DEVELOPMENT OF A HYDROGEN POWERED MICRO GRID FOR GRID SERVICES AND BACK-UP

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HYDROGEN STUDENT DESIGN CONTEST
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EXECUTIVE SUMMARY

Stable energy supply is now increasingly limited because of the use of large for human needs. Most notably energy and transport electrical energy using fossil energy sources. This energy will eventually run out. Under these conditions, the development of renewable energy is increasingly required to be an alternative for fossil energy such as solar, wind, and water. But the availability of energy is not for cash due to several factors of weather, climate and geography. Therefore, the development of energy storage increasingly required from small scale to large scale development to overcome the limitations of such availability.

Hydrogen as an element most commonly found in nature has the potential to be developed. One of the existing development of hydrogen fuel cell technologies such as fuel to provide energy for the vehicle. In addition, hydrogen also has the ability to store large amounts of energy even with a small volume so this element is potentially as an energy reserve. Fluctuations in the electricity grid is now an opportunity for the development of hydrogen energy to provide backup for the grid when macrogrid can’t meet demand for electricity users. At other times, macrogrid potentially be paralyzed for many days due to the potential of natural disasters, wars and so on.

The system are designed in this project is to develop hydrogen into the microgrid system as a support grid and energy reserves. Hydrogen is produced by renewable energy from solar power. PV technology is selected because PV energy efficiency is increasing due to the development of materials selection. In addition, this technology also produces no emissions. Production of hydrogen is produced using electrolyzer with greater capacity. Hydrogen is used to supply electricity during peak time as much as 15% of the total power in macrogrid. In addition, hydrogen is also used to be stored as energy reserves for two days if macrogrid paralyzed and use to provide fuel for fuel cell vehicle.
INTRODUCTION: ENERGY SECURITY

Border area is one of the strategic areas which is the outermost gate of a country. The region will reflect the sovereignty of a country. If the defense in the border region is not constructed properly, then the region will be vulnerable to criminal acts such as illegal goods smuggling, human trafficking, and hiding the separatists. Therefore, the development of defense in the border region becomes absolutely necessary.

The availability of energy is one important factor in the development of a region. The energy availability should be met based on the criteria of capacity, quality, reliability, and efficiency (PLN 2014). Energy availability is sufficient to inhibit the development of industry, trade, tourism, health care, education, social, and political stability, security even in an area. Thus, with the availability of reasonably can improve the security and defense in the border area.

Stable energy needs is indispensable in line with the population growth of a region. However, the network owned by the government to supply electricity to the residents on the West Timor Island is still not sufficient for the energy needs of the population. In addition, the electricity network is not able to compensate for fluctuations in the electrical load that occurs in the community, resulting in the low efficiency of fuel use. Most of the power plants are located in Indonesia currently uses fossil fuels, especially coal. With the condition of the network systems that are inefficient, the more damage to the environment caused by the use of fossil fuel.

The transportation sector is also a primary requirement for today's society. Vehicles required to transport logistics, passenger, went to the office, school, and others. The required intensive needs as well as economic growth and population growth in the area. The majority of Indonesia's population uses fuel vehicles as a source of propulsion for their vehicles. It also produces carbon emissions that affect the environment.

The more impact of global warming today, the more urgent need for the implementation of clean technology that produces no emissions. Hydrogen is an energy carrier into a mainstay for the fuel industry in the future. The need is increasingly urgent hydrogen fuel needed to meet various needs in the community. Car fuel cell technology in the transportation sector is a challenge that can be economic potential to be developed because of the need for a vehicle. In addition, hydrogen is also required for thermal industry for various purposes.

Therefore, an increase in efficiency of hydrogen production is a challenge today. One way to improve the efficiency of energy use in the production of hydrogen is to utilize renewable energy resources. The environment-friendly energy is also expected to reduce the use of fossil fuels, reduce production costs due to the availability of energy is unlimited and quite safe for the environment.

Timor Island geographically has low rainfall. Timor island is very potential for harnessing solar energy. Solar thermal technology with CSP or solar photons with Photovoltaic is a prime candidate for the production of renewable energy. Meanwhile, the island is a geographical Kupang rainfall so low that the probability for the application of energy production technology by utilizing solar energy is getting higher.
2 DESIGN AND EQUIPMENT

2.1 HYDROGEN PRODUCTION

Hydrogen production technology choice focused on some aspects of them convenience, response time, productivity and safety to the environment. Hydrogen production technology is chosen in this project is electrolysis. Electrolysis have been great for productivity, ease of data communication signals, and have a rapid response in the change mode when the production or use of hydrogen in the micro grid.

Electrolyzer that is used in this project comes from the company's products SIEMENS with a production capacity of 25 Nm$^3$/h or 20 kg/h and electrical energy needs for 1250 kW. Production of hydrogen in this project are used to help provide power to the macrogrid system, fueling stations are available and as energy reserves for two days if the system macrogrid paralyzed.

