Trends and future studies on policies to improve renewable energy share

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Abstract. Every country needs to set up robust policies to reach its future targets in renewable energy development. The objective of this article is to explore the trends and research opportunities in this subject area. Systematic Literature Review (SLR) is applied together with bibliometric analysis to satisfy the objective. The database used in this study is Scopus considering its size and wide acceptance by major publishers. This study applies structural literature review and bibliometric analysis within one of its stages. A simple meta-analysis is cooperated prior to other analyses in this study. Various models are exercised to analyse important aspects in renewable energy policies, namely Input-output models, CGE models, Theory-based evaluation, multi-criteria analysis, and hybrid approach. Nonetheless, renewable energy is considered as a complex system. Therefore, advanced simulation techniques such as the discrete event simulation model, the agent-based model, system dynamics, and mixed methods are considered. Due to its characteristics, the mixed method is the most comprehensive approach. However, because mix methods have not been supported by proper tools or simulation software, agent-based model and system dynamics are proposed individually. Future research also should consider other than a market-based approach to develop robust policies to reach the ideal renewable energy share.

1. Introduction

World leaders are now more concerned about energy due to its growing demand and importance for economic development. It is projected that in 2035 energy demand will reach 778 Etta Joule and will continue to multiply in line with population growth and the world economic progress in 2050. Unfortunately, it is attained by environmentally unfriendly sources. In 2015, most energy needs were met by petroleum, followed by coal and natural gas [1–3].

The United Nations Framework Convention on Climate Change (UNFCCC) established the Conference for Parties (COP) as the highest forum in dealing with global environmental issues. The third meeting (COP-3) was held in 2005 and was attended by 37 countries. All members of the country agreed and committed to reduce the adverse effects of development by running the Greenhouse Gas Protocol (GHG). This protocol is known as the Kyoto Protocol which was later amended with the Doha Agreement. The Kyoto Protocol ended in 2012 and was replaced by a new agreement at the twenty-first COP meeting (COP-21) known as the Paris Agreement. In accordance, the United Nations submitted a Sustainable Development Goals (SDG) document. The document is a continuation of the Millennium Development Goals (MDG) which ended in 2015 [4].

The countries representative agreed to increase the proportion of energy sources that are more environmentally friendly. A series of policies are needed to endeavor countries’ success in developing energy supply from renewable sources [5]. The purpose of this article is to investigate the trends of policies to develop a renewable energy mix.
2. Method
A literature review was applied to meet the objective of the study. Although there are several methods available to carry out the literature review, this research uses Systematic Literature Review (SLR) together with Bibliometric Analysis (BA). SLR explicitly contains information needed to be processed into some relevant information. The SLR is used to produce a comprehensive summary of the literature that is closely related to the research question. SLR identifies gaps in the literature [6] and results in classifications based on key themes in the area studied [7]. The literature review results are presented in two parts of the analysis, which are metadata analysis and renewable energy policy insights.

The SLR method is divided into four parts namely, (1) Identification; (2) Screening; (3) Eligibility; and (4) Inclusion [8]. BA is introduced at the identification stage to determine the keywords that will be used. BA is able to describe features and trends in energy policy research by combining information visualization technology and traditional citation analysis [9]. The tool used in BA is the VOS viewer version 1.6.13. The software displays the network and cluster of documents in visual form. The type of analysis used is co-occurrence with keywords as the unit of analysis. That is, relationships are determined based on the number of documents in which the keywords used appear. While the counting method used is full counting. That is, each relationship has the same weight. In addition, at least 5 keywords are also determined to form one cluster. The following are the detailed stages of SLR:

1. Identification. This step uses the Scopus database because large publishers such as Elsevier, Emerald, Taylor and Francis, Springer, and Willey can be found in it. In accordance with the research area, the first keyword used is "energy mix". These keywords produce 3,263 documents. Furthermore, BA is conducted to sharpen the research area by exploring topics related to the energy mix. Figure 1 shows that the topic of energy mix forms a cluster of subject areas. The first cluster consists of the energy mix and energy policy. The second cluster is the energy mix and renewable energy. The third cluster is the energy mix and sustainable development. The fourth cluster is the energy mix and the environmental impact (environmental impact) and carbon dioxide (carbon dioxide). From BA, it can be determined that search keywords with better relevance are "energy mix", "renewable energy", "sustainable development", "energy share" and "energy policy". Next, search for these keywords in the Scopus database with the format: (TITLE ("energy mix" OR "energy share" OR "renewable energy" OR "sustainable development") AND TITLE ("policy" OR "policies")).

