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Review Paper

Policy Simulation of Electricity-Based Vehicle Utilization in Indonesia (Electrified Vehicle - HEV, PHEV, BEV and FCEV)

Simulasi Kebijakan Pemanfaatan Kendaraan Berbasis Listrik di Indonesia (Electrified Vehicle - HEV, PHEV, BEV and FCEV)

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Abstract

In the past few years, the energy consumption of the land transportation sector has increased considerably. One of the breakthroughs by the Government through Presidential Regulation No. 22/2017 concerning General Plan for National Energy (RUEN) is the use of electricity-based vehicles to reduce fuel consumption and achieve energy security. Successful policy making for emerging industries depends on two main factors: the adoption of scientific perspectives and accuracy to predict impacts. Therefore, this review aims to conduct a study of policy simulation methodologies related to the use of electric vehicles in Indonesia. Also, identification of the gaps and limitations of previous research is carried out and recommending an agenda for further research.

Key words: Land transportation; Electric-based vehicles; Policy simulation

Abstrak

Dalam beberapa tahun terakhir, konsumsi energi sektor transportasi darat telah meningkat pesat. Salah satu terobosan Pemerintah melalui Peraturan Presiden No. 22/2017 tentang Rencana Umum Energi Nasional (RUEN) adalah penggunaan kendaraan berbasis listrik untuk mengurangi konsumsi bahan bakar dan mencapai keamanan energi. Pembuatan kebijakan yang berhasil untuk industri yang sedang berkembang tergantung pada dua faktor utama: adopsi perspektif ilmiah dan akurasi untuk memprediksi dampak. Oleh karena itu, review ini bertujuan untuk melakukan studi tentang metodologi simulasi kebijakan yang terkait dengan penggunaan kendaraan listrik di Indonesia. Juga, identifikasi kesenjangan dan keterbatasan penelitian sebelumnya dilakukan dan merekomendasikan agenda untuk penelitian lebih lanjut.

Kata kunci: Transportasi darat; Kendaraan berbasis listrik; Simulasi kebijakan

1. Introduction

Currently, the land transportation sector in Indonesia consumes 90% of total energy in the transportation sector [1]. The high growth of 4-wheeled private vehicles between 2010-2014 which was driven by the increased ability of consumers to buy vehicles were one of the main factors that led to the high level of energy

consumption in the land transportation sector, especially for oil [2]. To maintain energy security, the Government has set Presidential Regulation No. 22/2017 concerning the General Plan of National Energy (RUEN) [3], which regulates policies in the context of sustainable energy management in Indonesia. From the RUEN, then each region in Indonesia is required to prepare a General Plan of Regional Energy (RUED) within one year after the publication of RUEN. Of course, it is very important for the Central Government and Regional Governments to be able to execute policies as outlined in RUEN and RUED, and for that, the selection of priorities and availability of resources is an important consideration in their implementation.

One of the RUEN programs for energy diversification in the land transportation sector is the use of electricity-based vehicles which are believed to be one of the answers to the increasing energy consumption in this sector and also the high level of urban air pollution. Since 2003, Indonesia has become an oil importing country and the land transportation sector consumes almost 90% of fuel oil in the transportation sector. The transfer of energy sources from oil to electricity is expected to reduce Indonesia's dependence on imports and ultimately to improve overall energy security. Indonesia has various natural resources, including coal, natural gas, geothermal energy, sunlight, wind, which can all be used to generate electricity [4]. The Government's program to build 35,000 MW electricity plants as an effort to increase the electrification ratio is also another driving factor for the use of electric vehicles, especially in the land transportation sector.

Alternative fuel vehicles (AFV) are generally described as all types of vehicles that can use fully or partially alternative fuels, such as biofuels, electricity and gas. Especially for electric vehicles, it also consists of various kinds of technology, such as plug-in hybrid electric vehicle (PHEV), electric vehicle (FCEV) cells, battery electric vehicle (BEV) and hybrid electric vehicle (HEV). One electric vehicle that is quite famous today is a hybrid electric vehicle (like the Toyota Prius).

A hybrid electric vehicle (HEV) has an internal combustion engine along with an additional electric powertrain module consisting of an electric motor driven by a battery. The battery is charged by utilizing kinetic energy that is lost during braking or can be directly from the engine. Plug-in hybrid electric vehicle (PHEV) is a further development of HEV by increasing battery capacity and can be charged from outside the vehicle. Battery electric vehicle (BEV) has all electric drivetrain whose power comes from batteries that have a large capacity (compared to HEV and PHEV), and are charged via electric power lines. The mileage in electrical mode on the BEV is generally far more than PHEV. Cell electric vehicle (FCEV) is an electric vehicle that uses the fuel cell stack as an electricity source to drive an electric drivetrain. Fuel cells produce electricity from the conversion of hydrogen gas in the vehicle. Figure 1 describes the classification of electric-based vehicles that are currently being developed by various manufacturers and marketed globally.

