energies

Review

Review of Policies for Indonesia's Electricity Sector Transition and Qualitative Evaluation of Impacts and Influences Using a Conceptual Dynamic Model

Teuku Naraski Zahari and Benjamin C. McLellan *

Energy Economics Research Group, Department of Socio-Environmental Energy Science, Graduate School of Energy Science, Kyoto University, Kyoto 606-8501, Japan; teuku.zahari.35d@st.kyoto-u.ac.jp
* Correspondence: b-mclellan@energy.kyoto-u.ac.jp

Abstract: Indonesia's final energy demand is projected to increase by 70% in the next decade, with electricity expected to account for 32%. The increasing electricity demand poses a potential threat to national emissions reduction targets since fossil fuels generated 86% of the electricity in 2018, associated to 50% of the national CO_2 emissions. Indonesia plans to reduce its CO_2 emissions by 29% by increasing the total electricity generated from renewables, using a set of market-based and regulatory policies. However, economic, social, and environmental issues may arise from the widespread adoption of renewable energy. This study explores the economic, social, and environmental effects of renewable energy policies in the electricity sector. Our work presents an advance over previous studies that attempted to understand the electricity sector energy transition from a system perspective by exploring the structural feedback between it and economic, energy, and environmental systems. This enables the assessment of different energy policies using more macro indicators, which further emphasize the novelty of our work. A combination of system dynamics modelling and a policy analysis framework was applied to explore these issues. Our study proposes a dynamic hypothesis that the price of energy increases over time, in the absence of substitution, becoming a limiting factor in the transition to renewables in the electricity sector. The fiscal budget was found to be a bottleneck for renewable energy adoption in the electricity sector in Indonesia. We found that a fossil fuel depletion premium could be a potential supporting policy to enable the smooth phasing-out of fossil fuels and support a sustainable energy transition.

Keywords: system dynamics; policy analysis framework; energy transition; depletion premium

Citation: Zahari, T.N.; McLellan, B.C. Title Review of Policies for Indonesia's Electricity Sector Transition and Qualitative Evaluation of Impacts and Influences Using a Conceptual Dynamic Model. *Energies* **2023**, *16*, 3406. https://doi.org/10.3390/en16083406

Academic Editor: David Borge-Diez

Received: 28 March 2023
Revised: 7 April 2023
Accepted: 10 April 2023
Published: 12 April 2023

1. Introduction

Indonesia's final energy demand is projected to grow from 128.7 Mtoe 2020 to 219.7 Mtoe in 2030, and around 32% of this is expected to be in the form of electricity because of increased electrification in multiple sectors. On the other hand, Indonesia faces a surging level of CO_2 emissions, which increased from only 131.3 Mt in 1990 to 542.9 in 2018 [1], making it the 10th highest CO_2 emitter in the world [2]. Around 50% of CO_2 emissions come from the electricity sector, since around 86% of the electricity is generated from fossil fuels [3,4]. Indonesia's Nationally Determined Contribution (NDC) aims to reduce greenhouse gases (GHG) by 29% unconditionally by 2030 [5]. To support the goal, the Government ambitiously plans to increase the renewables uptake in the electricity sector by up to 80% by 2050 [4].

However, there are barriers to adopting renewable energy in the electricity sector. Some renewable energy sources, like hydro, solar, and wind power, require a larger land footprint than fossil energy [6]. Moreover, although the cost of renewable energy has been declining significantly in the last decade [7], an extensive integration of variable renewable energy into the grid may also increase the electricity price when the system cost is considered [8,9], which may be particularly true in case of Indonesia where the system cost of, for example solar PV, is more expensive than in other countries [7,10]. Phasing out fossil fuel could also lead to economic instability, as it provides almost 18% of the Indonesian government's revenue through tax and non-tax revenues [11]. Researchers have also found undesirable effects on food and water security from the use of biodiesel, which is being planned to replace diesel to generate electricity [12,13]. Furthermore, biodiesel is subject to supply risk since it is also used in the transportation sector, while palm oil as one of its feedstocks is used in the residential and industrial sectors [14].

The Indonesian government is planning to employ an array of energy policies to support the transition in the electricity sector. However, some policies show negative impacts on the economy. For example, the application of a Feed in Tariff (FiT) could lead to a spike in electricity price [15,16], while a carbon emission trading system (ETS) increases fossil energy prices and the production costs of various industries, leading to a decline in real GDP [17]. The latter example is particularly relevant to Indonesia as the country is heavily reliant on fossil fuel.

There have been a number of previous studies which evaluated the effectiveness of energy transition policies in the Indonesian electricity sector. For example, Hidayatno et al. compared the effectiveness between net metering policies and net billing mechanisms in increasing the adoption of solar rooftop photovoltaics and concluded that net metering was more effective [18]. Another study investigated the effectiveness of an FiT in increasing the adoption of geothermal adoption and found that this policy alone is not sufficient to achieve the national target [19]. While insightful, we argue that these studies have not comprehensively examined the whole energy system and policy landscape. Many of the complications in energy policy implementation, as previously mentioned, involve linkages and feedbacks between different systems—the economic system in particular—which creates complexities in the energy transition. Hence, increasing the electricity sector energy transition should be viewed from the energy system and the economic system [20]. One study has viewed the electricity sector energy transition issue from a wider perspective [21]. Although they have considered the link with economic growth, they view the problem predominantly from the perspective of the state-owned PT Perusahaan Listrik Negara (Persero) (PLN), which we argue limits the discussion with regards to structural feedback on the economic system. Furthermore, these studies used a specific model to assess each of the different policies. While this is an excellent way to analyse a specific policy, we argue that a generalized model would be more useful to understand the system as whole.

The objectives of this study are threefold. First, is to understand the underlying system structure that could hold back the energy transition in the electricity sector—this includes technological, social, economic, and policy-related factors. Secondly, the study reviews the current policies that the Indonesian government has enacted or may enact to promote the energy transition. Energy transition policies involve multiple variables and stakeholders, which create a complex system with uncertainties due to nonlinear interactions [13,22]. Thus, our third objective is to explore "what would happen" and "how does it happen" when these energy transition policies are implemented.

To accommodate this complexity, the method used to study the effects of energy transition policies should be able to model the system's non-linear behaviour during the transition period and the uncertainties associated with the system. Modelling approaches such as agent-based models, real options, game theory, system dynamics, economic modelling, and scenario analysis are suitable for such kinds of problem [23]. There have been many tools that model the energy system. However, some energy modelling tools such as MARKAL, TIMES, or NEMS are based around an optimization approach [24,25]. On the other hand, tools like LEAP are more explorative by accommodating scenarios. However, LEAP does not estimate the impact of energy policies on the economy [26], something this study wishes to address. Hence, we propose to use system dynamics to model the problem.

System dynamics has been used to model complex systems, including economic systems, technology diffusion, and energy systems [18,27,28]. System dynamics is also suitable for explorative studies as it can include scenario analysis and deal with uncertainty [29]. System dynamics is built upon the dynamic relationship of variables within the system. Given the complexity of energy transitions, we consider that it would be beneficial to have an in-depth elaboration on the variables involved and how their relationship affects the transition in the electricity sector. Thus, this paper will present a dynamic conceptual model that is aimed towards understanding the underlying structure and the behaviour of the electricity sector energy transition in Indonesia.

The next section of this paper will present a literature review on theories, policies, and indicators relevant to the energy transition. This policy review identifies specific policies that Indonesia has implemented or may be considered, addressing the second objective of this paper. Section 3 discusses the proposed method used to evaluate energy transition policies. Section 4 shows the process of building the conceptual model, and then we discuss the policy evaluation using the constructed model in Section 5. Finally, we conclude our paper in Section 6 and present the implications of our study on current and future energy transition policies.

2. Literature Review

2.1. Energy Sustainability

With the aim to shift away from fossil fuel, the Indonesian electricity sector is expected to grow at an accelerating rate. Many have argued that this shift is in line with the aim of achieving sustainability in the sector. However, one must remember that electricity is a secondary energy produced from primary resources, which are mostly finite. For example, even though solar PV generates electricity from an infinite source, the minerals that enable the conversion are finite resources. Furthermore, the land on which the solar PV is installed is also finite. These restrictions will be explored in detail in the next sections of this paper. Thus, the electricity sector sustainability discussion cannot be separated from these primary resources. In this section, we elaborate on the general concept of sustainability and how it relates to the electricity sector.

From the perspective of ecological economics, energy is the foundation of an economic system, which flows through resources, production processes, and goods consumed. The by-products of economic activity are wastes and emissions that flow back into the environment [30]. The aggregate demand from multiple sectors drives the economy and becomes the basis for producers' production quantity, which induces a requirement for energy and resources [27]. This cycle emphasises the importance of aggregate demand in the economy to scale energy demand and its environmental impact.

There are two fundamentally distinct analytical approaches for estimating energy demand. First, the bottom-up approach centres on the demand for different energy sources based on the intensity of use and efficiency of energy-using capital used by different energy consumers. On the other hand, the top-down approach attempts to relate macroeconomic variables such as Gross Domestic Product (GDP), relative energy price, and income to approximate energy demand [31]. Both approaches have advantages and disadvantages. For example, the bottom-up approach can be used to analyse the energy supply sector's restructuring but cannot endogenously model the saturation level of energy-using products. Top-down analysis can incorporate various economic scenarios but has difficulties dealing with energy price elasticity [31,32]. Nonetheless, these two approaches synergistically provide a better outlook on future energy demand [32,33].

The top-down approach is useful when analysing the effect of the energy price on energy demand [31,32]. Energy price is often related to other macroeconomic price indices, such as Consumer Price Index (CPI), to measure the real price of energy. In general, the price elasticity of energy demand is negative, indicating that the energy demand would decrease with an increase in real energy prices. However, with various energy sources, a decrease in one energy source could mean an increase in the other, which shows a substitutive relationship between energy sources. Conversely, two energy sources can also be complementary. The cross-price elasticity would be negative in the former case while positive in the latter [31].

Theoretically, the price of any goods, including energy, is affected by scarcity [31]. This scarcity is not to be confused with geological scarcity, as the price of energy is more driven by an imbalance in supply and demand [34]. Energy supply can be increased through more intensive exploration and extraction, thereby decreasing its reserve. In the case of a finite resource, ongoing extraction could cause a decreased supply in the future. The notion of sustainability aims to maintain the availability of a finite resource for future generations. There are two concepts of sustainability. Strong sustainability requires a certain amount of stock for subsequent generations, while weak sustainability allows for a reduced stock of an energy source if the demand for future generations is met through substitution. In other words, weak sustainability requires the overall per-capita energy consumption to not decrease [31,35]. These concepts of sustainability are applicable to any sector, the electricity sector included, as long as there is a finite resource involved.

From the weak sustainability standpoint, non-renewable energy sources could be entirely substituted by renewable energy sources if their potential and production inputs are sufficient for future primary energy demand [31]. However, with a growing population, constant per-capita energy resource consumption would be difficult, if not impossible, to achieve without technological change. Thus, rents from non-renewable energy resources must be allocated to reproducible capitals, called the Hartwick Rule [31,36], a task for central governments and other stakeholders in the energy transition.

2.2. Energy Transition Policy in Indonesia

The Indonesian electricity sector is based on a single-buyer model dominated by PLN. The PLN generates most of the electricity through its subsidiary and transmits and distributes it to consumers [37]. Independent power producers (IPP) also participate in electricity generation, albeit with a limited share [38].