2. Screening. Base to the previous search involved 160 keywords and then proceed to the screening process. This step considered only the articles with keywords related to the policy. These: Energy Policy, Renewable Energy Policy, Environmental Policy, Public Policy, Policy-Making, Policy Implementation, Policy Implementation, Policy Approach, Policy Development, Policy Instruments, Policy Strategy, Policies, Social Policy, Climate Policy, Health Care Policy and Renewable Energy Policies. It found 836 documents as result.

3. Eligibility. This step is to maintain the eligibility of the subject restricted by the subject area related to the purpose of the study, namely "energy". The result of this step found 466 documents related to the meta-analysis in the next section in this paper.

4. Inclusion. This stage verified the articles that are relevant to the research questions. In general, quantitative research is divided into three types, namely: correlational, comparative, and experimental research [10]. Correlational research tries to find the relationship between one or more independent variables on the dependent variable [11]. Comparative research aims to explain how a phenomenon occurs in different cases, variables, and relations [12]. Experimental research is intended to analyse the effects of changes in several independent variables on the dependent variable [13].
3. Metadata analysis
The metadata analysis in this study is limited to simple descriptive statistical analysis. As seen in Figure 2, research on energy mix policies began in 1989 and the number of studies continues to increase. In the 1990s, the number of studies in this area increased and has exponentially grown. A total of 50 articles were published in 2019. It indicates that this area of research is becoming increasingly relevant to ongoing developments and dynamics.

From 117 journals and proceedings, Figure 3 shows 11 most article sources. Energy Policy is a journal included in Q1 and has published 133 articles or about 28% of the total journals and proceedings. This number is the largest in this research area. In 2019, Energy Policy has a cite score of 6.01 and an impact factor of 4.88. Renewable and Sustainable Energy Reviews ranks second in the number of publications. A total of 55 articles or about 11% of the total journals and proceedings in this area. Nevertheless, this journal is included in Q1 and has a cite score of 14.36 in 2019 and an impact factor of 10.55.

Figure 4 shows ten authors who have the most citations. The article entitled "The politics and policy of energy system transformation - Explaining the German diffusion of renewable energy technology" with authors Jacobsson S. and Lauber V. received 537 citations [14]. Jacobsson himself managed to publish 58 articles indexed by Scopus and had an h-index of 27. Lauber publishes 26 articles indexed by Scopus and has an h-index of 10. Both are authors who have high credibility in this area of research. The second article that has the most citations entitled "Prices versus quantities: Choosing policies for promoting the development of renewable energy" published in 2003 by Menanteau P., Finon D., and Lamy M.-L [15].

This area of research is carried out extensively in many countries. Figure 5 shows the 20 countries with the most studies. America is the country with the most amount of research related to energy policy. A total of 68 articles or about 11% discuss energy policy in America. The study covers energy sources, energy policies at the state and national levels. The second country is China with 55 articles or around 9%, followed by Britain with 41 articles or about 7%. Germany as a developed country in the development of renewable energy is discussed in 33 articles or about 5% of the total articles in this research area.
4. Insight on renewable energy

Renewable energy is energy produced through the utilization of environmentally friendly energy sources. These energy sources are continuously filled by nature, come from the sun directly or indirectly, and which come from natural movements in nature. Fossils and their derivatives are not included in renewable energy because they are non-renewable so that they will eventually be used up. Some of the renewable energy sources are biomass energy, geothermal energy, hydropower energy, marine energy, solar energy, and wind energy [16].