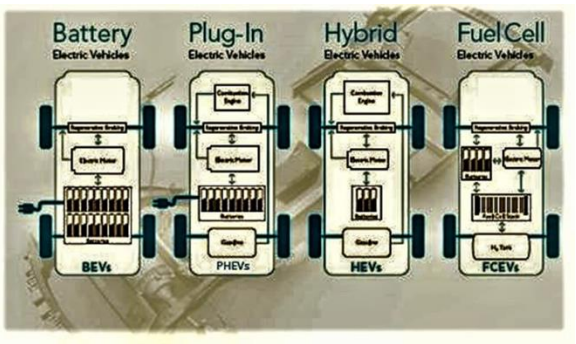

Figure 1. Classification of electric vehicles

Reflecting on a number of policies related to the diversification of energy sources for land transportation that has been felt to be unsuccessful so far, it is very necessary to review the readiness of stakeholders to be able to work together and achieve the expected targets. For example, in the oil to CNG conversion program that has been going on since 1997 [5], the fundamental problem between the availability of vehicles and CNG filling stations have not been resolved to date. However, the success of a program will be largely determined by the level of

consumer adoption of technology choices that is driven by the Government. Especially for technology that requires changes in people's behavior such as CNG and Electric vehicles.

Currently, electric vehicles are categorized as an Emerging Industry, which is generally driven by a new technology and market uncertainty, as well as a weak industrialization system [6]. China is the most powerful country to encourage the development of electric vehicles, but the energy policy mix that is run by the Chinese Government to date has not been able to popularize electric vehicles to match the popularity of oil-fueled vehicles. As of the end of 2016, the population of electric vehicles only reached 1.43% of the total sales of all new vehicles in China [7].

There are many factors that are interrelated and involve many stakeholders in an effort to encourage the diffusion of electric vehicles. Therefore, it is very necessary for an appropriate and sustainable policy design. Fortunately, the theory of stakeholders has the ability to resolve policy problems like this [7], especially to deal with unstructured issues such as policy formulation, while interacting dialogically among stakeholders, which can improve understanding of the problems and possible solutions.

Usually, in an innovation process, choices that are able to balance conflicting goals between stakeholders are absolutely necessary. Policy formulation in Indonesia is also a complicated problem. Since the early 2000s, Indonesia's bureaucracy has been classified as the lowest quality group in the world [8], that caused by weak training, promotion and compensation, difficult reporting requirements, and a lack of significant bureaucratic reform. This has an impact on the policy-making process in Indonesia, where Government employees have a very important role in the drafting process and the implementation of laws, regulations and guidelines, and also play a role in the stages of planning, financing and accounting processes. Until now, there is a very significant imbalance in the use of facts and research data in policy formulation. Many programs are run without adequate preparation, consultation, or empirical facts, and many policies are very bad communication.

The policy of utilizing electric vehicles in Indonesia, of course, will have a huge impact on all stakeholders and the necessary stages of policy formulation are needed along with good analysis. Therefore, the purpose of this research is to review the policy simulation methodology that can be used effectively to analyze the policy of utilizing electric vehicles in Indonesia.

2. Literature Review

As a country that currently has 100% market automotive products that still use internal combustion engine technology, both 2-wheeled and 4-wheeled vehicles or more, the move to the electric vehicle-based automotive industry requires a considerable transformation process. Moreover, the electric vehicle industry itself is still classified as an emerging industry innovation. Reflecting on the experiences of various countries that have started utilizing electric vehicles, there is still a considerable gap between market acceptance and government policy targets, and this certainly reflects an imbalance that occurs among stakeholders.

Therefore, it is necessary to review the literature from the results of research conducted in Indonesia and other countries (in this case China) related to the utilization of fuel and alternative fuel vehicles and literature review based on stakeholder theory, innovation policy and then policy simulation that would be appropriate to achieve the objectives of this research.

2.1. Results of Related Research Review

This review tries to find gaps and recommendations from previous research so that future policies taken by the Government through the policy simulation methodology offered can predict the impact, and then to take corrective steps. Some of the results of the review that are used as references are presented in Table 1.