By 2021, Coal-fired power plants (CFPP) accounted for 50.4% of all installed capacity in Indonesia. Gas-fired power plants were the second largest, with 28.9%, hydropower 8.6%, diesel 6.7%, geothermal 3.1%, biomass 2.4%, and small fractions of variable renewable energy, such as solar and wind. Consequently, the electricity generated was also dominated by coal-fired power plants with 65.6%, followed by gas-fired power plants 19.1%, hydropower 6.8%, geothermal power plants 5.5%, and diesel power plants 2.2%. With this mix, the electricity sector consumed more than 66 Gt of coal (46.68 Mtoe), as well as 9.54 Mtoe gas and 2.36 Mtoe oil [39]. The government plans to shift the energy mix to a share of at least 23% of renewable energy by 2025 and 31% by 2050 [13]. In a more ambitious scenario, the government aims to have around 80% of electricity generated from renewable sources by 2050. The government plans to focus on hydropower and geothermal power plants until 2030. Afterwards, solar is projected to have the largest share among renewables, which is expected to account for 68% of the electricity generated by 2050 [4].

The government has planned a set of energy policies aiming to increase renewable energy use and support energy security [13]. From the perspective of the electricity sector, these policies can be grouped into policies that affect the energy supply for electricity generation, electricity demand, and electricity generation itself. These policies can be further grouped into market-based and regulatory-based policies [40].

The most common market-based policies are financial incentives or subsidies, which artificially reduce the cost of goods. The Indonesian government has long provided large electricity subsidies to consumers [41], a common practice in developing countries [42]. The government also provides subsidies to energy producers, which amounted to USD 644.8 million for the coal industry and USD 132.8 million for renewable energy in 2015 [43]. The subsidy reform in 2015 removed some of the artificial cost reductions of fossil fuel generation [41]. However, pricing-based policies often pose consequences that counteract their goal [44]. For example, a poorly designed FiT can lead to higher electricity costs owing to overinvestment [15,16]. In some cases, other market-based policy instruments, like carbon pricing and taxes on air pollution, only result in a shift from higher carbon fuels to lower carbon fuels, such as a switch from coal to gas [40,45]. This phenomenon not only led to a less than anticipated carbon level reductions, but also imposes a considerable cost [46]. Finally, subsidies could create economic inefficiency, deadweight loss, and overconsumption [47].

The Indonesian government also designed a number of regulatory-based policies, such as Domestic Market Obligations for coal [48], purchase obligations for renewable electricity imposed on PLN, and installation obligations for solar PV in the residential sector [13]. These policies aim to increase a demand for renewable energy. However, obligatory policies could create uncertainty in price when the price is not regulated, leading to high investment costs, which could lead to an increased electricity cost [49]. Poor compliance with obligatory policies hinders their implementation [50]. Other regulatory-based policy includes budget allocation, energy price regulation, and energy intensity standardization [13]. Table 1 shows a summary of energy policies in Indonesia relevant to the renewable energy transition in the electricity generation sector.

Table 1. Renewable energy transition policy in the electricity generation sector [13].

Policy Group	No.	Policy	Mechanism
Market-Based	1.	Carbon Tax	A tax is imposed on individuals or institutions when purchasing or using carbon emitting energy-using products.
	2.	Energy Price Subsidy	The government provides subsidies for energy sources for consumers or producers.
	3.	Feed-In Tariff	The government mandates PLN to purchase electricity generated from renewable sources at a set price, and provides subsidies for this to PLN.
	4.	Fossil Fuel Disincentives	Implement excise or other disincentives on fossil fuels for a more favourable price comparison with renewable sources.
Regulatory Based	1.	Bureaucracy/Institutional Reform	The government improves bureaucratic processes to increase renewable energy investment attractiveness including by easing investment procedures and reducing the time for renewable energy auction processes.
	2.	Energy-Using Products Electrification	Increases the use of electricity in energy-using products especially for the residential and transportation sectors.
	3.	Construction/Installation Obligation	Obligates institutions to construct or install a minimum quantity of renewable energy.
	4.	Depletion Premium	Imposes a premium on the extraction of fossil fuel to be allocated for renewable energy.
	5.	Domestic Market Obligation (DMO)	The government requires energy producers to supply a minimum quantity of their production for the domestic market.
	6.	Energy Price Regulation	The government regulates energy prices by setting a base price, price ceilings, progressive pricing, price localization, or other pricing schemes.
	7.	Fiscal Budget Re-allocation	Readjusting fiscal budgets for energy price subsidy, renewable energy financing, energy accessibility, and research and development.
	8.	Fiscal Incentives	Incentives are provided by the government to consumers, industries, and institutions who participates in energy transition efforts, including the construction/installation of renewable energy or the use of energy efficient energy-using capital stock.
	9.	Purchase Obligation	Obligates a minimum purchase quantity of renewable energy to institutions.

2.3. Energy Transition Assessment Criteria

We identified several studies which attempted to assess energy transition pathways. Each of these studies used different indicators that can be broadly grouped into three dimensions: economic, social, and environmental, in accordance with the United Nations' Sustainable Development Goals dimensions [51].

2.3.1. Economic Indicators

Numerous studies have established economic indicators relevant to the energy transition. The most frequently used economic indicators were GDP related, including GDP growth, GDP loss, GDP per capita, and final energy intensity to GDP [30,52,53]. Supply and demand indicators are also often used to assess the energy transition pathway, among others, total primary energy supply per capita, shares of energy sources in total energy supply, and sectoral energy demand [30,54,55]. Massive changes to the system structure raise questions related to investments, such as costs and their returns, as well as policy costs, mitigation costs, and abatement costs [54–57]. Other authors include fiscal indicators, government budgets, and trade balance [30,58]. Finally, due to the unstable nature of transition, some studies add risk indicators such as GDP volatility, investment volatility, consumption volatility, the likelihood of crises, volatility of total debt, economic risks to ratepayers, long-term economic viability, and energy security [52,58–60].

2.3.2. Environmental Indicators

CO_2 emissions are an obvious indicator when discussing the impacts of the transition to renewable energy. However, broader impacts on the environment should also be considered. Madlener and Stagl (2005) [58] further classified the environmental impacts on the resources needed for energy production and the potential environmental consequences of energy production, use, and conversion. Land use, water use, and resource depletion appear in multiple studies as indicators of resources for required energy production [30,52,61–66]. Aside from CO_2 emissions, other air pollutants such as CH_4, N_2O, NO_x, SO_x, and Particulate Matter (PM) have been mentioned in several references as environmental consequences of energy production, use, and conversion [30,52,58,64].

2.3.3. Social Indicators

Most studies are concerned with how an energy transition would affect the labour market, in particular, unemployment and job creation, since there will be a shift between the fossil fuel industry and the renewable energy industry [30,52,58,67]. Other studies account for indicators that are related to income equality, including income distribution, the Gini coefficient, and household income disparity, as well as household income, in particular the cost of electricity [30,58,67,68]. Some authors include public health indicators related to environmental effects, such as morbidity, human toxicity, and life expectancy at birth because it is widely understood that certain pollutants adversely affect health [69–71]. Finally, other authors have also considered occupational hazards related to energy transition [58,64,69].

3. Methodology

We used the policy analysis framework to develop our conceptual dynamic model [72]. The first step in this framework is problem identification, where the systems dynamics approach [28] is employed since the energy transition is a complex issue. We modelled the qualitative relationship between relevant variables in the system with the aid of the Causal Loop Diagram (CLD). The causal links between variables are represented using arrows with two polarities, "+" and "-", which indicates a positive influence and negative influence of one variable on the other [28]. We conducted a literature review to identify the variables relevant to the formulated problem and the polarity between variables.

Based on the qualitative relationship between the variables, we construct a dynamic hypothesis which is the idea of how the behaviour of the system arises based on the system structure.

We proceeded with our method by investigating the indicators relevant to the identified problem. Indicator investigation is an essential step in the policy analysis framework, as it will eventually be the basis for discussing the outcomes of different policies. To enrich our analysis, we also incorporate a stakeholder analysis to help understand each of the stakeholder's positions and interests in the problem [73]. We explored how they would react to or influence policies which ultimately affect the outcome of the system.

Both system dynamics and the policy analysis framework acknowledge that there are exogenous factors to the system that could affect the system's behaviour [28,72]. Hence, as a final step, we developed a system diagram that connects the preceding steps with these external factors to the problem, representing uncertainties.

4. Result

4.1. Qualitative Model Development

The proposed qualitative model is broken into four sub-models. The first part presents the dynamics in the power plant investment which is generalised into the selection between non-renewable and renewable energy power plants and how it relates to the energy transition in general. We then continue our conceptualisation of the dynamics of energy substitution between fossil fuels and renewable energy. This is then linked to the environmental carrying capacity which serves as a limitation to both energy sources. Afterwards we present how the previous sub-models connect to the economy. The developed sub-model represents a generic model for all energy sources; thus, it is possible that a characteristic of one energy source is not present in the other sources.

4.1.1. Investments in Power Plants: Selection of Two Alternatives

Figure 1 shows the investment dynamics of two power plant technologies: fossil-based power plants or RE-based power plants. The total electricity demand from the residential, industrial, transportation, and commercial sectors can be served by electricity generated from non-renewable electricity (NRES-E) or renewable energy electricity (RES-E). The installed capacity and capacity factor of the respective technology are considered in this model instead, as they are the decision variables for the electricity generated. When the capacity factor is constant and the total capacity is insufficient, an additional capacity is required. Investment assessment for the additional capacity uses projected cash flow, profitability, and other investment risks to determine the investment execution, which may or may not fulfil the desired additional capacity for that technology (B1 and B2 loops). The realised additional capacity from either technology would add to the total installed capacity, ultimately fulfilling the total electricity demand (B3 and B4 loops). The current installed capacity is subject to decommissioning (B5 and B6 loops), which would create its own trigger to add capacity from either technology.

The decision to build either a non-renewable or renewable power plant would depend on the relative value of the respective technology. One of the factors influencing the relative value is the projected investment profitability of a power plant which is affected by the energy price used for that power plant [74]. Investment risks are also added to the technology's overall value, including environmental, social, and political risks [75]. A comparison of the relative value of one technology would induce shifting or persistent behaviour (R1 loop). If, for example, when there is a need for added total capacity and NRES-E is perceived to be more valuable after considering profitability and risks, then all additional capacity would be provided by NRES-E. On the other hand, investment for RES-E would be preferred when it is perceived to be the better alternative. Thus, the tendency to use one technology can persist if its relative value is consistently more than the other. However, a shit could occur when there is a change in their relative value.

According to the developed conceptual model, the decision to build a particular power plant is heavily dependent on factors outside the power plant boundaries. It involves relative energy prices and environmental, social, and political risks, forming a bigger picture of the energy transition. The following section elaborates on the general dynamics of the energy transition.

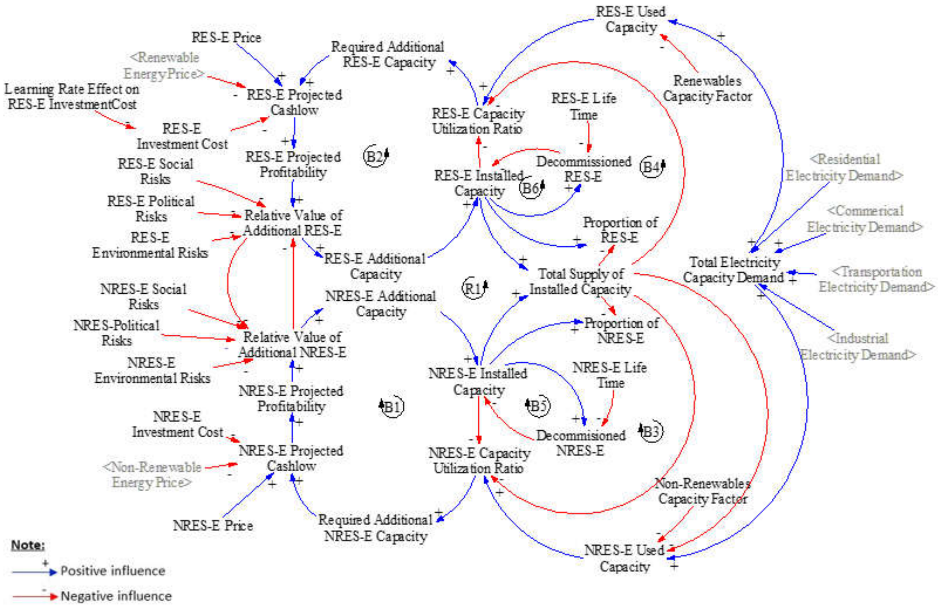

Figure 1. Choosing fossil-based power plants or RE-based power plants is an investment decision between two alternatives. Blue arrows are paired with (+) sign to indicate positive influence on the variable, red arrows paired with (-) indicate negative influence.

