# RESEARCH FUEL CELLS TECHNOLOGY BASED BY HYDROGEN GENERATOR USING SIMULATION

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**Abstrak:** Pada era penggunaan bahan bakar fosil dalam proses pembangkitan energi mulai dialihkan ke bahan bakar yang ramah lingkungan, hal ini dikarenakan sifat bahan bakar fosil yang menghasilkan emisi, emisi yang ada mencemari lingkungan sekitar, sehingga dalam beberapa dekade terakhir ini banyak digalakkan peralihan ke penggunaan energi terbarukan. Teknologi fuel cell merupakan pengembangan dari suatu proses pembangkitan energi yang berbasis pada prinsip kimia dari bahan yang digunakan. Generator Hidrogen merupakan suatu perangkat yang dapat mengubah proses kimia yang ada menjadi energi listrik, memiliki emisi yang rendah (hampir tidak ada), sehingga menjadikan generator hidrogen sebagai pilihan pembangkitan yang lebih baik dibandingkan generator konvensional. Pada sektor rumah tangga, pemanfaatan generator hidrogen sebagai sumber energi tambahan membawa manfaat yang positif, seperti mengurangi emisi karbon yang dihasilkan dari sektor pembangkitan energi, selain itu juga dapat mengurangi biaya konsumsi listrik rumah tangga, karena pasokan listrik dari perusahaan manufaktur hanya digunakan ketika daya yang dihasilkan oleh generator hidrogen kurang.
**Kata Kunci:** Sel Bahan Bakar, Energi Terbarukan, Energi Bersih, Optimasi, Generator Hidrogen.

**Abstract:** *At the era of the use of fossil fuels in the energy generation process began to be transferred to environmentally friendly fuels, this is due to the nature of fossil fuels that produce emissions, existing emissions pollute the surrounding environment, so in recent decades, many promoted the transition to the use of renewable energy. Fuel cells technology is the development of an energy generation process based on the chemical principles of the materials used. Hydrogen Generator is a device that can convert existing chemical processes into electrical energy, has low emissions (almost none), making hydrogen generators a better generation option than conventional generators. In the household sector, the use of hydrogen generators as an additional source of energy brings positive benefits, such as reducing carbon emissions generated from the energy generation sector, while also reducing household electricity consumption costs, because electricity supply from manufacturing companies is only used when the power generated by the hydrogen generator is less.*

**Keywords:** *Fuel Cells, Renewable Energy, Clean Energy, Optimazation, Hydrogen Generator.*

## INTRODUCTION

Electricity is one of the primary energy for human life, humans use electricity to help their lives, to powered evices, and to turn on lights, stoves, and water pumps. Present humans use electricity to powered up his vehicles, like bikes, cars, and a drone. But as time went fuel oil, natural gas, and coal were draining to empty, besides that the World Union was published the climate issues, and one of the biggest giver is user of coal and fuel oil. Start from that issue many countries researching on renewable energy. Like water, wind, gas stream, sunlight, and many more. One of the renewable energy was called a fuel cell. Fuel cell converted chemical energy stored into electrical energy, using electrochemical process. The fuel cell have many methods to produce electrical energy, and one of the methods was reduction and oxidation.