According to data RUPTL (Electricity Supply Business Plan) PT PLN (State Electricity Company) in 2012-2021, peak load electricity on the West Timor island to 2014 reached 59.95 MW of installed power in the network while macrogrid reached 68.32 MW. In our project, hydrogen-powered micro grid can provide electricity during peak loads by 15% during peak hours on macrogrid. Therefore, the power generation capacity is required by PEM FC technology by 9 MW. PEM FC chosen because it does not produce emissions. We use technology PEM FC derived from Hydrogenics Corporation with a capacity of 1 MWe with hydrogen fuel consumption 780 Nm$^3$/h, equivalent to 69 186 kg/h. On the island of West Timor, the peak load occurs average - average for 5 hours (18 AM - 23 PM) so that the fuel for PEM FC 9 unit amounted to 3110,776 kg/day which is used to provide electricity to 15% of peak load in macrogrid per day.

Meanwhile, according to (Rachmawati 2016) contained 63 Fuelling station in Nusa Tenggara Timur. If the fueling station assumed the target of making 10% of the total provided the fueling station that takes as much as 3 units. We assume each fueling station to fill 10 fuel cell cars per 3 days with an amount of 5 kg per charging. Therefore, the need for hydrogen fueling station is 100 kg/day.

On the other hand, the need for energy reserves if the system macrogrid paralyzed for two days was calculated based on peak loads that occur this time plus a 10% increase in order to avoid system outages. Hence the need power needed by 66 MWe. The energy required for the two days reached 3168 MWh. Assuming the efficiency of PEM fuel cell used at 0.49, and the calorific value of hydrogen in the standard state of 33.4 kWh/kg, then the hydrogen requirements for energy reserves for two days as many as 193 572 kg.

Hydrogen is produced by utilizing electrical energy derived from excess energy during off-peak electricity, Photovoltaic power plant owned by the government are available on the West Timor Island and new Photovoltaic power plants designed on the Timor island.

At off-peak time (00 AM - 05 AM), the electrical load that occurs in West Timor Island assumed to be only 50% of peak load due to industrial activities and electrical appliances such as housing residents do not walk during the day or evening. Therefore, the total energy can be stored during the off peak period amounted to 170.8 MWh. Hydrogen production can be maximized at the time by utilizing 27 electrolyzer units. Production of hydrogen that can be achieved during this period amounted to 2732.8 kg/day.
PV-powered power plants with a total capacity of 5 MWp government property can generate hydrogen as much as 400 kg / day assuming a maximum working hours of plant operation and constant for 5 hours. Total production has been meeting the needs of hydrogen per day to supply 9 MW of electricity to the Kupang macrogrid system on the island.

PV-powered power plants with a capacity of 7.5 MWp are designed to meet the needs of hydrogen for fueling stations and energy reserves for two days. Assuming the same with the government-owned power plants, hydrogen can be generated can reach 600 kg / day.

In other words, the production of hydrogen in operation for 5 hours a day during the early hours and 5 hours during midday. At night, the production of hydrogen can be of 2732.8 kg while it was on the day up to 1000 kg. Under normal conditions, our system can provide electricity to macrogrid by 9 MW per day, and provide hydrogen fueling station for 100 kg / day and store hydrogen at 522 kg / day for energy reserves for two days if macrogrid paralyzed.

According to statistical data from PT PLN 2014, power outage amount of electricity in the province of Nasa Tenggara Timur duration of 3.92 hours per customer as much as 4.88 times for 1 year. While on our systems, the charging time for the hydrogen energy reserves for two days reached 371 days. Under these conditions, the project is still proved to be reliable because there is no interference with the macrogrid for 2 days in the period of 371 days.

2.2 ELECTRICITY PRODUCTION

Electricity used to produce hydrogen derived from excess electricity from the system during of macrogrid peaking, PV power plants owned by the government and new PV plants. We use a PV power plants that are already available on the West Timor Island state property with a capacity of 5 MWp with an area of 7.5 ha of land reached. Meanwhile, we also drafted a new PV power plant with a capacity of 7.5 MWp. This design uses the PV of the company Solar Power 435NE with type SPR-WHT-D that produces electricity for 435 W per panel. These products have been selected for the PV efficiency is best compared to the others and has the economic life of up to 25 years. Therefore, the capacity requirements of 7.5 MWp will be reached if there are 15.291 panel units. Based on the specifications SPR 435NE-WHT-D, area of land required to build a new PV plant of 4.2 ha. The width is very likely to be implemented due to more efficient use of land in order to land on the island mussel can be used for other purposes such as residential or production area.
2.3 COMPRESSION