4.1.2. Fossil Fuel and Renewable Energy Substitution Dynamics

Renewable energy can be seen as a substitute for non-renewable energy, which is especially true in the context of achieving net-zero emissions. Hence, the demand for one energy would also be affected by its relative value over the other. To understand energy demand dynamics, we use the supply-demand perspective and adopt the idea of scarcity as the driver of commodity prices.

As a commodity, the scarcity of energy inventory drives energy prices. When there is a negative imbalance between supply and demand, energy prices would increase, signalling energy suppliers to provide more energy either from domestic production or imports, shown as B7 loop in Figure 2. The price increase would also drive consumers to consume less energy, governed by their demand elasticity to price (B8 loop). As with the supply and demand system archetypes, the interaction between these two balancing loops generates a seesaw behaviour of the system that tries to stabilise energy prices [28,76]. As demand is met with sufficient supply, energy prices would remain stable, thus encouraging more demand and creating a consumption-driven supply (R2 loop). This condition remains true as long as supply can be maintained. Short-run price changes would be the basis of the expected price in the future; hence, a rise in energy price makes investing in reserve exploration and extraction economically attractive [31]. However, increased extraction would eventually deplete reserves and limit the supply of energy which could lead to an increased price (R3 loop).

A reinforcing loop connecting both groups of energies is developed by differentiating the supply and demand dynamics of non-renewable and renewable energy (R6 loop). This reinforcing loop shows that there will be a period of price increase or decrease for both non-renewable and renewable energies, subject to the price of the other alternative. The interaction between supply and demand dynamics in non-renewable energy is also present in renewable energy, which is represented as B9 and B10 loops in Figure 1. Similarly, R4 loop shows the consumption-driven supply of renewable energy. Renewable energy is also subject to resource limitations (R5 loop), as briefly mentioned in the introduction.

From a substitution perspective, energy with a more sustainable supply will have a more stable price which would add to its relative value over the other. The supply of both energies is, however, are limited to resource constraints which will be explained next.

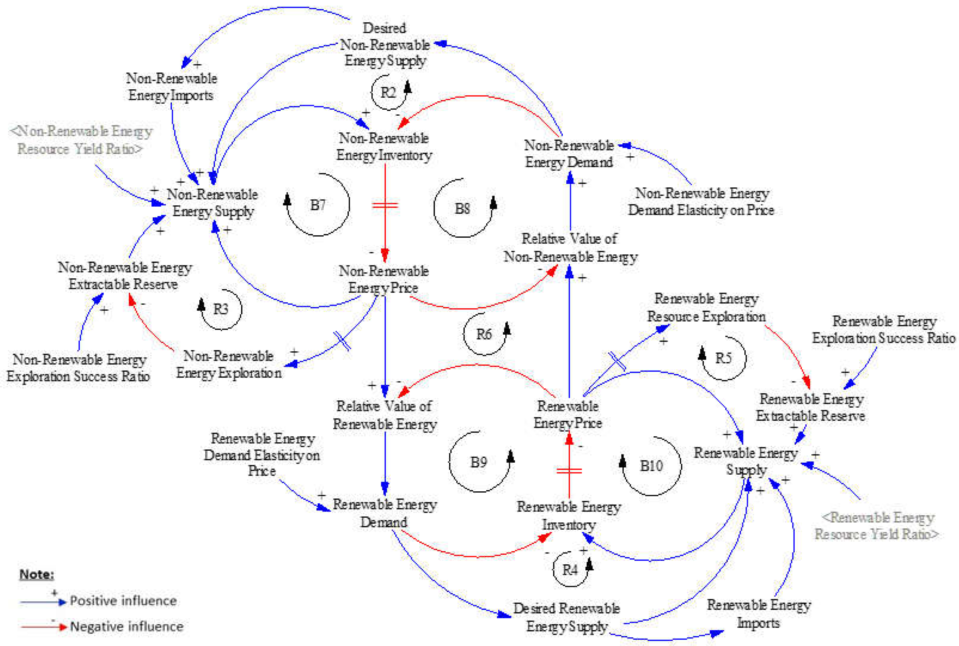

Figure 2. Substitution between non-renewable energy and renewable energy. Blue arrows are paired with (+) sign to indicate positive influence on the variable, red arrows paired with (-) indicate negative influence.

4.1.3. Environment Carrying Capacity

Figure 3 shows the dynamics of resource constraints, or carrying capacity, to energy supply. Some energy sources use a common resource, of which land and water are the primary examples [12]. Land is a finite resource where there is competition for its use, resulting in a potential shortage of land for a particular purpose, including energy production [77]. Similarly, water is used to grow crops for biofuels, running turbines in hydropower plants, and coal mining processes. Thus, land and water shortages threaten the energy supply, but on the other hand, energy supply contributes to resource shortages. Moreover, the fact that land and water are used by other sectors, such as agriculture, residential, and industry, adds complexity to the problem.

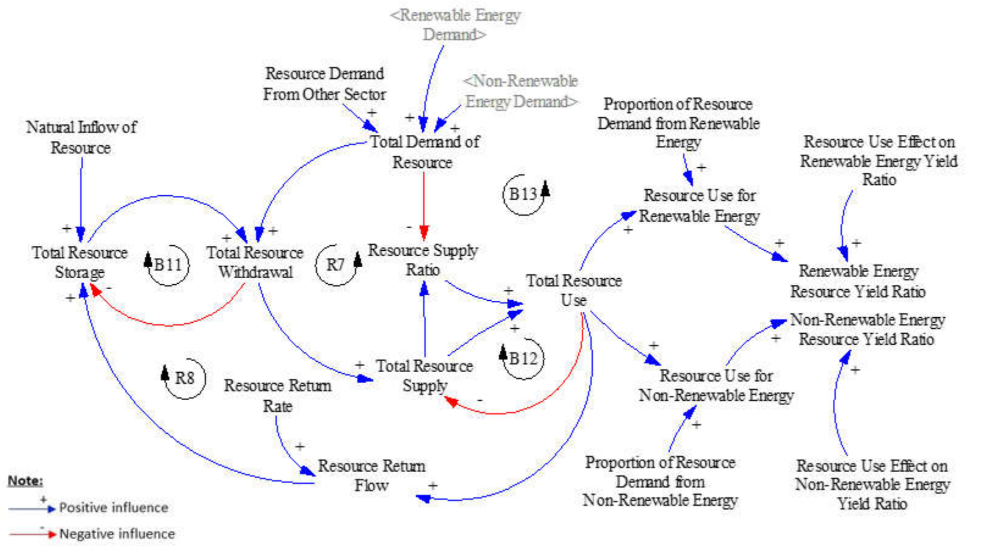

Figure 3. Environmental capacity linked to the supply of non-renewable energy and renewable energy. Blue arrows are paired with (+) sign to indicate positive influence on the variable; red arrows paired with (-) indicate negative influence.

As the demand for a particular resource increases with the increase of energy demand, so will the amount of resource required to be withdrawn and supplied (R7 loop). Also, in the case of renewable resources, there can be a return flow as an inflow for the resource storage alongside the natural inflows (R8 loop). However, the amount of withdrawable and suppliable resources is limited by its storage (B5 loop) and supply (B12 loop). Furthermore, the suppliable resource must then be allocated to other users across sectors, as pointed out before. These limitations affect the resource that can be used and, in turn, the resource's actual yield ratio for energy supply, which is linked to the yield ratio in Figure 1 (B13 loop). For example, if biofuel crops do not receive enough water, the actual crop yield would not be sufficient to fulfil the actual demand for biofuel production [78]. Different energies would require different amounts of common resources. With limited environmental capacity, energy supply can be compromised, leading to an increase in energy prices.

4.1.4. Macroeconomic Loop

Numerous studies have found a relationship between the economy and energy consumption. A set of studies support the hypothesis of unidirectional causality from economic growth to energy consumption [79–81]; this is particularly true for the consumption of renewable energy [82,83]. Conversely, some studies found that the causality is the other way around: energy consumption drives the economy [84–86]. Yet further studies suggest that the causality is bidirectional, involving feedback from energy consumption to the economy [87–89]. The causality between the economy and energy also depends on the length of observation. Most studies agree that there is a long-term causality between the economy and energy consumption, but some have dismissed the relationship between them in the short term [87,90]. However, a study among OECD countries found that there is a threshold in which GDP per capita would have a short- and long-term effect on energy consumption [91]. In addition, it has also been suggested that the causality between the two variables may be in a different direction between countries or even absent [81,92,93]. Since this study observes the dynamics of energy transition in the long term, we adopt the bidirectional causal relationship between energy consumption and economic growth.

Figure 4 shows the macroeconomic sub-model used in this study, adapted from Yamaguchi's work, which models the macroeconomy in a closed-economy setting [27]. The model consists of two parts: the short-run effect and the long-run effect of aggregate demand. In the short run, aggregate demand from consumption and government expenditure creates a reinforcing loop for GDP (R9 and R10 loops). Short-run aggregate demand drives the expectation of long-run aggregate demand, leading to an increased capital formation (R12 loop) and, with increased capital, so will the economic output (R13 loop). Aggregate demand would also affect the labour market through the desired output needed to fulfil that demand. The labour market then affects household income and, later, aggregate demand (B16). This sub-model also includes a fiscal budget essential for incentivizing the use of renewable energy in the economy, including for electricity generation.

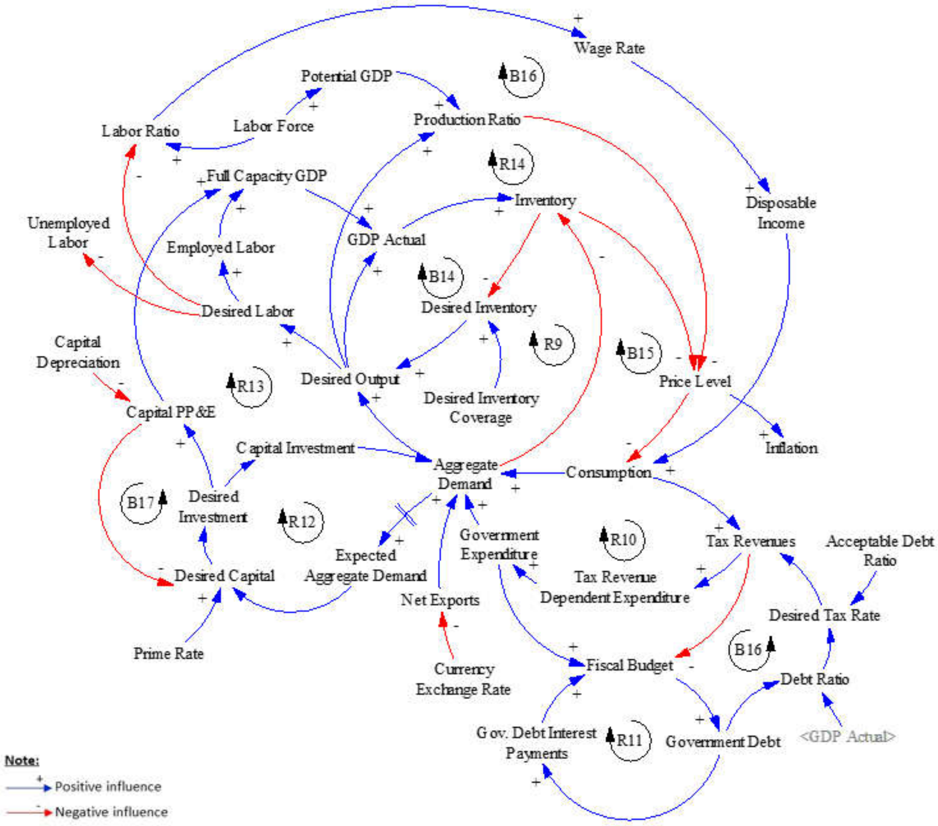

Figure 4. The macroeconomic sub-model showing aggregate demand as a key driver to the economy. Blue arrows are paired with (+) sign to indicate positive influence on the variable, red arrows paired with (-) indicate negative influence.