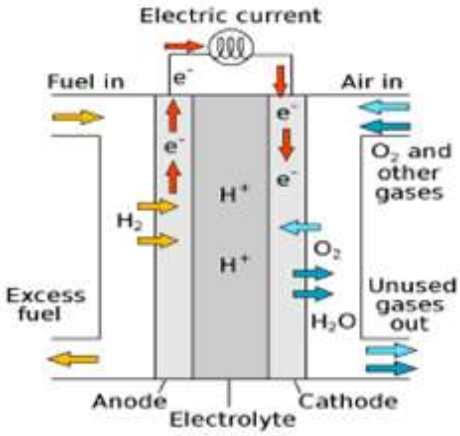


Figure 1. Basic Principles of Hydrogen Fuel Cells

**Membrane-Electrode Assembly**

The first layer of MEA is named proton exchange membrane (PEM), PEM was sandwiched between 2 layers of electrodes (Anode and Cathode). Main function of PEM is conducting the proton, separating fuel oxide, and insulting proton, the ideal PEM should exhibit a high proton conductivity rate, proper water content and gas molecular permeability, good electromechanical stability, with ideal characteristic decomposition temperature (250-500°C), water absorption rate (2,5-27,5 $H_2O/SO_3H$), and conductivity range ($10^{-5}$-$10^{-2}$S $cm^{-1}$. The second layer is Gas Diffusion Layer (GDL). GDL has provides the channel of electrode. The anode is negative electrode which the hydrogen was fueled and the cathode is positive electrode fueled by oxygen. The hydrogen in anode was split into protons ($H^+$) and electrons ($e^-$) through catalyst process. electron, and discharge water generating the reaction. The GDL consist of carbon, water, alcohol, polytetrafluoroethylene (PTFE), or another hydrophobic substance. The MEA has a three generations of development, the development. From this development MEA has increasing the demand for large scale of proton exchange membrane fuel cell (PEMFCs), besides that the development was improving the performance of MEA, lifespan of membrane and reducing the cost.

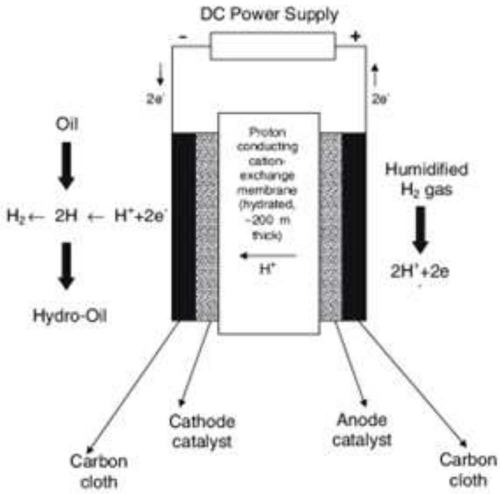


Figure 2. Basic Principles Membrane-electrode assembly

### 1.2 Solid Oxide Fuel Cells (SOFC)

SOFC have high work temperature (600°-1000°C), on high temperature the reaction of molecule can be more efficient, but also using materials that have a high durability, it uses solid oxide electrolyte not polymer membrane. SOFC are commonly uses in large-scale of power generator, like on building or industrial facilities.

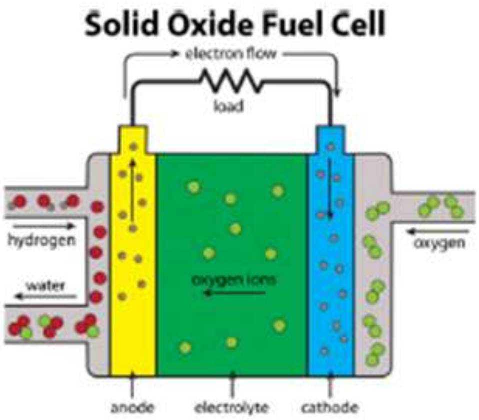


Figure 3. Basic Principle

### 1.3 Alkaline Fuel Cells (AFC)

Compared with another fuel cells technologies, The AFC was more limited users, it's because the AFC was using an alkaline electrolyte instead of an acidic, the AFC also using pure hydrogen and oxygen gases for the reactions. Besides that, the AFC use a lower work temperature (60°-90°C). AFC actually used in space exploration and submarine propulsion.

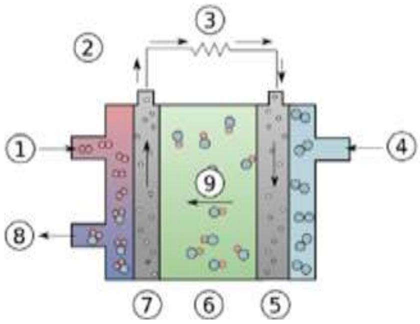


Figure 4. Basic Principles

### 1.4 Polymer Electrolyte Membrane (PEM)

PEM uses a polymer electrolyte membrane as the proton exchange membrane, besides that, PEM also uses a platinum-based catalyst to split the hydrogen molecule into proton and electron. PEM are the most common type of fuel cell technologies, are used in automobile and stationary industries to power the generator.