Table 1. Overview of the results of previous research

Author	Category (AFV)	Methodology	Recommendation/ concern
[9]	2-wheeled vehicles	*Mix logit model with random coefficient*	✓ Care is needed to interpret the results because consumers are not familiar with electric vehicles
[10]	4-wheeled CNG	*Agent Based Modeling*	✓ The future conditions of consumers can be different from those predicted at this time
[2]	Hybrid Electric Vehicles (HEV)	*Ordered response Logit Model with Scenario*	✓ No analysis was made regarding the role of the media. ✓ The intention to adopt HEV vehicles will increase if prices are competitive, as well as additional policies in the form of limiting vehicle age and eliminating fuel subsidies.
[11]	Hybrid Electric Vehicles (HEV)	*Fiscal instrument*	✓ Providing fiscal incentives is a feasible policy for the utilization of HEV in Indonesia.
[12]	Bio-fuel	*Policy reiew*	✓ Infrastructure is needed by the Government in the biofuel production process so as to reduce market prices.
[7]	PHEV, BEV	*Purchasing intention model*	✓ The two main factors that drive consumer intentions, namely EV prices and smog problems. ✓ The effects of network externatilities are still low because the EV population is still limited. ✓ Manufacturing is a key stakeholder that influences EV industrialization in the long term, followed by infrastructure and consumers.

2.2. *Stakeholder Theory*

In the era of openness as an improvement to the traditional management era, policy making has undergone a general polycentric shift [13], where stakeholders need to be involved as active participants in the decision-making process at various levels of social organizations. Stakeholder-based policies are able to facilitate the efforts of the Government which acts as a policy maker and for stakeholders from non-governmental parties to be able to voice their needs and encourage the adoption or acceptance of specific policies concerning the environment.

Important questions arise when we want to connect stakeholder theory with policy-related analysis, namely how much and what kind of stakeholders should be involved, because it is very unlikely to involve all parties. Some researchers argue that employees, consumers, suppliers, shareholders, and representatives of communities and companies must jointly manage the company [14], but there are also some researchers who state enough key stakeholders to be responsible in the management of the company. This debate about the theory of stakeholders continues, but in this review, what is meant by stakeholders is parties that are directly related to the impact of a business process.

2.3. Innovation Policy

Innovation policy is defined as a synthesis of various kinds of policies utilized by the Government to promote technological activities [15], which have been widely adopted by many countries in the world to improve the capabilities and competitiveness of national corporate companies, and promote structural reforms from the entire industry. Regarding categories and roles in innovation policy, the three main aspects include, supply, needs and environment form the most common perspective. On the supply aspect, the policy portfolio aims to increase the level of engineering and development both in terms of suppliers and manufacturing, economic, political and legal companies. Conversely, in terms of needs, the policy portfolio aims to explore and dominate markets both domestically and abroad. The next stage, this perspective is expanded and focuses on the industrial level and combines it with the process of industrial innovation with the industrialization policy system (as presented in Figure 2).

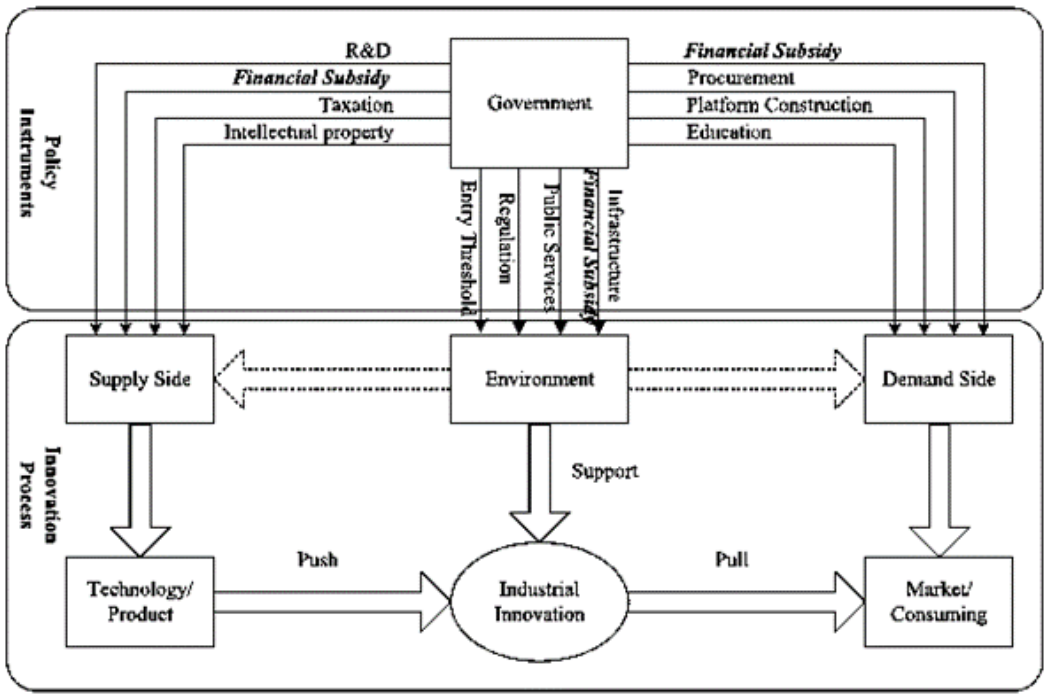

Figure 2. Policy instruments to stimulate industrial innovation [16]

The supply side is used primarily to encourage R & D and production, including science and technology, financial subsidies, tax incentives and intellectual property. The need side serves to stimulate market formation and sales, including financial subsidies, government purchases, foundation construction, and community education. The environmental side does not have a direct relationship with the industry itself, but the creation of relevant environmental conditions and supporting facilities is capable of realizing industrial innovation, by creating boundaries for entry, laws and regulations, providing public services, building infrastructure as part of policies, financial subsidies, and the provision of land as the main step.