The dynamics of supply and demand for goods in the macro economy are shown as the B14 and B15 loops, illustrating that production balances gaps in inventory and demands are fulfilled with sufficient inventory. The link between the economy and energy is the price of goods. When energy prices increase, the price of goods increase, decreasing aggregate demand, which leads to lower production and then GDP, creating a spiralling decline based on the reinforcing loops. The effect will be multiplied if the energy is produced from common resources for other goods, such as biofuels, which can create a spillover to food prices [94]. Conversely, an increase in aggregate demand drives energy consumption, creating fluctuations in energy prices governed by the dynamics shown in Figure 2 and affecting the power plant dynamics shown in Figure 1.

4.2. Selection of Relevant Indicators

From the power plant investment dynamics, we present environmental, social, and political risks as factors in the relative value of a power plant technology, aside from the economic risks represented by the energy price. We show that energy price is related to environmental capacity and stress the importance of energy within the whole economy, connecting to the labour market and fiscal budget. Hence, renewable energy adoption for electricity generation needs to be evaluated from a broader perspective, involving economic, environmental, and social dimensions.

In this section, we discuss which indicators would fit each of the dimensions. This research proposed the use of outcome-based indicators in line with the policy analysis framework method described in earlier sections.

4.2.1. Economic Dimension Indicators

As pointed out in the literature review, the Indonesian economy is dependent on fossil fuels. For example, in 2010, 83% of the energy supply in the transportation sector came from fossil fuels. In the last decade, this share shrank to 56%, owing to a gradual substitution of biofuel from Crude Palm Oil (CPO) [14]. However, this substitution affects supply and demand in the agriculture sector, leading to cooking oil price hikes, causing 3% food inflation and burdening the government budget with 250 million USD spent on subsidies [95,96]. This phenomenon shows the cross-sectoral impact of the energy transition on the economy. Thus, structural changes in the national energy supply and demand would influence the economy. This research proposes to use GDP growth as the overall economic indicator and the state of the government budget to capture the burden of energy policy on the government. The macroeconomic sub-model in Figure 4 includes both indicators as part of its dynamics.

Considering the challenge of fossil fuel phase-out while the Indonesian economy is dependent on it, this study proposes to include economic volatility as an indicator to evaluate the energy transition pathway. Economic volatility is often measured as a standard deviation of an economic variable from its reference value [97]. Different economic variables have been used in various studies, such as GDP growth [52,98], GDP per capita growth [99–101], export revenues [100], terms of trade [61], and price of primary goods or inflation [99]. We propose to use the latter as another economic indicator as it can directly capture the effect of energy price on aggregate demand, as shown in Figure 4.

4.2.2. Environment Dimension Indicators

Considering Indonesia will likely continue to use coal in its energy mix in the long term [13], other greenhouse gases (GHG) CH_4 and N_2O are relevant together with CO_2. Coal has the highest emissions factor of CH_4 and N_2O among fossil fuels; burning 1 ton of coal emits 156 to 276 g of CH_4 and 23 to 40 g of N_2O [62]. On the other hand, energy storage becomes a necessity with the integration of VRE into the grid. One of the increasingly common and convenient forms of energy storage is in batteries; however, the production of battery materials poses a negative climate impact with more than 10 kg CO_2eq per kWh battery capacity [102], and other risks around material supplies and non-climate environmental impacts are also possible concerns [103].

This study also considers land use to evaluate the energy transition pathway for electricity generation. Some of Indonesia's most prominent renewable resources, such as solar power, hydropower, and bioenergy which, respective to their required land area per megawatt output, are typically among the more land intensive. One study showed that solar power requires 17.6 ha of land for electricity production, transmission, and waste disposal per megawatt capacity, while large hydropower requires much more, with 127.6 ha per megawatt. These land requirements far surpass the land requirements of fossil fuel-based power generation such as coal which only requires 4.93 ha per megawatt [6]. When the latest capacity factor is considered, solar power would require 0.012 ha and hydropower requires 0.024 ha of land to produce 1 MWh of electricity, but coal power would only need less than 0.001 ha of land [7].

Resource depletion is another crucial factor to be considered. Lithium is among the most used materials for battery energy storage. A study on battery materials supply risk puts lithium as the one with the highest rank considering the future technology demand and a variety of factors that could influence supply security [65]. Another study on lithium availability for the transportation sector shows that, even when recycling is considered, there will not be enough lithium to supply even this one sector on a global scale [104]. Another reason to account for resource depletion is the premium depletion policy of fossil fuels that will be enforced by the government, in which fractions are to be allocated to the renewable energy development budget [13].

4.2.3. Social Dimension Indicators

One of the famous arguments for the transition towards renewable energy is the creation of green jobs. Multiple studies have supported the finding that the total jobs created by the energy transition can offset the jobs lost in the fossil fuel industry [17,105–107]. However, it is likely that those who lose their jobs will not be the ones who get the newly created green jobs. For example, a closed coal mining location might not be suitable as a renewable energy site, thus leading to unemployment in that area. The transitioning process needs to be considered, including retraining and relocation [17,108–110]. Hence, aside from the number of jobs created, this study also proposes to observe the unemployment rate over time. The match between job supply and demand during the transition period can be captured using both indicators.

Regarding the higher electricity cost from renewables, this study proposes to use household electricity burden as one of the social indicators, measured as the ratio of electricity expenditure to total household expenditure. This indicator is crucial for households in rural areas since almost 13% of their expenditure is on electricity which is equal to expenditure on staple food [111,112].

4.3. Stakeholders Identification

There are multiple stakeholders involved in the adoption of renewable energy for electricity generation. We group the stakeholders into four groups: energy users, energy producers, operators, and legislators [73]. The identified stakeholders are presented in Figure 5.

First are the energy users. Energy demand is commonly grouped into four sectors: residential, transportation, industrial, and commercial. The transportation and industrial sectors make up two of the largest energy consumers. Although both sectors currently consume fossil fuels, in the coming decade electricity consumption is expected to dominate. In the transportation sector, if all road transport was electrified by 2050, the sector has been estimated to require 107.25 MTOE of energy or equivalent to 1247.3 TWh of electricity [4,14]. The use of electricity in the Industrial sector has also been growing substantially, by 61% in the last decade, compared to coal which declined 22% owing to the rapid growth of the food and beverage industry, chemical industry, and electronics industry which primarily consume electricity for their production [14,113]. Similarly, electricity demands from the residential sector, electricity's largest consumer, is expected to grow further with plans to replace gas cookers with electric cookers [4].

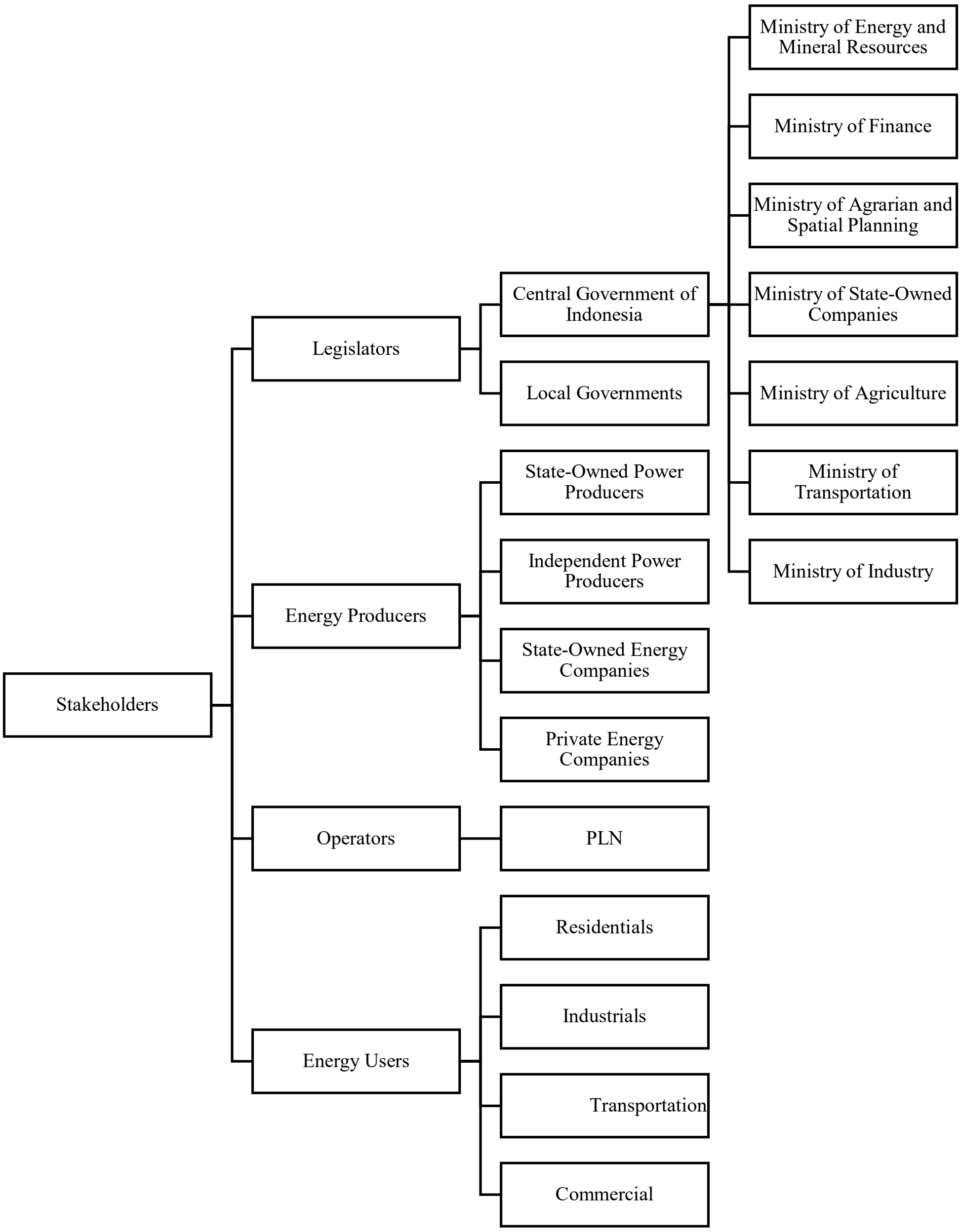

Figure 5. Stakeholders in the renewable energy adoption for electricity generation in Indonesia.