Biomass energy is an energy that is sourced from all biological materials, both living and dead. Biomass can come from trash, organic fertilizer, water disposal, plants, and animals and gas combustion. This energy source has advantages compared to other renewable energy sources. Processing biomass into energy does not require technology that is too sophisticated, so it has good economic value. Biomass is a versatile energy source because it can be converted into solid, liquid, and gas forms. In addition, the abundant availability of biomass makes energy reserves from this source important to meet energy needs in the future. One of the critical concerns about this energy source is its contribution to CO2 emissions [17].

Geothermal energy is the energy obtained from the conversion process from inside the earth. The utilization of geothermal energy has been done long before BC. The first time this energy was used for energy and industrial purposes was in 1904. Since then, this energy source has been developed by many countries such as America, the Philippines, Italy, Mexico, Indonesia, and others. Geothermal can be used in two ways. The first way is to use it directly for purposes such as baths, space heaters, greenhouses, and so forth. This method can use high temperature and low temperature. Characteristics of use in this way are the dependence on the location of geothermal sources. This limits the use of energy for broader interests. The second application is to use geothermal energy which comes from a depth of about 3 km. The use of geothermal in this way requires more intensive technological applications.
Despite this, due to its abundant availability, this energy can be relied upon for the development of renewable energy [18].

The wind is a promising source of energy to be converted into clean and environmentally friendly energy. Wind energy uses wind movement to drive turbines that produce electricity. This energy is formed from differences in pressure on the surface of the earth because of exposure to the sun. It is estimated that 1-3% of solar energy is converted to wind energy [19]. No complicated technology is needed to convert wind power into other energy such as electricity. Nevertheless, the main obstacle to developing wind power is its intermittent nature.

Energy sources originating from the sea are known by several terms such as marine energy, ocean energy, or blue energy. Marine energy can be taken from six sources, namely waves/waves, tidal range, tidal currents, ocean currents, differences in ocean temperature energy conversion, and salinity gradients. This energy potential is huge considering that around 70% of the earth consists of seas. The use of the sea as an energy source must be shared with other potentials as economic drivers in the fields of transportation, tourism, fisheries, and others. This requires integrated management through Marine Spatial Planning (MSP) and Environmental Impact Assessment (EIA) [16].

Energy sourced from solar energy (solar energy) is obtained through two ways, namely solar photovoltaic (PV) systems and concentrating solar power (CSP) systems. PV systems use PV cells, which are semiconductors that convert sunlight directly into electrical energy. PV cells are interconnected through PV modules with batteries, inverters, and other electrification applications forming PV systems. CSP works by concentrating sunlight to heat liquids, solid objects, or gases which are then used to generate electricity [16]. The potential of this energy source can be measured using global horizontal irradiation (GHI) and direct normal irradiation (DNI). GHI is the total solar radiation on the horizontal surface on Earth in units of kWh / m2. DNI is the power received from solar electromagnetic radiation in units of W / m2. There are several countries on earth that have great potential in utilizing this solar power.

5. Energy models for policy evaluation

Models are needed to represent real systems and involve certain simplifications in several aspects. Nevertheless, the credibility of the model needs to be supported by the level of model detail, flexibility, adaptive capacity for new research questions, and transparency. The models used in energy policy evaluation include: Input–output models, CGE models, Theory-based evaluation, multi-criteria analysis, and hybrid approach [20].

1. Input-output models. This model was first developed by Wassily Leontief in 1936. The input-output (I/O model) model is very popular in its use in the economic analysis by reviewing the relationships between production, consumption, labor, and export imports. The application of I/O models in the renewable energy sector is counted less by researchers especially to enlarge the mix of renewable energy. Kung, 2016 uses the Big Data approach to analyse Taiwanese government policy in the bioenergy sector. The data used are the results of I/O modeling of crop production, demand elasticity, international customs and excise, process technology, commodity prices, and energy prices [21].

