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Potential and Challenges of Hydrogen Development as New Renewable Energy in Indonesia

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Abstract. *The use fossil energy consumption in Indonesia is increasing along with population growth and industrial development. Fossil energy oil and coal can produce greenhouse gas emissions and environment pollution. The largest producer of CO2 emissions comes from exhaust gases in the production process and motor vehicles. Indonesia's energy mix target in 2025 is around 23% from New and Renewable Energy (NRE). Given the importance of using NRE, Indonesia is starting to look for alternative energy that is environmentally and sustainable, like hydrogen energy. Green hydrogen technology has the potential to be developed in Indonesia. Hydrogen production processes commonly carried out are through the electrolysis of water, methanol, and biomass. The use of hydrogen can be applied to motor vehicles and power plants. Hydrogen can reduce greenhouse gas emissions. However, Indonesia has problems in developing green hydrogen technology* [1], *one of which is the high production cost, so it requires other parties to develop it.*

Keywords – *CO2 Emissions; New Renewable Energi; Production Thecnology*

INTRODUCTION

The need for energy is increasing day by day. As well as electrical energy which is the primary need of today's society. Without electricity, some community activities will not be carried out. The electrical energy that we use every day is generated from various sources such as SEPP (Steam-electric Power Plant), HEPP (Hydro-electric Power Plant), GEPP (Geothermal-electric Power Plant) etc. In the 20th century, power plants in Indonesia are still dominated by Steam-electric Power Plants (SEPP) where the fuel source still uses coal or fossil energy which produces greenhouse gases and can lead to global warming [1].

Indonesia itself has begun to experience an energy crisis due to the high consumption of energy and the increasing standard of living of the people. This kind of thing needs to be addressed immediately by utilizing new and renewable energy that is far from environmental pollution, and has a high level of sustainability, as well as reducing the use of coal so that Indonesia's coal reserves do not run out quickly, because Indonesia is still dependent on coal energy. The results of coal combustion contain CO2, Nox, and SO2 gases which result in air pollution and pollution that will have an impact on global warming [2]. In addition, air pollution is also caused by the combustion of motor vehicles that use oil energy with incomplete combustion rates so that the exhaust gases of motor vehicles contain Nox, SO2, HC, CO, Ox [3]. The following is a description of the supply of New Renewable Energy (NRE) in Indonesia:

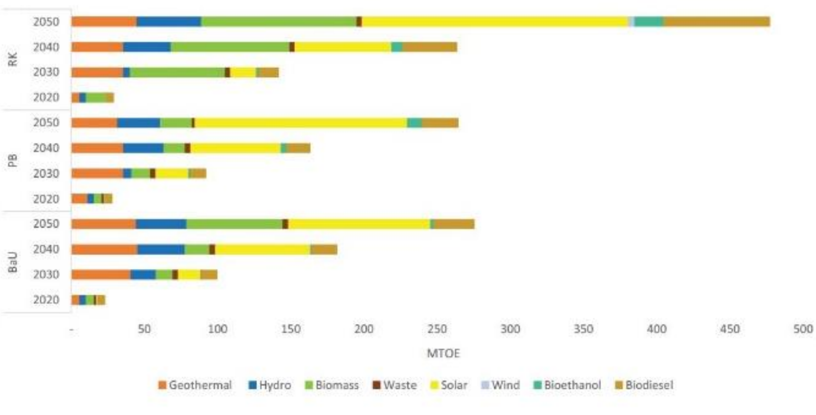

Figure 1. Indonesia's NRE Supply [4]

Based on statistical data in Indonesia shown in Figure 1, in terms of saving on the use of coal with renewable energy, it is estimated that it will only reach 25% in 2025 [4]. For a comparison of new renewable energy and the use of coal, see the following graph:

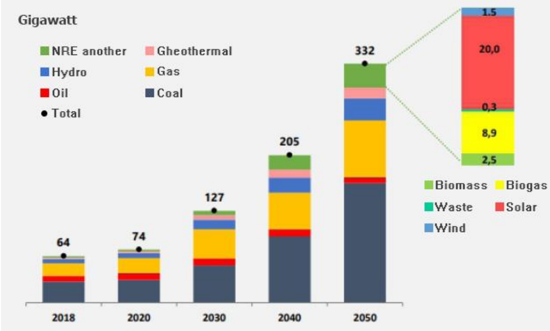

Figure 2. Development and growth of power plants in Indonesia [5]