The state-owned electricity company, Perusahaan Listrik Negara (PLN), holds a unique role since it is both a power producer and an electricity distributor. Thus, it has dual objectives and interests in this problem. Since 2002, the electricity market has become open to Independent Power Producers (IPPs). However, their participation has been low because the market is only quasi-competitive and political constraints cause IPPs to be less competitive [37,114]. Both state-owned power producers and IPPs can purchase fuel from state-owned or private energy companies to run their power generation. These energy companies hold an important role in power generation, as is evident from recent domestic coal supply shortages that led to blackouts in Indonesia [115].

Policies developed by legislators are affecting and affected by other stakeholders. The central government of Indonesia, through its ministries, has different roles in supporting the renewable energy goal, as stated in the National Energy Masterplan [13]. However, in fulfilling their roles, some programs clash, or at least depend on other ministerial programs. For example, carbon emissions from the biomass CFPP co-firing policy are not accounted for as emissions from power generation but are allocated to the forestry sector instead [116]. There is also a dependency between actors when incentivising renewable energy projects such as FiT. The Ministry of Finance would need to carefully reallocate fiscal budgets to avoid other economic problems [13]. These short examples show that the adoption of renewable energy is not limited to just one actor in the system. The central government needs to involve local governments, particularly for policies involving local interventions, such as aligning land use for energy with the Regional Spatial Plan [13].

4.4. System Boundary

The system boundary for the modelling exercise identifies the scope of the problem that is being discussed, which variables are endogenous, exogenous, or completely excluded. This is necessary because different contexts may lead to different perceptions of the problem. As previously mentioned, this study aimed to capture the qualitative phenomenon of the renewable energy adoption dynamics for electricity generation in Indonesia. We observe this problem from the perspective of the Government of Indonesia, whose goal is to reduce GHG emissions by increasing renewable energy use for electricity generation while maintaining socioeconomic stability and environmental protection.

In modelling the economy, we do not consider the role of banks and central banks, as initially designed by Yamaguchi [27]. However, we consider the actions taken by both actors, such as setting interest rates, exchange rates, and other monetary policies, as exogenous factors to the system. Labour and capital elasticities to GDP are also considered to be exogenous, as they are essential to the economic output, but modelling them as endogenous does not directly relate to the energy transition. Population dynamics as the primary driver of aggregate demand is also modelled as endogenous in that we do not consider the effect of the energy transition on the population but simply as a driving factor. Other behavioural factors affecting aggregate demand, such as the propensity to consume, are also considered to be exogenous. Finally, although the macroeconomic sub-model includes capital investments, we did not consider their effect on the technology innovation rate. We acknowledge its importance in energy transition as it may lead to a reduced renewable energy investment cost. However, as it involves multiple factors outside the discussed problem, we include the learning rate effect on technology cost as an exogenous factor, as suggested by Nykvist and Nillson [117].

We did not consider the effects of pollution and waste on public health and the economy, as suggested by Shmelev [30]. We argue that impacts on health can indirectly be gauged from the level of emissions that cause adverse health effects, such as SO_x, NO_x, and PM2.5. Furthermore, to comprehensively discuss the impacts of public health, the public health provision should be considered in itself—something out of context when discussing energy transition. This study also does not consider the dynamics of income inequality, including multiple social factors outside the system boundary set in this study. Furthermore, the wage rate, one of the factors of income inequality, can be captured from employment based on the macroeconomic sub-model.

4.5. System Diagram

We proposed a system diagram that summarises the dynamics within and between the sub-models, indicators used, involved stakeholders, and policies supporting renewable energy adoption for electricity generation in Indonesia. Figure 6 depicts the system diagram of this study.

We construct a dynamic hypothesis from the relationship between sub-models which formulates the underlying structural limitations to the electricity sector energy transition. First, from Figure 1, we observe that the demand for additional capacity, either from an increase in electricity demand or a decrease in supply due to decommissioning, triggers investments in new power plants. Once there is a demand for more capacity, power producers have the option to either invest in non-renewable energy or renewable energy. Power producers will invest in the technology which provides them with a higher value subject to economic, environmental, social, and political constraints. Next, the economic constraints and the environmental constraints are represented by the energy substitution dynamics and environmental capacity limitations in Figures 2 and 3, respectively. Based on the dynamics between the two models, it is understood that energy prices could continue to increase due to resource depletion and increased demand. When the relative value of one energy is less than its substitute, we will see a shift towards the substitute, which will continue to be the better alternative if the situation persists.

In the meantime, the price of energy affects the price of electricity which is inversely related to electricity demand. This relationship was confirmed when the subsidy reforms in 2015 led to higher electricity prices, which consequently reduced electricity consumption by around 7% [41]. The effect of an increase in the electricity price creates a chaining effect on the economy, as described in the macroeconomic sub-model in Figure 4. Without changes in household income, an increase in the price of electricity could lead to a decreased aggregate demand in the economy and, in turn, electricity demand, narrowing the opportunity for renewable energy power plants to gain investment. This effect could be further exacerbated by an increase in the primary energy price. Thus, our dynamic hypothesis is as follows: the price of energy could increase over time in the absence of substitution, due to constraints on resource availability and environment carrying capacity, becoming a limiting factor to the renewable energy transition in the electricity sector, both directly affecting electricity prices and indirectly affecting aggregate demand in the economy. The dynamic hypothesis can be assessed using a system dynamics simulation model.

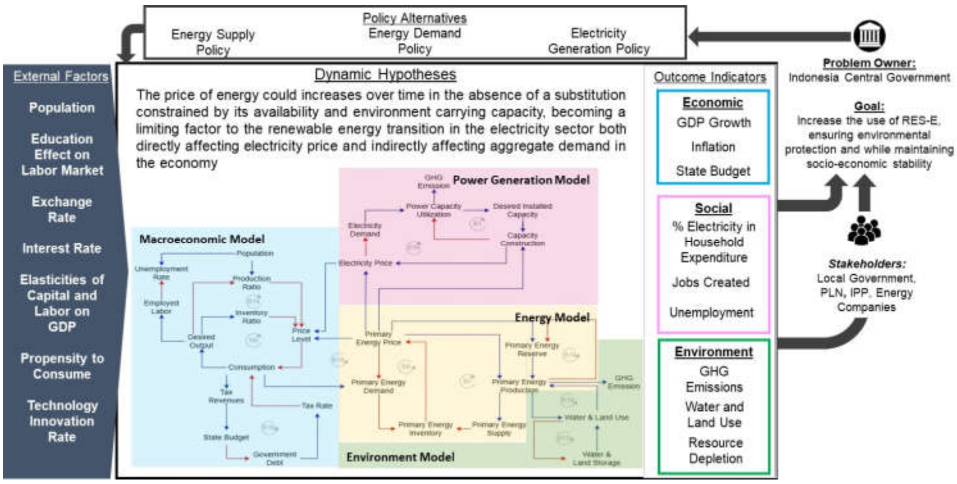

Figure 6. System Diagram of Energy Transition for Electricity Generation in Indonesia.

5. Discussion

The Indonesian Government has designed several policies to increase renewable energy adoption in electricity generation. This study discusses the economic, social, and environmental effects of market-based and regulatory-based policy examples using the developed conceptual model. Two policies are taken as initial examples: the market-based policy to be discussed is FiT, whereas the discussed regulatory policy is RPO. The FiT is one of the most common renewable energy policies implemented in developed countries such as Germany, Japan, and Denmark [118,119], as well as in developing countries such as China, India, and Thailand [50,120,121]. Indonesia has been implementing a FiT since 2011. Initially targeting geothermal power plant adoption, the FiT policy has now expanded to other renewables [18,19]. While the FiT policy aims to increase the renewable energy supply, an RPO obligates institutions to purchase electricity from renewable sources [13,50]. Hence, these two policies represent the supply side and demand side of renewable energy. The two policies have a more direct government intervention on renewable energy supply and demand as opposed to other policies presented in Table 1, and they are, therefore, selected for further discussion in this study.

Renewable energy investment is perceived as risky due to its higher cost [40]. The FiT policy aims to reduce this risk by eliminating the gap between the actual generation cost and the electricity market price [16]. In our conceptual model, this policy would increase the projected annual cash flow, which pushes the probability of investing in RES-E when there is a demand for additional installed capacity. The RES-E investment will balance out the demand, rendering additional NRES-E capacity unnecessary. However, like other incentives, FiT requires a substantial amount of the government's fiscal budget. When the budget deficit increases, the government can take on new debts, which in turn increases the budget deficit and creates a reinforcing loop shown as R11 Figure 4. Governments use the ratio of debt to GDP, as opposed to its amount, to gauge whether it is acceptable or not. To reduce the debt ratio, the government can increase the tax rate or reduce its spending. Alesina et al. found that increasing the tax rate was more harmful to economic growth than cutting expenditures [122]. If the government chooses to cut spending, this could limit the amount of FiT that can be deployed. On the other hand, the increasing tax could lead to a slowing economic activity [123], which would lead to reduced electricity demand, reducing the prospects of adding new RES-E capacity, as shown as B4 in Figure 1. In either case, the FiT would be limited to the government's fiscal budget; hence it should be paired with other policies that could alleviate the fiscal budget deficit. The problem with the FiT policy and the fiscal budget was hinted by Setiawan et al. who noted that despite the push for renewable energy, the Indonesian government still promotes the use of coal [19] which is a vital commodity for the nation's economy.

The RPO obligates institutions to purchase a minimum amount of their electricity from renewable energy sources. In Indonesia, this policy is imposed on the PLN as the national electricity distributor, government institutions, and even some residential consumers [13]. As more renewable energy penetrates on-grid electricity through purchases by the PLN, electricity prices would increase [9,10]. This would directly lead to an increased burden on households and industries. Furthermore, if industries cannot mitigate or absorb the increase, they would pass this through to the price of goods, which becomes an additional burden on households. Consumers could then (potentially) reduce their electricity consumption, creating balancing loops B3 and B4, as shown in Figure 1. Consumers can also find substitutes for electricity, as explained by the energy substitution dynamics in Figure 2, which makes electrification policies such as shifting to electric cookers or EV adoption ineffective. The regulatory-based policy would function as a new constraint to affected stakeholders, which would lead them to re-optimise their activities. However, as Scheinkman stated, optimising agents in a dynamic system can create chaotic behaviour [124]. Moreover, RPO also requires incentives to be enforced which, based on the issue found in the FiT policy, would be limited to the fiscal budget.

The fiscal budget limitation from both policies would be expected to lead to a slow renewable adoption and hinder the government's efforts to reduce GHG emissions. In line with this, the government has planned to develop an Energy Security Fund to support renewable energy policies sourced from, among others, the depletion premium and consumption of fossil fuels [13]. The use of a fossil fuel depletion premium, which follows the Hartwick Rule for weak sustainability [31,36], could be helpful for enhancing the outcomes of the system because its value would increase over time based on R3 in Figure 2. However, imposing premiums on fuel consumption would increase consumer costs, which could reduce the aggregate demand and slow down the economy based on R14 in Figure 4. Based on the energy substitution dynamics in Figure 2, fuel consumption premiums can be safely enforced when there is a substitution whose relative value is close to fuel is available and accessible. More importantly, the funds must be allocated correctly to the right policies. As previously mentioned, a poorly designed policy could lead to counterproductive economic, social, and even environmental effects.

6. Conclusions

We present this work as an explorative study to understand the economic, social, and environmental effects of renewable energy policies on electricity generation. We did not use the common energy modelling tools to investigate this issue. We argue that MARKAL, TIMES, or NEMS tools are more appropriate answer "what should happen" questions. While LEAP addresses "what would happen", it cannot help to answer the impact of energy transition policies on the economy. Thus, we used a combination of the system dynamics approach and policy analysis framework. We also note the urgency of integrating the bottom-up and top-down approaches that the model accommodates. Our work enhances previous studies that attempted to understand the electricity sector's energy transition from a system perspective by exploring the structural feedback between it and the economic, energy, and environmental systems. Our expansive view enables a more unified approach in assessing different energy policies using more macro indicators which further emphasises the novelty of our work.