2. Multi-criteria analysis. Each country has a set of policies in developing renewable energy. Therefore, it is important for the government to determine the policy priorities taken to achieve the renewable energy mix target. Some research is dedicated to sorting policy priorities using established methods such as multi-criteria decision making (MCDM). The popular method used is the Analytic Hierarchy Process (AHP) [22–24]. Several studies apply fuzzy MCDM to accommodate the ambiguity within the criteria of assessment [25–27]. Similar combinations are necessary to address certain problem properties. Some of the combined methods are MULTIMOORA and Topsis [28], and Stochastic Multi-Criteria Acceptability Analysis and Long-range Energy Alternatives Planning [29].

3. CGE model. One of the developing optimization models is the Computable General Equilibrium Model (CGE Model). This model was adopted from the general equilibrium theory in the market
where supply and demand meet. CGE model has been widely applied in the social field especially to explain phenomena in the economic system [30]. In its development, this model is also applied in other fields including the renewable energy policy area. At least 68 energy policy analysis tools have been developed based on this model. A total of 37 of them were evaluated to provide guidance on choosing the right tool according to the needs of the analysis. The field of application for this tool varies from energy analysis for one building to the national energy system. In addition, other considerations such as the energy sector, technology used, and time parameters were included [31,32]. Some tools that are widely used to analyse policies in increasing the renewable energy mix are EnergyPLAN [33], TIMES [34], OseMOSys [35], and Prometheus [36]. These tools intend to minimize the total cost of energy supply for short and also long term activities. This includes technology choices and policy instruments. However, these models cannot describe the behaviour of individuals involved in the energy system.

4. **Theory-based evaluation (TBE).** Policies are often taken without enough theoretical basis or academic paper. Successful implementation of policies must be seen from the outcome studies that are produced. For this reason, a theory-based evaluation study is needed. TBE has two objectives, namely, to develop new theories and to prove theories empirically [20]. The TBE study methods that are often used are the Payback Framework, Contribution Analysis (CA), and Outcome Evaluation [37]. One study in this area examined the causal relationship between renewable energy consumption and economic growth in South Korea. This study examines the theory of neoclassical production functions from capital, labor, and renewable energy. The test used in this study is an autoregressive distributed lag bounds test. The results show that renewable energy consumption has a negative impact on economic growth. In addition, the causality test did not show a reciprocal relationship between the two variables. The author suggests that the South Korean government concentrates on economic growth rather than extending the use of renewable energy to grow the economy [38]. Other studies in this field examined the correlation of the type of energy consumed on total factor productivity (TFP). The results show that the use of fossil will decreases TFP growth and vice versa renewable energy consumption will increase it. Nonetheless, there are some results showing inconsistencies in different sub-panels [39].

5. **Hybrid.** This approach, also known as a mixed method of the research. It combines quantitative and qualitative methods to answer research questions. This method can be classified into three types of studies. The first type is called the convergent mixed method. This method merges qualitative and quantitative approaches to get an adequate understanding of the problems. The second type is called the explanatory mixed method. This approach carries out quantitative studies first and then continues with qualitative studies. The third type is the exploratory mixed method. This research is the opposite of exploratory studies. The study will carry out a qualitative study first and then continue with a quantitative study [40]. One of the mixed methods explanatory studies in this research area was conducted to analyse the effectiveness of energy policies to increase the renewable energy mix. In particular, the policy on investor preferences in the renewable energy technology sector. The study involved 60 venture companies in Europe and America. From this study, it is known that the Tariff Feed-in policy is effective in increasing investor preferences to invest in the renewable energy generation sector. So that will ultimately increase the renewable energy mix [41]. These results of this study similar to the research had conducted in Germany [42].

The models mentioned above could not capture the whole complexity appear in the energy system. Policy studies should be able to analyse its effectiveness in the long run as well as the short run. Therefore, a more complex model is needed.