As shown in Figure 2, policies that can target all sides of industrial innovation have a central role in determining success later. Especially for the use of electric vehicles, the financial subsidy policy is a factor that really needs to be studied further.

2.4. Policy Simulation

To study the policy making process, an effective way is through policy simulation, especially for complex, adaptive, and dynamic

environments. From the perspective of methodology, mathematical statistics, Dynamics System (DS), and Agent-Based Modeling (ABM) are methods that are used continuously for policy simulation. However, due to the complexity of the evolving industrial innovation system, traditional methodology using statistical mathematics is not designed to overcome nonlinear relationships arising from the existence of different parameters and variables. Therefore, DS and ABM are two methods that are suitable for policy simulation.

DS was first introduced by Forrester in 1958 using feedback loops, stocks, and flows to model the behavior of complex systems over time. This involves internal feedback loops and delay times that affect the behavior of the entire system. ABM itself arises from interactions between agents, where the behavior of each agent is determined by its cognitive structure and scheme, and ABM is a powerful tool for modeling adaptive complex systems with various entities interacting according to the patterns created by the entity together. It has been widely used since the mid-1990s [17]. Although both DS and ABM have overlaps in the use of computer simulations to investigate non-linear social problems and socio-economic systems that focus on understanding and qualitative predictions of a system's behavior, there are still fundamental differences as illustrated in Table 2.

Table 2. Differences DS and ABM [18]

Criteria	Dynamic Systems (DS)	Agent-Based Model (ABM)
Basic Building Block	Feedback loop	agent
Unit of Analysis	Structure	Rules
Level of Modeling	Macro	Micro
Perspective	Top-Down	Buttom-Up
Adoption	Change of Dominan Structure	Change of Structure
Handling of Time	Continuous	Discrete
Mathematical formulation	Integral equations	Logic
Origin of dynamic	Levels	Events

From the difference between ABM and SD, this review focuses more on SD, because SD methodology can provide a better understanding of the system structure and behavior deduction of the system. This is a continuous [19], and popular simulation methodology when the general principle of feedback is introduced more widely to audiences through the term system thinking. From the various literatures and information available regarding industrial innovation in Indonesia and the policies that have been taken by the government in utilizing alternative fuel vehicles so far, this review intends: first, to propose a key stakeholder-based policy framework and identify key stakeholders which plays a role in the policy of utilizing electricity-based vehicles in Indonesia. Furthermore, secondly, an SD model will be built that will simulate the theoretical framework described earlier. Finally, a variety of simulations will be conducted with various scenarios to be able to understand the implications of the policy.

3. Research Novelty

Appropriate policy making is the most influential thing in determining the success of the policy itself later. Based on the explanation previously explained, the following problems will be answered (Table 3).

Table 3. Research Questions and Objectives

Research Problem	Research Question		Objective
RP 1: Qualitative predictive methodology that is effective and accurate to analyze the impact of the policy of using electric vehicles in Indonesia in accordance with the current conditions	RQ 1	What methodology is the most effective and accurate for predicting the impact of electric vehicle policy in the long term?	Select methodology by comparing Dynamic Systems and Agent-Based Models (ABM)
	RQ 2	What is the framework that fits the methodology that will be chosen?	Identify the framework that best fits the actual conditions in Indonesia
RP 2: For developing industries such as electric vehicles, the role of key stakeholders is vital in determining the success of technology adoption	RQ 3	Who are the main stakeholders in the vehicle utilization policy?	Identify key stakeholders who will play an active role in realizing the use of electric vehicles in Indonesia
	RQ 4	What is the most effective policy formulation that will actively involve the main stakeholders in terms of their supply, needs and supporting environment?	Propose policy formulations along with accurate quantitative impact analysis that will ensure policy sustainability

4. Conclusion

This literature review tries to provide an overview of the use of a scientific approach in helping formulate a policy that will be taken by the Government of Indonesia, especially in terms of the use of electric vehicles. As the emerging industry, the role of key stakeholders will greatly determine the success of the adoption of these technologies by consumers. It is expected that the results of this study will be utilized by the Government to be able to evaluate policies effectively and accurately and take the steps needed to adjust the policy.

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