Using the conceptual model, this study qualitatively assessed the effects of renewable energy policies. We evaluated both market-based and regulatory-based policies, represented by FiT and RPO. FiT is a commonly used policy globally to increase the supply of renewable energy, due to its simplicity [125]. On the other hand, the RPO obligates institutions to purchase a certain amount of renewable electricity. Based on our exploration, we found that both policies are limited by the government's fiscal budget. This limitation could be passed on to the state-owned PLN that is required to increase RES-E supply or other state-owned institutions and government entities obligated to purchase RES-E. Our finding is in line with that of [38], who found the PLN resistant to increasing their renewable energy uptake due to economic constraints as well as the ineffectiveness of RPO. The government must find more financing sources to fund the transition towards renewable energy sustainably. We also note the prospects of using fossil fuel depletion premiums to create fiscal space for renewable energy. This instrument could support a smooth energy transition for fossil fuel-dependent countries because it allows them to continue the extraction of fossil fuels while steadily financing renewable energy [126]. However, it should be noted that this fund must be carefully managed and coordinated.

Externally, the Indonesian government can obtain funds from bilateral or multilateral entities such as the Energy Transition Mechanism (ETM) of the Asian Development Bank (ADB). ETM specifically aims for an early replacement of CFPP with renewable energy in three different funding models: CFPP asset transfer, debt, and equity [127]. With the cash received from the CFPP acquisition, asset owners are expected to invest in renewables which is in line with the Hartwick Rule [31,127]. Alternatively, the government can pursue green financing through loans and bonds [128,129]. Funding through debt should be treated with caution, especially in developing countries, as it could lead to increased taxation and, in turn, reduce consumption and investment [130].

This research is a precursor to a complete system dynamics study. A quantitative expansion of the presented conceptual model could provide a better understanding of the problem discussed. We were able to assess two policies qualitatively. In future work, these two policies could be quantitatively assessed, together with the remaining policies mentioned in Table 1. The qualitative model can also be further expanded by making net exports endogenous, which could be relevant for energy-importing countries. For simplicity, we only consider the substitution between non-renewable and renewable energy. In practice, substitution also happens within the respective energy type; for example, the substitution from coal to gas. This model can be further enriched by adding these dynamics.

Author Contributions: Conceptualization, T.N.Z. and B.C.M.; Methodology, T.N.Z.; Software, T.N.Z.; Formal Analysis, T.N.Z.; Data Curation, T.N.Z.; Writing—Original Draft Preparation,

T.N.Z.; Writing—Review & Editing, T.N.Z. and B.C.M.; Visualization, T.N.Z.; Supervision, B.C.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. IEA. Total CO_2 Emissions, Indonesia 1990–2018. 2018. Available online: https://www.iea.org/data-and-statistics?country=INDONESIA&fuel=Energy transition indicators&indicator=CO2BySource (accessed on 4 May 2021).
2. IEA. IEA Atlas of Energy. 2020. Available online: http://energyatlas.iea.org/#!/tellmap/1378539487 (accessed on: 4 May 2021).
3. IEA. CO_2 Emissions by Sector, Indonesia 1990–2018. 2018. Available online: https://www.iea.org/data-and-statistics?country=INDONESIA&fuel=CO2 emissions&indicator=CO2BySector (accessed on 4 May 2021).
4. National Energy Council. *Indonesia Energy Outlook 2019*; National Energy Council: Jakarta, India, 2019.
5. Government of Indonesia. *Enhanced Nationally Determined Contribution (NDC) Republic of Indonesia*; Government of Indonesia: Jakarta, Indonesia, 2022.
6. Landon, S.; Barrett, A.; Cowan, C.; Colton, K.; Johnson, D. The Footprint Of Energy: Land Use of U.S. Electricity Production. 2017. Available online: https://www.strata.org/pdf/2017/footprints-full.pdf (accessed on 2 February 2021).
7. IRENA. *Renewable Power Generation Costs in 2021*; IRENA: Abu Dhabi, United Arab Emirates, 2022.
8. Batalla-Bejerano, J.; Trujillo-Baute, E. Impacts of intermittent renewable generation on electricity system costs. *Energy Policy* **2016**, *94*, 411–420. https://doi.org/10.1016/j.enpol.2015.10.024.
9. Ueckerdt, F.; Hirth, L.; Luderer, G.; Edenhofer, O. System LCOE: What are the costs of variable renewables? *Energy* **2013**, *63*, 61–75. https://doi.org/10.1016/j.energy.2013.10.072.
10. Putranto, L.M.; Widodo, T.; Indrawan, H.; Ali Imron, M.; Rosyadi, S.A. Grid parity analysis: The present state of PV rooftop in Indonesia. *Renew. Energy Focus* **2022**, *40*, 23–38. https://doi.org/10.1016/j.ref.2021.11.002.
11. Braithwaite, D.; Gerasimchuk, I. *Beyond Fossil Fuels: Indonesia's Fiscal Transition*; International Institute for Sustainable Development: Winnipeg, MB, Canada, 2019;.
12. Bazilian, M.; Rogner, H.; Howells, M.; Hermann, S.; Arent, D.; Gielen, D.; Steduto, P.; Mueller, A.; Komor, P.; Tol, R.S.J.; et al. Considering the energy, water and food nexus: Towards an integrated modelling approach. *Energy Policy* **2011**, *39*, 7896–7906. https://doi.org/10.1016/j.enpol.2011.09.039.
13. Government of Indonesia. *Rencana Umum Energi Nasional*; Government of Indonesia: Jakarta, Indonesia, 2017.
14. Ministry of Energy and Mineral Resources. *Handbook Of Energy & Economic Statistics Of Indonesia 2021*; Ministry of Energy and Mineral Resources: Jakarta, Indonesia, 2021.
15. Klein, A.; Merkel, E.; Pfluger, B.; Held, A.; Ragwitz, M.; Resch, G. *Evaluation of Different Feed-In Tariff Design Options—Best Practice Paper for the International Feed-In Cooperation*; Fraunhofer IEE: Kassel, Germany, 2010.
16. Lesser, J.A.; Su, X. Design of an economically efficient feed-in tariff structure for renewable energy development. *Energy Policy* **2008**, *36*, 981–990. https://doi.org/10.1016/j.enpol.2007.11.007.
17. Zhang, X.; Cui, X.; Li, B.; Hidalgo-Gonzalez, P.; Kammen, D.M.; Zou, J.; Wang, K. Immediate actions on coal phaseout enable a just low-carbon transition in China's power sector. *Appl. Energy* **2022**, *308*, 118401. https://doi.org/10.1016/j.apenergy.2021.118401.
18. Hidayatno, A.; Setiawan, A.D.; Wikananda Supartha, I.M.; Moeis, A.O.; Rahman, I.; Widiono, E. Investigating policies on improving household rooftop photovoltaics adoption in Indonesia. *Renew. Energy* **2020**, *156*, 731–742. https://doi.org/10.1016/j.renene.2020.04.106.
19. Setiawan, A.D.; Dewi, M.P.; Jafino, B.A.; Hidayatno, A. Evaluating feed-in tariff policies on enhancing geothermal development in Indonesia. *Energy Policy* **2022**, *168*, 113164. https://doi.org/10.1016/j.enpol.2022.113164.
20. Crespo del Granado, P.; van Nieuwkoop, R.H.; Kardakos, E.G.; Schaffner, C. Modelling the energy transition: A nexus of energy system and economic models. *Energy Strateg. Rev.* **2018**, *20*, 229–235. https://doi.org/10.1016/j.esr.2018.03.004.
21. Sunitiyoso, Y.; Mahardi, J.P.; Anggoro, Y.; Wicaksono, A. New and renewable energy resources in the Indonesian electricity sector: A systems thinking approach. *Int. J. Energy Sect. Manag.* **2020**, *14*, 1381–1403. https://doi.org/10.1108/IJESM-11-2019-0019.
22. Morçöl, G. *A Complexity Theory for Public Policy*, 1st ed.; Routledge: New York, NY, USA, 2012; ISBN 9781136283475.
23. Dyner, I.; Larsen, E.R. From planning to strategy in the electricity industry. *Energy Policy* **2001**, *29*, 1145–1154. https://doi.org/10.1016/S0301-4215(01)00040-4.
24. Loulou, R.; Remne, U.; Kanudia, A.; Lehtila, A.; Goldstein, G. Documentation for the TIMES Model—PART I. IEA. 2016. Available online: https://iea-etsap.org/docs/Documentation_for_the_TIMES_Model-Part-I_July-2016.pdf (accessed on 8 August 2022).
25. Gabriel, S.A.; Kydes, A.S.; Whitman, P. The National Energy Modeling System: A Large-Scale Energy-Economic Equilibrium Model. *Oper. Res.* **2001**, *49*, 14–25. https://doi.org/10.1287/opre.49.1.14.11195.
26. Stockholm Environment Institute. *User Guide for LEAP, no. May*; Stockholm Environment Institute: Stockholm, Sweden, 2005.
27. Yamaguchi, Y. *Developing an Asd Macroeconomic Model of the Stock Approach-with Emphasis on Bank Lending and Interest Rates*; University of Bergen: Bergen, Norway, 2017.