Based on Figure 2 above, it can be seen that the use of coal still dominates compared to other energy uses. Currently, new renewable energies being developed in Indonesia are geothermal, wind, water, solar cells and most recently Hydrogen. The following are some of the potential renewable energy in Indonesia which are presented in Table 1:

Table 1. Indonesia's NRE Potential [4]

Energy Type	Potention (GW)
Wind	94,3 GW
Geothermal	28,5 GW
Bioenergy	PLT Bio : 32,6 GW & BBN : 200 ribu Bph
Sun	207,8 GWp
Wind	60,6 GW
Ocean Energy	17,9 GW

Hydrogen is a flammable substance, the element is abundant about 75% in nature and is included in zero emission because it does not cause environmental pollution and does not have exhaust gases when burned so it will not damage the air atmosphere [6]. According to UU 30/2007 bagian 1 it is stated that Hydrogen is a new energy source with new technology that absolutely must be controlled as the basis of the economy. In the National Research Agenda 2010 – 2014 there are several points regarding New and Renewable Energy Research:

- Blue-print for National Energy Management 2005-2025
- Policy Directions and Key Priorities
- Achievement target for 2009 is 2.5 KW and target for 2025 is 250 qMW
- Fuel cell application for remote areas.

In 2020, Germany, Spain, Canada and Russia have developed a hydrogen development strategy that is formulated by the end of 2020 to produce around 52% hydrogen globally. Around 2030, it is estimated that the European Union will build around 2x40 GW of renewable energy through electrolysis with a yield of 10 million tons of hydrogen [7]. Meanwhile in South Korea, the government plans to build a liquid hydrogen filling station with a capacity of 900 kg/day of more material, while Japan is targeting the construction of 400 hydrogen gas filling stations by 2030[8].

METHOD

The method used in this study uses a qualitative analysis with a descriptive method, by conducting a discussion through a review of various relevant library materials from the formal academic literature. To get the right literature for this review, a formal search engine was used that could explore the literature relevant to the research objectives.

The right keywords can filter every existing literature to get relevant literature. The literature used for the discussion on this topic was selected based on the judgment of visitors to the literature website, the relevance of the content of the literature and the focus of the literature on the review to be made. The search results using keywords on the search engine obtained 300 related literature, but only 80 literatures were further processed to view the contents of the literature. After reviewing the contents of the selected literature, 43 literatures were found that meet the relevance of this review.

The next step is to conduct a descriptive analysis of the potential for hydrogen production as clean energy in the future. The discussion also describes the use of hydrogen and the application of hydrogen technology that has been carried out by various other countries for their energy fulfillment, as well as the potential and application of hydrogen technology as a new renewable energy in Indonesia.

RESULT AND DISCUSSION

A. Hydrogen Potential and manufacture

Currently, hydrogen gas in Indonesia is marketed as a chemical and not a fuel. The price range of hydrogen gas as a chemical is sold at Rp. 200,000 to Rp. 1,700,000 per 600 L (1 large tube) according to the level of purity of the hydrogen.

To achieve the energy demand target in 2025 of 250 MW, the demand for hydrogen gas will reach 3.6 million m3/day or the equivalent of 600 hydrogen tubes per day. In Indonesia alone, hydrogen gas is produced by 4 large gas industries so that to reach 600 hydrogen cylinders every day, it is necessary to develop a new company that produces 30 times more hydrogen [9]. Looking at other countries, such as Canada, currently it is capable of producing 8.2 tons of hydrogen per day [10]. In Serbia, the potential for hydrogen is sourced from food industry wastewater and biogas. The total production of hydrogen through steam reforming biogas is 4,094.70 tons and through the electrolysis process is 1,751.08 tons [11] The hydrogen production process can be carried out in several ways:

A.1. Water electrolysis method

In using the electrolysis method, a DC current is needed to decompose water compounds (H2O) into hydrogen gas (H2) and oxygen (O2). In this method, 2 molecules of H2O dissociate into O2 and release 4 H+ ions at the anode and flow electrons to the cathode where water molecules gain 2 electrons so that they are reduced to H2 and OH-. Due to neutralization, some H+ and OH- ions will return to water molecules. Through this electrolysis method, hydrogen is produced as a producer of electricity through a fuel cell to drive an electric motor for hydrogen transportation [12]. Fuel cell technology works on the principle of burning electricity into a chemical where there is an electrolyte that separates the cathode and anode poles. At the anode fuel is flowed and oxygen is flowed at the cathode which takes place separately. Due to the effect of the catalyst on the electrode, the flowing gas molecules will turn into ions and at the anode a reaction will occur which produces free electrons and these electrons are bound to the cathode. In order for the chemical principle to occur, the free electrons are flowed out through the conductor to the anode [13]. In this method there are 2 forms of technology that can be used, namely Proton Exchange Membrane (PEM) and Solid Oxide Electrolysis Cells (SOEC) [14]. Proton Exchange Membrane (PEM) has the properties of high hydrogen proton conductivity and low impurities, high mechanical properties, low gas permeability and decreased hydrogen return by diffusion. In addition, PEM has drawbacks such as high manufacturing costs, low material strength, water treatment is required, and hydrogen diffuses again if the temperature continues to increase. Despite these drawbacks, the PEM method is the best solution because of its good thermal conductivity and low gas content without compromising equipment performance [15]. In addition to PEM, there is also the Solid Oxide Electrolysis Cells (SOEC) method which does not cost any production costs and the production of hydrogen can use high temperature electrolysis and the technology can be used for thousands of hours of processing, the scheme and mechanism of water electrolysis can be seen in Figure 3 [16].

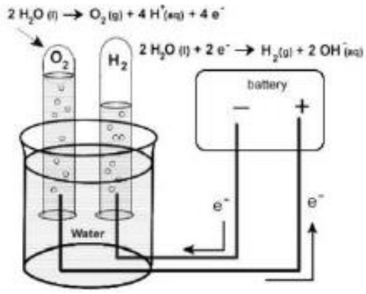

Figure 3. Schematic and mechanism of H2O electrolysis [12]

Electrolysis from water has its own challenges in its use, namely high electrical energy consumption, costs and unit maintenance for electrolysis, costs to increase the reliability of production equipment as well as durability and safety factors [17].

A.2. Methanol electrolysis

Similar to the previous electrolysis, what is different is that this electrolysis uses liquid methanol. This method is quite widely developed by scientists in the world because the amount of electrical energy used is less and the results of hydrogen production are much more. To produce hydrogen using this method, it can be done using photovoltaic solar energy (Dewi, 2011). Hydrogen produced from methane requires high temperatures and has catalytic properties [18]. Here's the reaction equation:

$$CH_4+H_2O=CO+3H_2 \text{or} CH_4+1/2O_2=CO+2H_2O$$

A.3. Steam reforming

The process of producing hydrogen through steam reforming is considered cheaper and can be produced in large quantities, around 330,000 kg hydrogen/day [19]. Steam reforming processed by reacting methane gas and steam at high temperatures with a thermal efficiency rate of about 70% [20]. When using this method, there are several things that need to be assumed [21] :

- The simulation location has various types of tools/components
- Particle motion in the form of laminar, stationary, and symmetrical axes
- Reactor temperature is 1073 K, pressure 1 atm
- Mass transfer occurs by diffusion throughout the reactor

A.4. Hydrogen from biomass

Apart from electrolysis of methanol and water, Hydrogen can also be produced from biomass. Hydrogen from biomass conversion tends to be cleaner and environmentally friendly with an energy level of around 122 KJ/gr [22]. The process of producing hydrogen from biomass is done by adding bacteria or microorganisms to the substrate through chemical processing of biomass. Here are the types of hydrogen production and their differences.

Table 2. Types of biohydrogen production and their advantages [22]

Organism / Process	Subtrate Type	Advantage
Biophotolysis (green algae and cyanobacteria)	• water	• Abundant amount • Cheap substrate price • The energy from capturing sunlight has a high flux
Biofermentation (purple nonsulfur photosynthetic bacteria)	• Organic acid • Sugar • Glycerol	• Substrate conversion is almost perfect • Able to use various wastes from gelam fermentation
Dark fermentation (proper anaerobic and facultative anaerobic)	• Sugar • Ingredients that contain a lot of carbohydrates	• Simple reactor • Able to use a variety of substrates • High volumetric rate
Electrolytic microbes (wide variety of Electrogen, Geobacter, and Shewanella)	• Sugar • Organic Acid • Protein	• Possibility of complete substrate degradation • Hydrogen from organic acids • Hydrogen from various components

Looking at the conditions of other countries, for example on the European continent, the potential for hydrogen has been widely used, especially in densely populated areas such as Rome, Italy, Belin and London with production levels reaching 12.5 Mton/year [23]. While in Germany in 2019, hydrogen production through the electrolysis process was obtained around 80% which will produce 500-600 TWh/a and this is certainly much more than the demand for electrical energy consumption which is around 500 TWHh/a [24]. Moving to the Asian continent, precisely in China, the potential for methane and hydrogen can be obtained more from food scraps such as rice and pasta with hydrogen production ranging from 22.4% - 70.2% [25].