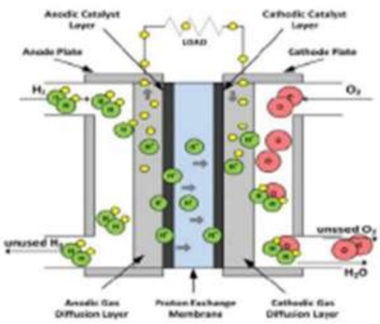


Figure 5. Basic Principles Proton Exchange Membrane

### 1.5 Polymer Electrolyte Membrane (PEM) Fuel Cells Stack

Polymer Electrolyte Membrane generates electricity by combining hydrogen and oxygen like another electrolyser in fuel cells technologies. When the PEM fuel cells operating in closed mode, the rated of power in the fuel cell consume need more much hydrogen. This is fact will affect in the hydrogen amount in storage tank.

### 1.6 Hydrogen Production

Hydrogen production is a fundamental of precondition in a hydrogen power plan, and four decarbonised hydrogen production paths are identified as, water electrolysis, natural gas reforming, solid fuel gasification, and biomass transformation. Water electrolysis can carried with power produced with a higher sharing in renewable in electricity generation proses to ensuring the decarbonisation. Natural gas reforming is combined carbon capture and storage (CCS) or carbon capture usage (CCU) to ensuring decarbonisation. In biomass transformation, biomass through digestion, gasification, or reforming with an upgrading process.

Water electrolysis and reforming technologies is a main path to producing the hydrogen. But it wasn't economically and technically feasible to using electrolysis in produced hydrogen in larger value. According to IEA, global hydrogen production is approximately 70 Mt/year, with 76% was produced from reforming natural gases from many facilities around the world, and the remainder of reforming gas from coal gasification almost exclusively in China. In now day electrolysis distribution only 2% of global hydrogen production, but it can be increasing in assumption the market penetration with increase of renewable energy production. Based on cost of installation projection, electricity that using fossil fuel its was dominated European landscape up to near 2030.

### 1.7 Hybrid Optimization Model for Multiple Energy Resources (HOMER)

Homer is an application that uses to analyse and design micro-power system. It can be use in large number of design operation, and parameters (load size, and future fuel price). In case use a Homer, because the renewable energy source power output may be intermittent seasonal, non-dispatchable. Homer performs three principal tasks: make a system simulation, calculate the system optimization and system sensitivity analysis. Homer can simulate many different system energy configurations, make a specifics time line (hour, day, week, and years) to determine its technical feasibility. When Homer running sensitivity analysis, it can run multiple optimization process under a range from the input. The output from sensibility analysis is to helping the designer calculating the effect of uncertainly or variable changes that can't be controlled by the designer, like a average wind power, sun power, and future fuel cost

## RESEARCH METHODS

### Simulation AC and DC Power Source

For the first condition, we use 2 type generators, first use a power source from main utility manufacture (PLN), in assume the power generator uses fuel base boiler stream. And the second is photovaltaic. In resedential case, photovoltaic has mayorities user, it is because in Indonesia has a big potential in photo energy. For this simulation, we use inverter and rectifier with an efficiency was 95%.

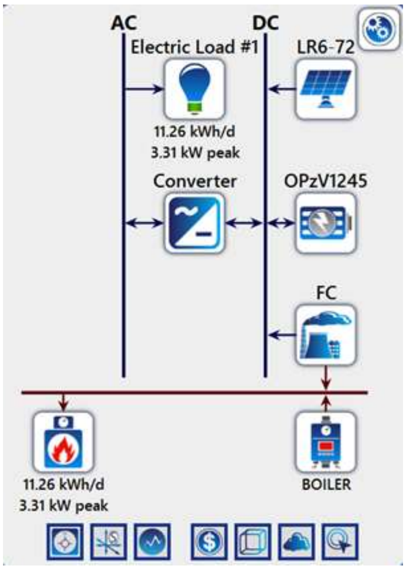


Figure 6. Simulation uses AC and DC Power

## 2.2 Simulation DC Power Source

The second simulation uses 2 type of DC power source, as the first simultaion we using photovoltaic to be backup power in simualtion. For main source using a electrolyzer to generate electircity, and we build tank to stored the hydrogen for electrolyzer supply. And for the backup power, electricity can produce same amount as first simulation