28. Sterman, J.D. *Business Dynamics: Systems Thinking and Modeling for a Complex World*; McGraw-Hill Higher Education: New York, NY, USA, 2000; ISBN 0-07-23113.
29. Pruyt, E. Dealing with Uncertainties? Combining System Dynamics with Multiple Criteria Decision Analysis or with Exploratory Modelling. *Policy Anal.* **2007**, 1–22. Available online: http://www.systemdynamics.org/conferences/2007/proceed/papers/PRUYT386.pdf (accessed on 8 August 2022).
30. Shmelev, S.E. *Ecological Economics: Sustainability in Practice*; Springer: Berlin/Heidelberg, Germany, 2012; ISBN 9789400719729.
31. Zweifel, P.; Praktiknjo, A.; Erdmann, G. *Energy Economics: Theory and Application*; Business A; Springer Nature: Berlin/Heidelberg, Germany, 2017; ISBN 978-3-662-53022-1.
32. Jacobsen, H.K. Integrating the bottom-up and top-down approach to energy-economic modelling: The case of Denmark. *Energy Econ.* **1998**, *20*, 443–461. https://doi.org/10.1016/S0140-9883(98)00002-4.
33. Koopmans, C.C.; Te Velde, D.W. Bridging the energy efficiency gap: Using bottom-up information in a top-down energy demand model. *Energy Econ.* **2001**, *23*, 57–75. https://doi.org/10.1016/S0140-9883(00)00054-2.
34. Henckens, M.L.C.M.; van Ierland, E.C.; Driessen, P.P.J.; Worrell, E. Mineral resources: Geological scarcity, market price trends, and future generations. *Resour. Policy* **2016**, *49*, 102–111. https://doi.org/10.1016/j.resourpol.2016.04.012.
35. Solow, R.M. On the Intergenerational Allocation of Natural Resources. *Scand. J. Econ.* **1986**, *88*, 141–149. Available online: https://www.jstor.org/stable/3440280?seq=1#metadata_info_tab_contents (accessed on 9 August 2022).
36. Solow, R. An almost practical step toward sustainability. *Resour. Policy* **1993**, *19*, 162–172. https://doi.org/10.4324/9781936331642.
37. Setyawan, D. Assessing the current 20ndonesia's electricity market arrangements and the opportunities to reform. *Int. J. Renew. Energy Dev.* **2014**, *3*, 55–64. https://doi.org/10.14710/ijred.3.1.55-64.
38. Burke, P.J.; Widnyana, J.; Anjum, Z.; Aisbett, E.; Resosudarmo, B.; Baldwin, K.G.H. Overcoming barriers to solar and wind energy adoption in two Asian giants: India and Indonesia. *Energy Policy* **2019**, *132*, 1216–1228. https://doi.org/10.1016/j.enpol.2019.05.055.
39. Ministry of Energy and Mineral Resources. *2020 Electricity Statistics*; Ministry of Energy and Mineral Resources: Jakarta, Indonesia, 2021.
40. Parra, P.; Okubo, Y.; Roming, N.; Sferra, F.; Fuentes, U.; Schaeffer, M.; Hare, B. Science Based Coal Phase-Out Timeline for Japan Implications for Policymakers and Investors, 2018. Available online: https://climateanalytics.org/media/coalphaseout-2018-en-report_1.pdf (accessed on 17 May 2021).
41. Burke, P.J.; Kurniawati, S. Electricity subsidy reform in Indonesia: Demand-side effects on electricity use. *Energy Policy* **2018**, *116*, 410–421. https://doi.org/10.1016/j.enpol.2018.02.018.
42. Myers, N.; Kent, J. *Perverse Subsidies: How Tax Dollars Can Undercut the Environment and the Economy*; Island Press: Washington, DC, USA, 2001; ISBN 1559638354.
43. Attwood, C.; Bridle, R.; Gass, P.; Halimanjaya, A.S.; Laan, T.; Lontoh, L.; Sanchez, L.; Toft, L. *Financial Supports for Coal and Renewables in Indonesia*; International Institute for Sustainable Development: Geneva, Switzerland, 2017.
44. Komives, K.; Foster, V.; Halpern, J.; Wodon, Q. *Water, Electricity, and the Poor*; The International Bank for Reconstruction and Development: Washington, DC, USA, 2005; ISBN 978-0-8213-6342-3.
45. DIW Berlin. *Phasing Out Coal in The German Energy Sector*; DIW: Berlin, Germany, 2019.
46. Wagner, L.; Molyneaux, L.; Foster, J. The magnitude of the impact of a shift from coal to gas under a Carbon Price. *Energy Policy* **2014**, *66*, 280–291. https://doi.org/10.1016/j.enpol.2013.11.003.
47. Davis, L.W. The Economic Cost of Global Fuel Subsidies. *Am. Econ. Rev.* **2014**, *104*, 581–585.
48. Ministry of Energy and Mineral Resources. *Ministry Regulation 255.K/30/MEM/20202 Coal Domestic Market Obligation*; Ministry of Energy and Mineral Resources: Jakarta, Indonesia, 2020.
49. Mendonça, M.; Jacobs, D.; Sovacool, B. *Powering The Green Economy: The Feed-In Tariff Handbook*; Taylor& Francis: Abingdon, UK, 2010; ISBN 978-1-84407-857-8.
50. Chatterjee, S.K. The Renewable Energy Policy Dilemma in India: Should Renewable Energy Certificate mechanism compete or merge with the Feed-in-Tariff Scheme? *M-RCBG Associate Working Paper Series*; Harvard Kennedy School, Mossavar-Rahmani Center for Business and Government: Cambridge, MA, USA, 2017; p. 61.
51. United Nations. *Resolution Adopted by the General Assembly on 25 September 2015*; United Nations: New York, NY, USA, 2015.
52. Lamperti, F.; Dosi, G.; Napoletano, M.; Roventini, A.; Sapio, A. Faraway, So Close: Coupled Climate and Economic Dynamics in an Agent-based Integrated Assessment Model. *Ecol. Econ.* **2018**, *150*, 315–339. https://doi.org/10.1016/j.ecolecon.2018.03.023.
53. IPCC. Emissions: Enery, Road Transport. In *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*; IPCC: Geneva, Switzerland, 1998; pp. 55–70.
54. IPCC. *Assessing Transformation Pathways*; IPCC: Geneva, Switzerland, 2015.
55. Kim, H.; McJeon, H.; Jung, D.; Lee, H.; Bergero, C.; Eom, J. Integrated Assessment Modeling of Korea's 2050 Carbon Neutrality Technology Pathways. *Energy Clim. Chang.* **2022**, *3*, 100075. https://doi.org/10.1016/j.egycc.2022.100075.
56. Cavallaro, F.; Ciraolo, L. A multicriteria approach to evaluate wind energy plants on an Italian island. *Energy Policy* **2005**, *33*, 235–244. https://doi.org/10.1016/S0301-4215(03)00228-3.
57. Rye, C.D.; Jackson, T. A review of EROEI-dynamics energy-transition models. *Energy Policy* **2018**, *122*, 260–272. https://doi.org/10.1016/j.enpol.2018.06.041.
58. Madlener, R.; Stagl, S. Sustainability-guided promotion of renewable electricity generation. *Ecol. Econ.* **2005**, *53*, 147–167. https://doi.org/10.1016/j.ecolecon.2004.12.016.

59. Government Budget. Public Finance. 2008. Available online: https://tradingeconomics.com/country-list/government-budget?continent=asia (accessed on 14 November 2019).
60. Diakoulaki, D.; Karangelis, F. Multi-criteria decision analysis and cost-benefit analysis of alternative scenarios for the power generation sector in Greece. *Renew. Sustain. Energy Rev.* **2007**, *11*, 716–727. https://doi.org/10.1016/j.rser.2005.06.007.
61. Serven, L. *Uncertainty, Instability, and Irreversible Investment: Theory, Evidence, and Lessons for Africa*; Policy Research Working Paper; The World Bank Group: Washington, DC, USA, 1997.
62. EPA. Emission Factors for Greenhouse Gas Inventories. 2014. Available online: https://www.epa.gov/sites/default/files/2015-07/documents/emission-factors_2014.pdf (accessed on 22 May 2022).
63. Dorini, G.; Kapelan, Z.; Azapagic, A. Managing uncertainty in multiple-criteria decision making related to sustainability assessment. *Clean Technol. Environ. Policy* **2011**, *13*, 133–139. https://doi.org/10.1007/s10098-010-0291-7.
64. Chatzimouratidis, A.I.; Pilavachi, P.A. Sensitivity analysis of the evaluation of power plants impact on the living standard using the analytic hierarchy process. *Energy Convers. Manag.* **2008**, *49*, 3599–3611. https://doi.org/10.1016/j.enconman.2008.07.009.
65. Helbig, C.; Bradshaw, A.M.; Wietschel, L.; Thorenz, A.; Tuma, A. Supply risks associated with lithium-ion battery materials. *J. Clean. Prod.* **2018**, *172*, 274–286. https://doi.org/10.1016/j.jclepro.2017.10.122.
66. Gunnarsdottir, I.; Davidsdottir, B.; Worrell, E.; Sigurgeirsdottir, S. Indicators for sustainable energy development: An Icelandic case study. *Energy Policy* **2022**, *164*, 112926. https://doi.org/10.1016/j.enpol.2022.112926.
67. Gamboa, G.; Munda, G. The problem of windfarm location: A social multi-criteria evaluation framework. *Energy Policy* **2007**, *35*, 1564–1583. https://doi.org/10.1016/j.enpol.2006.04.021.
68. Afgan, N.H.; Carvalho, M.G. Multi-criteria assessment of new and renewable energy power plants. *Energy* **2002**, *27*, 739–755. https://doi.org/10.1016/S0360-5442(02)00019-1.
69. Noble, B.F. A multi-criteria analysis of Canadian electricity supply futures. *Can. Geogr.* **2004**, *48*, 11–28. https://doi.org/10.1111/j.1085-9489.2004.002b16.x.
70. Del Pero, F.; Delogu, M.; Pierini, M. Life Cycle Assessment in the automotive sector: A comparative case study of Internal Combustion Engine (ICE) and electric car. *Procedia Struct. Integr.* **2018**, *12*, 521–537. https://doi.org/10.1016/j.prostr.2018.11.066.
71. Linh Nguyen, T.N.; Pimonsree, S.; Prueksakorn, K.; Bich Thao, P.T.; Vongruang, P. Public health and economic impact assessment of PM2.5 from open biomass burning over countries in mainland Southeast Asia during the smog episode. *Atmos. Pollut. Res.* **2022**, *13*, 101418. https://doi.org/10.1016/j.apr.2022.101418.
72. Walker, W.E. Policy Analysis: A Systematic Approach to Supporting Policymaking in The Public Sector. *J. Multi-Criteria Decis. Anal.* **2000**, *9*, 11–27. https://doi.org/10.1002/1099-1360(200001/05)9:1/3<11::AID-MCDA264>3.0.CO;2-3.
73. Hamadneh, J.; Duleba, S. Stakeholder viewpoints analysis of the autonomous vehicle industry by using multi-actors multi-criteria analysis. *Transp. Policy* **2022**, *126*, 65–84. https://doi.org/10.1016/j.tranpol.2022.07.005.
74. Madlener, R.; Stoverink, S. Power plant investments in the Turkish electricity sector: A real options approach taking into account market liberalization. *Appl. Energy* **2012**, *97*, 124–134. https://doi.org/10.1016/j.apenergy.2011.11.050.
75. Yuan, J.; Li, X.; Xu, C.; Zhao, C.; Liu, Y. Investment risk assessment of coal-fired power plants in countries along the Belt and Road initiative based on ANP-Entropy-TODIM method. *Energy* **2019**, *176*, 623–640. https://doi.org/10.1016/j.energy.2019.04.038.
76. Kim, D.H. *System Archetypes I: Diagnosing Systemic Issues and Designing High-Leverage Interventions*; Pegasus Communications: Cambridge, MA, USA, 1992; ISBN 1-883823-00-5.
77. Lambin, E.F. Global land availability: Malthus versus Ricardo. *Glob. Food Sec.* **2012**, *1*, 83–87. https://doi.org/10.1016/j.gfs.2012.11.002.
78. Naderi, M.M.; Mirchi, A.; Bavani, A.R.M.; Goharian, E.; Madani, K. System dynamics simulation of regional water supply and demand using a food-energy-water nexus approach: Application to Qazvin Plain, Iran. *J. Environ. Manage.* **2021**, *280*, 111843. https://doi.org/10.1016/j.jenvman.2020.111843.
79. Kraft, J.; Kraft, A. On the relationship between energy and GNP. *J. Energy Dev.* **1974**, *3*, 401–403. Available online: http://www.osti.gov/scitech/biblio/6713220 (accessed on 2 August 2022).
80. Lean, H.H.; Smyth, R. Multivariate Granger causality between electricity generation, exports, prices and GDP in Malaysia. *Energy* **2010**, *35*, 3640–3648. https://doi.org/10.1016/j.energy.2010.05.008.
81. Acheampong, A.O.; Boateng, E.; Amponsah, M. *Econometric Analysis of the Economic Growth-Energy Consumption Nexus in Emerging Economies: The Role of Globalization*; Elsevier: Amsterdam, The Netherlands, 2021; ISBN 9780128244418.
82. EL-Karimi, M.; El-houjjaji, H. Economic growth and renewable energy consumption nexus in G7 countries: Symmetric and asymmetric causality analysis in frequency domain. *J. Clean. Prod.* **2022**, *342*, 130618. https://doi.org/10.1016/j.jclepro.2022.130618.
83. Gyimah, J.; Yao, X.; Tachega, M.A.; Sam Hayford, I.; Opoku-Mensah, E. Renewable energy consumption and economic growth: New evidence from Ghana. *Energy* **2022**, *248*, 123559. https://doi.org/10.1016/j.energy.2022.123559.
84. Shahbaz, M.; Khan, S.; Tahir, M.I. The dynamic links between energy consumption, economic growth, financial development and trade in China: Fresh evidence from multivariate framework analysis. *Energy Econ.* **2013**, *40*, 8–21. https://doi.org/10.1016/j.eneco.2013.06.006.
85. Lee, C.C.; Chang, C.P. Energy consumption and economic growth in Asian economies: A more comprehensive analysis using panel data. *Resour. Energy Econ.* **2008**, *30*, 50–65. https://doi.org/10.1016/j.reseneeco.2007.03.003.
86. Narayan, P.K.; Smyth, R. Energy consumption and real GDP in G7 countries: New evidence from panel cointegration with structural breaks. *Energy Econ.* **2008**, *30*, 2331–2341. https://doi.org/10.1016/j.eneco.2007.10.006.

