in the future. MEMR (2022b) estimated that the energy storage capacity in Indonesia will be 4.2 GW of hydro-pumped storage, 140 GW of battery energy storage system (BESS), and 52 GW of hydrogen in 2060. The first hydro-pumped storage is expected to operate in 2025; meanwhile, the developments of BESS and hydrogen are planned for 2031. Moreover, compared to the EU, Indonesia, as the largest archipelago, has additional challenges in transmitting electricity and ensuring electricity grid stability. In this light, a transmission network connecting major islands is essential to transfer electricity from variable renewable energy from areas with low-electricity demand to areas with higher electricity demand. These energy storages, smart grids, and inter-island transmission require a significant investment, which is only feasible when reaching their economies of scale.

The fifth recommendation for the EU is also valid for Indonesia. MEMR (2022b) projected that the electricity demand in 2060 will reach 1,885 TWh with electricity consumption per capita of 5,000 kWh/capita. It means that the electricity consumption in 2060 will increase four-fold from electricity consumption in 2021, i.e., 1,123 kWh /capita (IRENA, 2021). The increasing electricity demand and the net-zero emission target require infrastructure investments of USD 1,043 billion or USD 25 billion/year on average. Such immerse investment will be challenging because investments in electricity infrastructures in 2021 were only USD 4 billion (IRENA, 2021).

Moreover, the most crucial challenge is the levelized costs of energy (LCOE) from power plants in the future. LCOE of most existing renewable energy technologies is still higher than the PLN's average generation costs (MEMR, 2021c). Therefore, reducing the investment costs of renewable energy plants is key to avoiding increases in either retail electricity tariffs or electricity subsidies. Several options to reduce the investment costs are an incentive policy and adjustments to local content mandatory. Ministry of Industry [MI] (2017) regulates the local content requirement for electricity sectors, including power plants. Low-cost components of renewable energy power plants cannot be freely imported, potentially increasing the investment costs of renewable energy (Limenta & Ing, 2022; Sitompul et al., 2022).

The sixth recommendation to EU countries is to pay special attention to natural gas investment because fossil energy infrastructure will be potentially neglected in the future. This recommendation is also important and relevant for Indonesia, that is not yet anticipated the potential for abandoned gas infrastructure due to the energy transition policy toward net-zero emissions in 2060. Indeed, the net-zero emission document aims to increase natural gas production to reach 12,000 million standard cubic feet per day (MMSCFD) in 2030, increasing two-fold from production in 2021. Measures to achieve the natural gas production target are the gas infrastructure developments such as gas pipelines, liquified natural gas (LNG) facilities, and other gas infrastructure.

Developing and constructing massive gas infrastructures toward 12 bscf in 2030 and renewable energy infrastructure toward 100% renewables in 2060 will potentially hinder each other. If the electricity is fully supplied by renewable energy, the gas infrastructure will be idle and unused after 2060.

In this light, the Indonesian government should re-evaluate the construction plan for gas infrastructures that have a lifespan of 50 years while the gas production peak is estimated in 2030. Neglected assets within the commercial lifespan will be a loss for the country because the upstream oil and gas contract states that the assets belong to the state after the cost recovery is paid off. Moreover, the government should also analyze export and domestic gas markets after 2050 and the analysis results should be a basis for anticipating investments in gas production and infrastructure. MEMR (2022b) predicted that the main gas consumers in 2060 are industrial and residential sectors, so gas infrastructure developments in 2050–2060 should be directed to support these sectors.

The seventh recommendation related to the social aspect also aligns with the clean energy transition in Indonesia. Job opportunities in the new and renewable energy sector increase when the total capacity of new and renewable energy power plants increases. The energy transition process will affect non-green jobs, but the growing green jobs will reduce energy consumption and raw materials. The green jobs also encourage the process of economic decarbonization, protect and enhance ecosystems and biodiversity, and reduce waste and pollution (EC, 2020a). The energy transition process in the EU will increase 1.2 million job opportunities by 2030 (Griffin et al., 2019). Indonesia also expects job opportunities with high qualifications from the massive new and renewable energy developments. MEMR (2022a) estimated that the construction of accumulated 43 GW of renewable energy power plants by 2030, as stated in the General National Electricity Plan, needs 3.7 million workers. Asian Development Bank [ADB] (2021) estimated 160,000 new job opportunities by 2030 in the power generation sector. For that, Grafakos et al. (2020) suggested that Indonesia set human resources development programs to produce qualified manpower for technical designers, operators, and managers in the renewable energy industries.