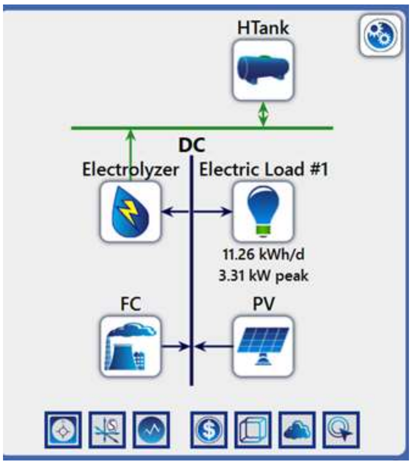


Figure 7. Simulation uses 2 DC Power

## 2.3 Electricity Demand

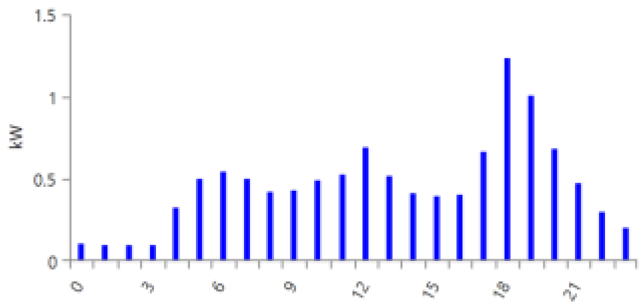


Figure 8: Residential Power Consumption Analysis

Figure 7 illustrated the electricity demand of residentials when people are still sleeping, in 12 at night to 5 am, electricity consumption is still low, recently in the range of 0.10kW, after that it increases as people wake up and carry out their activities. In the picture we can see that 12 noon and 6 pm are the peak hours because 12 noon is the activity for residents to take a lunch break and also at 6 pm when people have just returned from the office, they simultaneously turn on the electricity

## RESULTS AND DISCUSSION

### Simulation AC and DC Power Source

Homer simulation results in figure 9 show the electricity production from a hybrid system consisting of solar panels and fuel cells. Solar panels can produce 8,093 kWh per year, while fuel cells produce 181 kWh per year. In terms of electricity consumption, AC loads require 4,108 kWh per year. The monthly graph shows stable electricity production throughout the year, with solar panels as the main source of energy and minimal contribution from fuel cells. These results show that the system produces more electricity than required, with a significant proportion of renewable energy.

Figure 9. Electrictiy

Figure 10 show the annual emissions data from the resulting energy system. The largest emissions come from carbon dioxide ($CO_2$) with an amount of 997 kg per year, which is the main greenhouse gas resulting from combustion. Carbon monoxide (CO) is produced in small quantities, namely 0.245 kg per year, indicating incomplete combustion. Meanwhile, there were no emissions of unburned hydrocarbons, particulate matter (PM), or sulfur dioxide ($SO_2$), with each recorded at 0 kg per year, indicating that the combustion of the fuel used does not produce these pollutants. Nitrogen oxide ($NO_x$) emissions are also very low, only 0.000761 kg per year.

| Quantity | Value | Units |
|---|---|---|
| Carbon Dioxide | 997 | kg/yr |
| Carbon Monoxide | 0.245 | kg/yr |
| Unburned Hydrocarbons | 0 | kg/yr |
| Particulate Matter | 0 | kg/yr |
| Sulfur Dioxide | 0 | kg/yr |
| Nitrogen Oxides | 0.000761 | kg/yr |

Figure 10: Yearly Emission

Figure 11 shows the total calculation of cost analysis for fuel cells and wind generators. The Net Capital Cost (NPC) includes the capital cost, replacement cost, and operation maintenance cost. The value of fuel cells generators, photo voltaic, and wind generator hybrid systems are lower than systems that use one wind generator and one biomass generator. or use an additional hydrogen generator. But this system are more expensive than a hybrid that use a biomass generator, win generator, and diesel generator. It because cost of installing and spare parts for diesel generator are more cheaper than system that we use in simulation. And for fuel cells system have a lower COE value than other system, it because fuel cells system have more lower energy production, and NPC. Because hydrogen generator that are use in this system can produce 11,26 KW/H for a day. It was lower than other system.

| | Base Case | Lowest Cost System |
|---|---|---|
| NPC | Rp338M | Rp254M |
| Initial Capital | Rp292M | Rp211M |
| O&M | Rp2.06M/yr | Rp1.97M/yr |
| LCOE | Rp3,223/kWh | Rp2,305/kWh |

Figure 11: Summary Cost

### 3.2 Simulation DC Power Source

In figure 12, the schematic of fuel cells using a hydrogen from electrolyze. And photovoltaic is use to be suppling voltage for electrolyze. The hydrogen stored in the tank, the hydrogen is used to produce the electricity. the electricity distributed to the grid. Whit this schematic, we can see the integrated from the renewable energy and conventional energy that contributed to reduce the emission and increasing users of renewable energy.