The potential for hydrogen is very possible to be developed into renewable energy that is environmentally friendly, for example in Turkey. The potential of solar energy is abundant to be utilized and combined with biomass, water, geothermal and of course hydrogen production through electrolysis known as Alkaline Elecrolyser (ALEL), Proton Exchange Membrane (PEM), and Solid Oxide Electrolyser (SOE) [26]. The potential for electrical energy in Turkey mostly comes from hydropower because there is a high water flow rate of around 202 m3⁄s so it is possible to produce 108.53 kt of hydrogen per day [27].The basic material for hydrogen production in Turkey is water from sea water, lakes, and river water [28].

Meanwhile in Nepal, the potential for hydrogen production is estimated at 63,072 – 3,153,360 tons with energy needs of 20 – 100% each, so it can be said that Nepal is a country rich in green hydrogen production potential that can completely replace coal use [29].

Hydrogen from biomass conversion is very possible to be developed in Indonesia because its sources are abundant. In addition, hydrogen production is very profitable because it can help process waste into biohydrogen, is environmentally friendly, does not produce greenhouse gas emissions, and can be produced sustainably [22]. The following is the potential of biomass in Indonesia:

Table 3. Potential source of biomass in Indonesia [22]

Biomass Type	**Amount (Mwe)**
Palm oil	12,654
Sugarcane	1,295
Rubber	2,781
Coconut	177
Paddy	9,808
Corn	1,733
Cassava	271
Wood	1,335
Cow and Buffalo	535
City Garbage	2,066

Apart from the several sources above, hydrogen can also be produced from the aluminum plate of Green Sands beverage cans and water assisted by a NaOH catalyst where the wider the aluminum plate, the faster the gas production rate [30].

B. Effective use of hydrogen production

The use of hydrogen has not been widely developed in Indonesia because it is still considered a chemical. About 48% of the hydrogen comes from natural gas restoration, 30% comes from petroleum refining, and 18% from coal. From this it can be seen that about 96% of Hydrogen comes from fossil energy containing CO2 and the rest comes from electrolysis [31]. Through the production method mentioned earlier, it is hoped that CO2 emissions can be minimized so that hydrogen can be developed sustainably and can be used widely. CO2 emissions can be minimized from 34% to 28% by producing 20% hydrogen, and if hydrogen is varied from 5% to 20% it can increase NO and No2 from 4.06 g/day to 7.45 g/day [32]. Another technology being developed is methane decarburization and its comparison with other productions is presented in Table 4.

Table 4. Comparison of hydrogen production with fossil fuels [31]

Reaction	Methane Vapor Reform **CH4+2H2O=CO2+4H2**	Coal Gasification **C+2H2O=CO2+2H2**	Methane Pyrolysis **CH4=C+2H2**
Heat of reaction kJ (mol C)-1.	235,00	178,15	74,85
Heat of reaction kJ (mol H2)-1.	63,25	89,08	37,43
Transformation time energy efficiency (%).	74	60	55
Energy efficiency in CCS (%).	54	43	55
CO2 emissions, moles CO2 (mol H2)-1.	0,34	0,83	0,05
CO2 emission with CO2-free energy source, mol CO2 (mol H2)-1.	0,25	0,5	0
Production of CO2 with free energy sources, CO2 kg GJ-1.	611	150,9	0
Carbon production kg GJ-1.	0	0	24,8

C. Challenges of Hydrogen Development in the World and in Indonesia

The development of hydrogen as a renewable energy turned out to be not as smooth as imagined, especially in the field of technology used, namely fuel cell technology with the BTM (Behind The Meter) system where the efficiency and reliability of the system are still low and fuel costs and infrastructure are inadequate [33]. Viewed from a broad perspective that covers the whole world, the biggest challenges in hydrogen development are the unavailability of adequate infrastructure, the level of risk of using hydrogen, lack of government support, integration of systems such as codes, regulations and code standards, and requires large costs [34]. In South Korea itself, the toughest challenge in hydrogen development is that the cost of raw materials and construction of infrastructure is still quite expensive [35]. In China, precisely in Guangdong province, a wind power plant has been built to be used as a supplier of electrical energy in the electrolysis of water into hydrogen, but the challenge in its construction is the high construction cost and China has only invested around CNY 6.17 million in infrastructure development [36].