The public acceptance of new and renewable energy in the eighth recommendation is also a significant and relevant input for Indonesia. Energy usage in the future is determined not only by the technology used and its capacity but also by the social relations that shape society as a whole (EC, 2020a). Public acceptance of the energy transition process in Indonesia has different levels of diversity because of the multi-cultures and ethnicities as well as the education level discrepancy of Indonesia (Yudha & Tjahjono, 2019). Moreover, 1.5% of households in Indonesia do not have access to electricity yet (IRENA, 2021); and renewable energy offers an efficient electricity supply for these households. Around 1.5% of households in Indonesia still do not have electricity access and, therefore, providing 100% electricity access is still the top priority in the national budget. In addition, people also prefer low-cost electricity from coal instead of relatively expensive electricity from renewables.

However, central and local governments usually conduct renewable energy development in such isolated and off-grid areas because the feasibility of the electricity supply business in those areas is unattractive. Al Irsyad et al. (2019) suggested that a partial capital subsidy can effectively encourage rural households to invest in rooftop solar photovoltaic; and, at the same time, reduce government budget burdens.

Public acceptance is also influenced by the received impacts on the economy, environment, and health (Thombs, 2019). The economic concerns include the purchasing power to buy electricity and the purchasing power will affect the investment decisions by renewable energy developers. The public also expects employment in renewable energy projects and, therefore, the government should prepare knowledge and technology transfer to the community (Ho et al., 2022; Umam et al., 2021).

The EU countries have contrasting social issues. The EU community has actively participated in sustainable energy activities ranging from using renewable energy, environmentally-friendly vehicles, and low-emission household appliances (EC, 2018a). The EU society has understood the importance of clean energy usage for the survival of their children and grandchildren in the future. Changing lifestyles and people's perception needs mutual support between the private sector and social trends. In addition, the social conditions of each EU member have been considered in developing the scenario to reach net-zero emissions. The EU society has high purchasing power, and therefore, imposing high tariffs on electricity from renewable energy is feasible without subsidy support. Consequently, renewable energy investments in the EU grow faster than in Indonesia.

The EU adopts a liberal electricity market allowing electricity utilities to offer various electricity supply packages. The residential sector can freely change their electricity utility company in 2–3 weeks (EC, 2021b). The liberal electricity market has been used in the last 20 years from previously using the vertically integrated electricity market like in Indonesia. Nevertheless, the EU will use a new electricity market system as stated in the EU 2019/944 Internal Energy Market (EC, 2020b). By 2019, household electricity prices on average in the EU increased to EUR 21.6 per 100 kWh or USD 23.3 ¢/kWh, while in Indonesia, is USD 0.96 to 10.03 ¢/kWh and the electricity price almost half from the EU (Eurostat, 2020; MEMR, 2021b). To summarize, all the discussion is shown in the Table 4 below.

Table 4. Summary of Hainsch et al. (2022) recommendation and Indonesia’s condition comparison.

Hainsch et al. (2022) recommendation	Indonesia’s condition
Rapidly develop renewable energy	Indonesia plans to increase renewable energy share to 23% of the total energy mix in 2025 and 27% in 2030. In the long term will achieve 100% in 2060 to supply electricity demand.
Renewable energy development by phasing out the fossil energy	Indonesia will gradually diminish the coal-fired power plants until 2060 with consider other supporting things such as finance, regulation, and technology.

Hainsch et al. (2022) recommendation	Indonesia's condition
Develop offshore wind farm	Indonesia has offshore wind farm potential. It has to innovate the technology, thus reducing the LCOE of the offshore wind farm.
Innovate the energy storage technology	Indonesia, as the largest archipelago country, need energy storage to utilize various renewable energy which has intermittency characteristic. The technology consists of hydro pump storage and a battery energy storage system.
Electricity demand increases significantly and needs huge investment	Indonesia will need electricity demand in 2060 of around 1,885 TWh or 5,000 kWh/capita of electricity consumption and it needs investment of around USD 1,043 billion.
Consider gas infrastructure in the future	The gas infrastructure in Indonesia will be potentially neglected in the future since renewable energy will be the majority of the energy.
Green jobs opportunities and reskilling the talent from the fossil industry	Indonesia expects a new jobs from renewable energy development with an accumulated of capacity around 43 GW, then increase the quality of talent.
Public acceptance of renewable energy development	Indonesia has a different level of diversity because of various cultures and ethnicities. It needs several strategies to increase outreach activities to make people understand and accept renewable energy development.