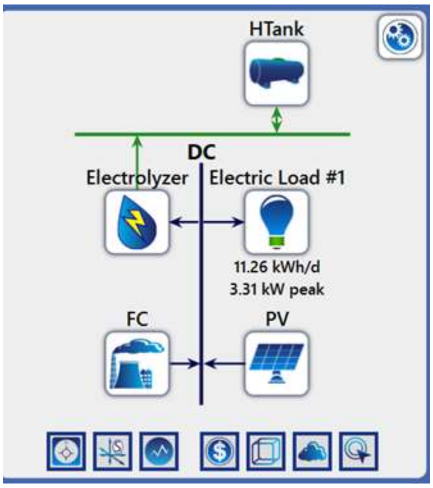


Figure 12: Schematic Fuel Cells and DC Grid

In figure 13 the schematic using a photovoltaic to suppling power to electrolyze and store the energy to the tank, hydrogen is use in fuel cells to produce the electricity. from figure 13 showing the result of fuel cells. The fuel cells systems produce 12,312 KWH/years, PV produce 10,069 KWH/years, and reduce for the electrolyze is 4.017 KWH/Year, PV still have 6,879 KWH/Years. It is indicated that fuel cells can be fill electricity demand. The peak of electricity producing on March to September.

Figure 13: Electricity
Producing

Figure 14 shown us the outcome from the fuel cells productivity has a carbon dioxide emission is 0Kg/Years. That indicate the fuel cells can use to reducing the carbon emission from electricity productivity. But fuel cells have another gas emissions, one of them is Nitrogen Dioxides. Nitrogen Dioxides is pollutant that can make an Acid Rain.

| Quantity | Value | Units |
|---|---|---|
| Carbon Dioxide | 0 | kg/yr |
| Carbon Monoxide | 0.875 | kg/yr |
| Unburned Hydrocarbons | 0.0969 | kg/yr |
| Particulate Matter | 0.0660 | kg/yr |
| Sulfur Dioxide | 0 | kg/yr |
| Nitrogen Oxides | 7.81 | kg/yr |

Figure 14: Yearly Emission
Calculated

The Summary Cost from the schematic is about the NPC and LCOE. NPC from this schematic is higher than schematic that connect to AC Grid, and cost/KWH also higher than PLN. This can happen because schematic which using a natural gas, has a high investment cost. The device that using in the schematic is expensive and rarely to buy than device that using in another grid, and last reason is because the hydrogen fuel is more expensive than another fuel.

| NPC (Rp) | LCOE (Rp/kWh) |
|---|---|
| Rp1.71B | Rp18,730 |

Figure 15: Summary Cost

## CONCLUSION

In the DC-DC power source hydrogen generator can produce 12.312 kWh/year, and for each photovoltaic can produce 10.069 kWh/year. In this area the peak period for electiricity generation is March-September. For the residential AC-DC power source emission has Carbon Diokside has 997 kg/year, and Carbon Monokside 0,245 kg/year, for DC-DC power source not have carbon dioxides and carbon monoxides as emission, but have nitrogen dioxides.

In cost analysis DC-DC power source has more expensive than AC-DC power source, it is because in DC-DC power source investment cost is more expensive (installation cost), and price fuel for hydrogen generator is more expensive than fossil fuel. It was because in DC-DC power source the utility equipment is more expensive, because the hydrogen generator technologies is latest technologies in power generation, its make the technologies more expensive because the equipment still have research.

AC-DC power source its was upgrading from the convensional power generation technlogies, that was adding the photovoltaic to be backup power for main power source from utility manufacture. AC-DC power source has more cheaper than DC-DC power source, because in AC-DC just adding the photovoltaic and battery, but still produced emissions (carbon monoxide and carbon dioxide), it was make DC-DC more friendly for enviromental.

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