The use of hydrogen, especially in Indonesia, is still considered a non-fuel chemical, so it is still difficult to develop [9]. On the other hand, it was previously mentioned that hydrogen in Indonesia is only produced by 4 large gas industry companies, so to achieve the large demand for hydrogen energy, more companies that produce hydrogen still need to be developed. To get to renewable energy, it is very possible to develop a methanol plant and it will be a challenge and its own value for a methanol plant developer, but its development requires no small amount of money [37].

The most competitive way to produce hydrogen is by gasification of coal, but this cannot be separated from carbon emissions, so carbon capture and sequestration (CCS) methods are needed [31]. The application of this method will actually increase production costs by 30%. The SOLHYCARB project utilizes solar energy to cut production costs and reduce unnecessary costs. The following are some of the costs of Hydrogen production technology which can be seen in Table 5:

Table 5. Cost of hydrogen production technology [31]

Technology Type	Fuel	Production Cost ($\$kg^{-1}$)	Reference
Central Steam Reforming	Natural gas	1,5	Guerrero-Lemus & Martínez-Durant, 2010; Pregger, 2009
Gasification	Coal	2,6	Guerrero-Lemus & Martínez-Durant 2010
Gasification with CCS	Coal	1,8	Guerrero-Lemus & Martínez-Durant, 2010; Pregger, 2009
Scattered Electrolysis	Electric network	6,8	Guerrero-Lemus & Martínez-Durant 2010
Centralized Electrolysis	Wind	3,8	Guerrero-Lemus & Martínez-Durant 2010
Water Electrolysis	Water	7.5-10.3	Campbell, 2020

Hydrogen production through coal gasification is a process of converting hydrocarbons into volatile hydrogen gas compounds in gasification (such as air or water vapor) where the biomass enters the furnace and is then heated and dried after which the water evaporates as the temperature increases and the material decomposes and produces hydrocarbon gas [38].

D. Hydrogen utilization

In Philippines, hydrogen is used in various chemical production industries such as ammonia, plastics (polymers), and resin production. In addition, green hydrogen is also used to generate electricity to run electric cars with hydrogen fuel cells [39]. Hydrogen is used as a fuel because it has the characteristics of high flame speed and high diffusivity [40]. In America, hydrogen is used as fuel energy to propel the shuttle. In addition, hydrogen is also used as a chemical intermediate in chemical reactions, desulfurization of the petroleum industry, hydroxylation treatment, and steel production [41]. The state of Serbia utilizes hydrogen as an energy product that is directly used in the food industry, production of the national electricity grid, transportation, injection in natural gas, and resources in the chemical industry [11].

In Indonesia, hydrogen is used as internal cobustion in engines, besides that it is also used for cutting and welding metals such as aluminum, steel, and iron [42]. Internal combustion in the engine here is a form of combustion in vehicles using fuel such as hydrogen. Hydrogen here combined with gasoline requires only a small number of spare parts with a low level of structure and vibration. Combustion in gasoline-powered engines requires a long combustion chamber and high operating speeds require high ignition rates and simple evaporation so that hydrogen can be combined with gasoline [40]. Combustion on an engine with hydrogen fuel is assumed to be 80 km/1 kg of hydrogen and can reduce fuel consumption by 40% and save energy by 142 Mj/kg [43].

CONCLUSION

The potential use of Hydrogen is very possible to be developed in Indonesia where Hydrogen has abundant potential and does not damage the environment or produce CO_2 emissions. The ideal hydrogen production can be done simply by electrolysis of water, methanol, and biomass. However, to achieve Indonesia's NRE target in 2025, which is around 23%, it is necessary to apply the use of hydrogen energy to combine combustion, hydrogen cars, or to Hydrogen Gas Power Plants. In the hydrogen production process, it must be from renewable energy so it will not pollute the environment. However, hydrogen production using renewable energy on a large scale is still quite expensive and a bit difficult to develop due to expensive technology and infrastructure, so that the production process requires other parties to participate in the development of hydrogen products.

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