5. Conclusions

This study shows that almost all recommendations for the energy transition in the electricity sector in the EU are relevant to Indonesia, except for the scenario of nuclear power plants and differences in electricity tariff policies. The EU will phase out the nuclear power plants, while Indonesia will construct the first nuclear power plant in 2049. The electricity tariff in Indonesia is subsidized, so it does not represent the actual market price. In Indonesia, renewable energy projects also have higher electricity generation costs than the average PLN's generation costs, so the projects are only feasible with incentive support. The EU electricity market in EU is more attractive and represent the actual market since adopting the liberal electricity market thus led to competitive price among the providers. In conclusion, Hainsch et al. (2022) are in line with EU policy recommendation. Furthermore, our discussions help the Government of Indonesia sharpen the plan for implementing the energy transition in the electricity sector.

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References

Al Irsyad, M. I., Halog, A., & Nepal, R. (2019). Estimating the impacts of financing support policies towards photovoltaic market in Indonesia: A social-energy-economy-environment model simulation. *Journal of Environmental Management*, *230*, 464–473.

Al Irsyad, M. I., Halog, A. B., Nepal, R., & Koesrindartoto, D. P. (2017). Selecting tools for renewable energy analysis in developing countries: An expanded review. *Frontiers in Energy Research*, *5*.

Allen, M., Antwi-Agyei, P., Aragon-Durand, F., Babiker, M., Bertoldi, P., Bind, M., Brown, S., Buckeridge, M., Camilloni, I., & Cartwright, A. (2019). Technical summary. In V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, & Waterfield, T. (Eds.), *Global warming of 1.5° C. An IPCC Special Report on the impacts of global warming of 1.5° C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Intergovernmental Panel on Climate Change (IPCC).

Andreucci, M. B., & Marvuglia, A. (2021). Investigating, implementing and funding regenerative urban design in a post-COVID-19 pandemic built environment: A reading through selected UN Sustainable Development Goals and the European Green Deal, Rethinking sustainability towards a regenerative economy. *Springer*, 95–413.

Anggono, T., Nepal, R., Liu, Y., Al Irsyad, M. I., & Taghizadeh-Hesary, F. (2021). Financing of energy efficiency in public goods: The case of street lighting systems in Indonesia, energy efficiency financing and market-based instruments. *Springer*, 243–261.

Asian Development Bank. 2021. *Improving skills for the electricity sector in Indonesia*. Asian Development Bank.

Blazquez, J., Fuentes, R., & Manzano, B. (2020). On some economic principles of the energy transition. *Energy Policy*, *147*, 111807.

British Petroleum. (2021). *BP statistical review of world energy July 2021*. British Petroleum.

Breetz, H., Mildenberger, M., & Stokes, L. (2018). The political logics of clean energy transitions. *Business and Politics*, *20*, 492–522.

Ćetković, S., & Buzogány, A. (2016). Varieties of capitalism and clean energy transitions in the European Union: When renewable energy hits different economic logics. *Climate Policy*, *16*, 642–657.

Drosos, D., Kyriakopoulos, G. L., Ntanos, S., & Parissi, A. (2021). School managers perceptions towards energy efficiency and renewable energy sources. *International Journal of Renewable Energy Development*, *10*.

European Commission. (2018a). *A clean planet for all. A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy*. European Commission.

European Commission. (2018b). *The commission presents strategy for a climate neutral Europe by 2050 – Questions and answers*. European Commission.

European Commission. (2019). *The European green deal*. European Commission.

European Commission. (2020a). *Green growth, jobs and social impacts fact sheet*. European Commission.

European Commission. (2020b). *Stepping up Europe's 2030 climate ambition: Investing in a climate-neutral future for the benefit of our people*. European Commission.

European Commission. (2021a). *Delivering the European green deal*. European Commission.

European Commission. (2021b). *EU energy markets and energy prices*. European Commission.

European Environment Agency. (2021). *Greenhouse gas emission intensity of electricity generation in Europe*. European Environment Agency.

Esmaeili-Shayan, M., Najafi, G., Ghobadian, B., Gorjian, S., & Mazlan, M. (2022). *Sustainable design of a near-zero-emissions building assisted by a smart hybrid renewable microgrid. 2022*(11), 10.

Eurostat. (2020). *Energy prices in 2019: Household energy prices in the EU increased compared with 2018 +1.3% for electricity and +1.7% for gas*. European Commission.

Government of Indonesia. (2016a). *First nationally determined contribution Republic of Indonesia*. Government of Indonesia.

Government of Indonesia. (2016b). *Law number 16 of 2016 on the ratification of the Paris Agreement to the United Nations Framework Convention on Climate Change*. Government of Indonesia.

Government of Indonesia. (2017). *Presidential decree number 22 of 2017 on the national energy general plan*. Government of Indonesia.

Government of Indonesia. (2021a). *Indonesia long-term strategy for low carbon and climate resilience 2050 (Indonesia LTS-LCCR 2050)*. Government of Indonesia.