87. Sadorsky, P. Energy consumption, output and trade in South America. *Energy Econ.* **2012**, *34*, 476–488. https://doi.org/10.1016/j.eneco.2011.12.008.
88. Shahbaz, M.; Tang, C.F.; Shahbaz Shabbir, M. Electricity consumption and economic growth nexus in Portugal using cointegration and causality approaches. *Energy Policy* **2011**, *39*, 3529–3536. https://doi.org/10.1016/j.enpol.2011.03.052.
89. Rahman, M.M. The dynamic nexus of energy consumption, international trade and economic growth in BRICS and ASEAN countries: A panel causality test. *Energy* **2021**, *229*, 120679. https://doi.org/10.1016/j.energy.2021.120679.
90. Menegaki, A.N. Growth and renewable energy in Europe: A random effect model with evidence for neutrality hypothesis. *Energy Econ.* **2011**, *33*, 257–263. https://doi.org/10.1016/j.eneco.2010.10.004.
91. Tran, B.L.; Chen, C.C.; Tseng, W.C. Causality between energy consumption and economic growth in the presence of GDP threshold effect: Evidence from OECD countries. *Energy* **2022**, *251*, 123902. https://doi.org/10.1016/j.energy.2022.123902.
92. Yildirim, E.; Sukruoglu, D.; Aslan, A. Energy consumption and economic growth in the next 11 countries: The bootstrapped autoregressive metric causality approach. *Energy Econ.* **2014**, *44*, 14–21. https://doi.org/10.1016/j.eneco.2014.03.010.
93. Destek, M.A.; Aslan, A. Renewable and non-renewable energy consumption and economic growth in emerging economies: Evidence from bootstrap panel causality. *Renew. Energy* **2017**, *111*, 757–763. https://doi.org/10.1016/j.renene.2017.05.008.
94. Abdelradi, F.; Serra, T. Food-energy nexus in Europe: Price volatility approach. *Energy Econ.* **2015**, *48*, 157–167. https://doi.org/10.1016/j.eneco.2014.11.022.
95. Reuters. Indonesia will Subsidise 1.2 bln Litres of Cooking Oil to Cool Prices. 2022. Available online: https://www.reuters.com/markets/commodities/indonesia-will-subsidise-12-bln-litres-cooking-oil-cool-prices-2022-01-05/ (accessed on 28 June 2022).
96. BPS. Inflasi Indonesia Menurut Kelompok Pengeluaran, Jakarta. 2022. Available online: https://www.bps.go.id/statictable/2020/02/04/2083/inflasi-indonesia-menurut-kelompok-pengeluaran-2020-2022.html (accessed on 29 June 2022).
97. Cariolle, J. *Measuring Macroeconomic Volatility: Applications to Export Revenue Data, 1970–2005*; Innovative Indicators Series; Fondation pour les Etudes Et Recherches sur le Developpement International: Clermont-Ferrand, France, 2012.
98. Acemoglu, D.; Johnson, S.; Robinson, J.; Thaicharoen, Y. Institutional causes, macroeconomic symptoms: Volatility, crises and growth. *J. Monet. Econ.* **2003**, *50*, 49–123. https://doi.org/10.1016/S0304-3932(02)00208-8.
99. Raddatz, C. Are external shocks responsible for the instability of output in low-income countries? *J. Dev. Econ.* **2007**, *84*, 155–187. https://doi.org/10.1016/j.jdeveco.2006.11.001.
100. Van der Ploeg, F.; Poelhekke, S. Volatility and the natural resource curse. *Oxf. Econ. Pap.* **2009**, *61*, 727–760. Available online: http://www.jstor.org/stable/27784157 (accessed on 22 June 2022).
101. Di Giovanni, J.; Levchenko, A.A. The Risk Content of Exports: A Portfolio View of International Trade. In *NBER International Seminar on Macroeconomics*; The University of Chicago Press: Chicago, IL, USA, 2012; Volume 8, p. 16005.
102. Oliveira, L.; Messagie, M.; Rangaraju, S.; Sanfelix, J.; Hernandez Rivas, M.; Van Mierlo, J. Key issues of lithium-ion batteries—From resource depletion to environmental performance indicators. *J. Clean. Prod.* **2015**, *108*, 354–362. https://doi.org/10.1016/j.jclepro.2015.06.021.
103. Koyamparambath, A.; Santillán-Saldivar, J.; McLellan, B.; Sonnemann, G. Supply risk evolution of raw materials for batteries and fossil fuels for selected OECD countries (2000–2018). *Resour. Policy* **2022**, *75*, 102465. https://doi.org/10.1016/j.resourpol.2021.102465.
104. Greim, P.; Solomon, A.A.; Breyer, C. Assessment of lithium criticality in the global energy transition and addressing policy gaps in transportation. *Nat. Commun.* **2020**, *11*, 4570. https://doi.org/10.1038/s41467-020-18402-y.
105. Ram, M.; Aghahosseini, A.; Breyer, C. Job creation during the global energy transition towards 100% renewable power system by 2050. *Technol. Forecast. Soc. Chang.* **2020**, *151*, 119682. https://doi.org/10.1016/j.techfore.2019.06.008.
106. Garrett-Peltier, H. Green versus brown: Comparing the employment impacts of energy efficiency, renewable energy, and fossil fuels using an input-output model. *Econ. Model.* **2017**, *61*, 439–447. https://doi.org/10.1016/j.econmod.2016.11.012.
107. Ju, Y.; Sugiyama, M.; Kato, E.; Oshiro, K.; Wang, J. Job creation in response to Japan's energy transition towards deep mitigation: An extension of partial equilibrium integrated assessment models. *Appl. Energy* **2022**, *318*, 119178. https://doi.org/10.1016/j.apenergy.2022.119178.
108. Dicce, R.P.; Ewers, M.C. Solar labor market transitions in the United Arab Emirates. *Geoforum* **2021**, *124*, 54–64. https://doi.org/10.1016/j.geoforum.2021.05.013.
109. Pai, S.; Zerriffi, H.; Jewell, J.; Pathak, J. Solar has greater techno-economic resource suitability than wind for replacing coal mining jobs. *Environ. Res. Lett.* **2020**, *15*, 034065. https://doi.org/10.1088/1748-9326/ab6c6d.
110. Blankenship, B.; Aklin, M.; Urpelainen, J.; Nandan, V. Jobs for a just transition: Evidence on coal job preferences from India. *Energy Policy* **2022**, *165*, 112910. https://doi.org/10.1016/j.enpol.2022.112910.
111. Azmi, R. *Analysis of Indonesian Residential Electricity Consumption and Burden: Using Indonesia Family Survey*; Ministry of Finance: Jakarta, Indonesia, 2014.
112. BPS. Persentase Pengeluaran Rata-Rata per Kapita Sebulan Menurut Kelompok Barang. Jakarta. 2022. Available online: https://www.bps.go.id/statictable/2009/06/15/937/persentase-pengeluaran-rata-rata-per-kapita-sebulan-menurut-kelompok-barang-indonesia-1999-2002-2021.html (accessed on 1 July 2022).
113. BPS. Indonesia GDP 2010–2022. Jakarta. 2022. Available online: https://www.bps.go.id/indicator/11/65/2/-seri-2010-pdb-seri-2010.html (accessed on 12 July 2022).

114. Gultom, Y.M.L. When extractive political institutions affect public-private partnerships: Empirical evidence from Indonesia's independent power producers under two political regimes. *Energy Policy* **2021**, *149*, 112042. https://doi.org/10.1016/j.enpol.2020.112042.
115. Ministry of Energy and Mineral Resources Hindari Pemadaman 10 Juta Pelanggan PLN, Pemerintah Larang Sementara Ekspor Batubara. Ministry of Energy and Mineral Resources. 2022. Available online: https://www.esdm.go.id/id/media-center/arsip-berita/hindari-pemadaman-10-juta-pelanggan-pln-pemerintah-larang-sementara-ekspor-batubara (accessed on 5 August 2022).
116. PLN. *Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) PT PLN (Persero) 2021–2030*; PLN: Jakarta, Indonesia 2021.
117. Nykvist, B.; Nilsson, M. Rapidly falling costs of battery packs for electric vehicles. *Nat. Clim. Chang.* **2015**, *5*, 329–332. https://doi.org/10.1038/nclimate2564.
118. Dong, Y.; Shimada, K. Evolution from the renewable portfolio standards to feed-in tariff for the deployment of renewable energy in Japan. *Renew. Energy* **2017**, *107*, 590–596. https://doi.org/10.1016/j.renene.2017.02.016.
119. Pyrgou, A.; Kylili, A.; Fokaides, P.A. The future of the Feed-in Tariff (FiT) scheme in Europe: The case of photovoltaics. *Energy Policy* **2016**, *95*, 94–102. https://doi.org/10.1016/j.enpol.2016.04.048.
120. Zhang, M.M.; Zhou, D.Q.; Zhou, P.; Liu, G.Q. Optimal feed-in tariff for solar photovoltaic power generation in China: A real options analysis. *Energy Policy* **2016**, *97*, 181–192. https://doi.org/10.1016/j.enpol.2016.07.028.
121. Tantisattayakul, T.; Kanchanapiya, P. Financial measures for promoting residential rooftop photovoltaics under a feed-in tariff framework in Thailand. *Energy Policy* **2017**, *109*, 260–269. https://doi.org/10.1016/j.enpol.2017.06.061.
122. Alesina, A.; Favero, C.A.; Giavazi, F. Climbing Out of Debt. *Financ. Dev.* **2018**, *55*, 6–11.
123. Hines, J.R.; Keen, M.J. Certain effects of random taxes. *J. Public Econ.* **2021**, *203*, 104412. https://doi.org/10.1016/j.jpubeco.2021.104412.
124. Scheinkman, J.A. Nonlinearities in Economic Dynamics. *Econ. J.* **1990**, *100*, 33–48. Available online: https://www.jstor.org/stable/2234182 (accessed on: 8 August 2022).
125. Samper, M.; Coria, G.; Facchini, M. Grid parity analysis of distributed PV generation considering tariff policies in Argentina. *Energy Policy* **2021**, *157*, 112519. https://doi.org/10.1016/j.enpol.2021.112519.
126. Monasterolo, I.; Raberto, M. The impact of phasing out fossil fuel subsidies on the low-carbon transition. *Energy Policy* **2019**, *124*, 355–370. https://doi.org/10.1016/j.enpol.2018.08.051.
127. Asian Development Bank. *ETM Introduction*; Asian Development Bank: Mandaluyong, Philippines, 2022.
128. Du, G. Nexus between green finance, renewable energy, and carbon intensity in selected Asian countries. *J. Clean. Prod.* **2023**, *405*, 136822. https://doi.org/10.1016/j.jclepro.2023.136822.
129. Wang, S.; Sun, L.; Iqbal, S. Green financing role on renewable energy dependence and energy transition in E7 economies. *Renew. Energy* **2022**, *200*, 1561–1572. https://doi.org/10.1016/j.renene.2022.10.067.
130. Galli, C. Self-fulfilling debt crises, fiscal policy and investment. *J. Int. Econ.* **2021**, *131*, 103475. https://doi.org/10.1016/j.jinteco.2021.103475.