6. **Discussion**

Many studies mentioned that energy systems have complex systems attributes, due to the interactions between diverse actors in turning energy sources [43]. Energy systems showed the characteristics of complex systems, namely (1) System uncertainties; (2) Nonlinear relationships between system variables; (3) Feedback structures; and (4) Causal relationships [44,45].
Non-linearity is often the cause of complexity in the system. However, the existence of feedback behaviour is more responsible for complexity in the system. That is, changes in the behaviour of one actor or element will cause the other actor or element to change. But at a certain point, it will change the behaviour or the element itself. Numerous actors and elements involved in a complex system make it hard to decide which is the first element causing the change. In some cases, the interactions formed a complex network. The system is considered to have spontaneous cause and effects relations. Consequently, the system will be sensitive to change and have no dominant elements (robustness and lack of central control). In complex systems, macro behaviour is an accumulation of several behaviours at the level of the microsystem (emergence) which indicates a smaller system involved within the larger system (hierarchical organization) [46].

Discrete Events (DE), Agent Base Model (ABM), System Dynamics (SD), and Multi-approach Model (MM) are models that are often used to analyse complex systems [20,47]. The complexity in the DE model expects to appear from the uncertainty of events in the system with discrete changes over time. It is possible to apply DE for systems behaviour projection in the long run. Nevertheless, energy systems involve sources that have continuous flow over time. Thus, DE is not a suitable approach for the purposes of the next study.

ABM capable to model individual interactions between agents and predict behaviours in their environment even though it seldom drives the model dynamics [48]. ABM unable to analyse the dynamics between elements in the long run which is a major drawback because energy policy analysis involves a long period of time as shown by energy policy targets in many countries [49]. ABM views an individual or agent as a unique and independent entity that interacts with other agents and their environment. Thus, ABM will be able to produce patterns at the macro level, only a way of determining properties and interactions at the micro-level. ABM has been a appropriate tool directed to implement in various socio-technical systems, including energy [50]. In the area of renewable energy research, this model is used to analyse agents’ behaviour in the energy market [51–53]. ABM can also be used to analyse the selection of renewable energy policies as shown in several studies such as German [54].

SD model is capable to solve problems with dynamic complexity. There is no formal definition for the term dynamics complexity, but it can be recognized by the characteristics. The system will always experience changes in various time units, and it is common for these units to interact with each other. The change that happened in the system is rarely proportional to its causes which adds system complexity called non-linearity. The change in an element will change itself in a certain time unit. It shows that the system is controlled by a feedback causal loop, therefore has adaptive and self-organizing properties. The policy is an important element because it determines the behaviour of the energy system in the long run. However, in certain conditions, the system shows behaviour against the direction of the policy (policy resistant) and which is contrary to conjecture (counter-intuitive) [55]. Although it is very good to model interactions between agents in the system over time, SD cannot show the behaviour of agents individually. Several studies have made a conceptual model to describe the elements and relationships that exist in order to analyse the policy of developing renewable energy in Indonesia [56]. SD is also used to analyse systems in the context of reducing carbon emissions by increasing investment in the solar PV and wind power sectors and eliminating fossil-based energy subsidies [57]. In addition, an analysis of the conversion of fossil-based fuels to hydrogen and biofuel-based fuels [58].

MM saw the weaknesses of the earlier approaches and tried to expect them to use other approaches. Complex system analysis requires a various level of abstraction required so that modelers need more than one approach to formulating models. Although conceptually interesting, MM is still hard to find in studies especially in energy policy. This is mainly due to the availability of software as a tool for formulating models [47].

7. Conclusion
In terms of model, the mixed model shows a promising comprehensive result. It captures the micro as well as macro behaviour as responses to renewable energy applied. Availability and access are the drawbacks of this model. The agent-based model and system dynamics are proofed to be a suitable
model to analyse renewable energy policy. In many cases, individuals and several combinatory scenarios show positive outcomes of the renewable energy mix. However, there is still a wide gap to fill because none of those scenarios can reach the national or regional renewable energy mix targets. Future research could consider the demand side or non-market-based approach to accelerate the growth of the renewable energy mix in order to reach the targets.

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