Government of Indonesia. (2021b). *Law number 7 of 2021 on the harmonization of tax regulations*. Government of Indonesia.

Grafakos, S., Senshaw, D., Quezada, D., & Toro, A. (2020). *Employment assessment of renewable energy: Indonesian power sector pathways*. Global Green Growth Institute.

Griffin, M., György, E., Jakšič, K., & Siebern-Thomas, F. (2019). Towards a greener future: Employment and social impacts of climate change policies. *Employment and Social Developments in Europe*. European Commission Brussels.

Hainsch, K., Löffler, K., Burandt, T., Auer, H., del Granado, P. C., Pisciella, P., & Zwickl-Bernhard, S. (2022). Energy transition scenarios: What policies, societal attitudes, and technology developments will realize the EU Green Deal?. *Energy*, *239*, 122067.

Ho, S. S., Yu, P., Tandoc Jr, E. C., & Chuah, A. S. (2022). Mapping risk and benefit perceptions of energy sources: Comparing public and expert mental models in Indonesia, Malaysia, and Singapore. *Energy Research & Social Science, 88*, 102500.

International Renewable Energy Agency. (2021). *Renewable power generation costs in 2020*. International Renewable Energy Agency.

Jäger-Waldau, A., Kougias, I., Taylor, N., & Thiel, C. (2020). How photovoltaics can contribute to GHG emission reductions of 55% in the EU by 2030. *Renewable and Sustainable Energy Reviews*, *126*, 109836.

Kuyper, J., Schroeder, H., & Linnér, B.-O. (2018). The evolution of the UNFCCC. *Annual Review of Environment and Resources*, *43*, 343–368.

Limenta, M., & Ing, L. Y. (2022). *Indonesia's local content requirements: Assessment with WTO rules*.

Ministry of Energy and Mineral Resources. (2021a). *Handbook of energy & economic statistics of Indonesia 2020*. Ministry of Energy and Mineral Resources.

Ministry of Energy and Mineral Resources. (2021b). *Materials of the Ministry of Energy and Mineral Resources*. Ministry of Energy and Mineral Resources.

Ministry of Energy and Mineral Resources. (2021c). *Ministerial decree of energy and mineral resources number 169.K/HK.02/MEM.M/2021 of the electricity supply costs of the state-owned electricity company in 2020*. Ministry of Energy and Mineral Resources.

Ministry of Energy and Mineral Resources. (2021d). *Strategies and progress of eenewable energy on a working meeting with the Commission VII of the House of Representatives*. Ministry of Energy and Mineral Resources.

Ministry of Energy and Mineral Resources. (2022a). *2021 achievement and 2022 plan of performance of the energy and mineral resources sector*. Ministry of Energy and Mineral Resources.

Ministry of Energy and Mineral Resources. (2022b). *Energy transition priority program in 2022 on a working meeting with the Commission VII of the House of Representatives*. Ministry of Energy and Mineral Resources.

Ministry of Industry. (2017). *Peraturan Menteri Perindustrian nomor 05 tahun 2017 tentang perubahan atas peraturan Menteri Perindustrian Nomor 54/M-IND/PER/3/2012 tentang pedoman penggunaan produk dalam negeri untuk pembangunan infrastruktur ketenagalistrikan*. Ministry of Industry.

Qadir, S.A., Al-Motairi, H., Tahir, F., & Al-Fagih, L. (2021). Incentives and strategies for financing the renewable energy transition: A review. *Energy Reports, 7*, 3590–3606.

REN21. (2015). *Renewables 2015 global status report*. Renewable Energy Policy Network for the 21 Century.

Sitompul, R.F., Endri, E., Hasibuan, S., Jaqin, C., Indrasari, A., & Putriyana, L. (2022). Policy challenges of Indonesia's local content requirements on power generation and turbine production capability. *International Journal of Energy Economics and Policy, 12*, 225–235.

Tasri, A., & Susilawati, A. (2014). Selection among renewable energy alternatives based on a fuzzy analytic hierarchy process in Indonesia. *Sustainable Energy Technologies and Assessments, 7*, 34–44.

Thombs, R. P. (2019). When democracy meets energy transitions: A typology of social power and energy system scale. *Energy Research & Social Science, 52*, 159–168.

Umam, M. F., Purba, D., Yanuarizky, R., Selia, S., Napitu, A., Hendinata, L. K., & Ramadhani, I. (2021). *Renewable energy literacy in supporting geothermal project in Indonesia: Where are we now?*. 46th Workshop on Geothermal Reservoir Engineering.

Yudha, S. W., & Tjahjono, B. (2019). Stakeholder mapping and analysis of the renewable energy industry in Indonesia. *Energies*, *12*, 602.