Hydrogen gas is a compression process to meet demand for fuel to fuel cell cars and increase the efficient use of space for storage tanks. In this project, out of the electrolyzer pressure is 35 bar. At a later stage, hydrogen will be pressed to the pressure of 345 bar in storage due to the pressure required for charging the delivery truck with a capacity of 250 bar. At the fueling station, hydrogen gas will be pushed back towards the 850 bar in order to meet the needs of long charging time takes up to 10 minutes and the pressure tank fuel cell cars at 700 bar. The compressor power requirement depends on the hours of operation of hydrogen production. Hydrogen production reached 0.152 kg/s at night, and 0.056 kg/s at noon. Assuming conditions out electrolyzer hydrogen gas at a pressure of 35 bar and a temperature of 40 °C, the compressor power requirements up to 345 bar pressure is

\[
W = \dot{m} \cdot c_p \cdot T_1 \cdot \left( \frac{p_2}{p_1} \right)^{\frac{k-1}{k}} - 1
\]

\[
W = \left( 0.152 \frac{kg}{s} \right) \left( 14.43 \frac{kJ}{kg \cdot K} \right) (40 + 273.15 K) \left( \frac{276}{35} \right)^{1.4 - 1 - 1.4} - 1 = 567 kW
\]

Note: Along 5 hours during night
\[ W = \left( 0.056 \frac{kg}{s} \right) \left( 14.43 \frac{kJ}{kg \, K} \right) \left( 40 + 273.15 \, K \right) \left( \frac{276}{35} \right)^{\frac{1.4-1}{1.4}} - 1 \right) = 203 \, kW \]

Note: Along 5 hour during midday

Specific heat value of hydrogen is obtained from the interpolation table properties at a pressure of 35 bar and a temperature of 40 °C. For backup storage needs energy for two days and a fueling station, the necessary pressure reaches 827 bar with the power requirements of

\[ W = \left( 0.056 \frac{kg}{s} \right) \left( 14.43 \frac{kJ}{kg \, K} \right) \left( 40 + 273.15 \, K \right) \left( \frac{827}{35} \right)^{\frac{1.4-1}{1.4}} - 1 \right) = 371 \, kW \]

Compressor used come from the company’s products with specifications Haskel compressor as follow:

Tabel 1. Model and power of microgrid

<table>
<thead>
<tr>
<th>Model</th>
<th>Supply Pressure (bar)</th>
<th>Hydrogen Max (bar)</th>
<th>Flow rate need (Nm³/s)</th>
<th>Power (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGT-15</td>
<td>35</td>
<td>276</td>
<td>1.71 0.63</td>
<td>567 203</td>
</tr>
<tr>
<td>AGT-30/75</td>
<td>35</td>
<td>827</td>
<td>0.63</td>
<td>371</td>
</tr>
</tbody>
</table>

2.4 STORAGE

Storage is needed to store hydrogen in a certain time. In this project, storage is divided into three, namely the need for the requirements and delivery peak demand, fueling station, and back up for two days.

Peak demand storage and delivery designed to accommodate hydorgen production of 3210 kg / day. Assuming compressors used in pressure of 276 bar and a temperature of 20 °C was obtained Z (Compresibility factor) = 1.2456, then the volume of storage required is

\[ v = Z \left( \frac{RT}{p} \right) \]

\[ = 1.2456 \left( \frac{4124 \frac{Nm}{kg \, K}}{\left( 276 \times 10^5 \frac{N}{m^2} \right)} \right) \left( 293.15 \, K \right) = 0.5456 \frac{m^3}{kg} \]

\[ V = m \times v \]
\[ V = (3210 \, kg) \left( \frac{0.5456 \, m^3}{kg} \right) = 175.2 \, m^3 \]

Peak demand storage and delivery is divided into four storage units with a capacity of 44 m³. Dimensions of the storage tank has a diameter of 1.5 m x 25 m. Assumptions material used is carbon fiber with a strength of 700 MPa (Callister WD 2007). Storage is designed to be able to withstand pressures up to 300 bar. Therefore, the thickness needed to prevent leakage in the tank was 39 mm on the shell and 19 mm at the hemispherical. Storage will be placed in the ground in the area of hydrogen plant. This is done to avoid severe damage if an explosion because most of the blast will not lead to horizontal.

Storage is also designed to use salt cavern method for storage of energy reserves if the system macrogrid paralyzed for two days. Salt cavern is chosen because manufacturing costs are cheaper than storage pressure vessel and a high security level because not much affected environment. The amount of hydrogen to be accommodated in this storage as much as 193 572 kg. If the assumption storage pressure of 827 bar and a temperature of 20°C, the obtained \( Z = 1.5421 \). Using the same equation as above, then the need for salt cavern volume is 4364 m³.

2.5 H₂ FUELING STATION DESIGN AND EQUIPMENT

Hydrogen planning fueling station based on the calculation of the need to meet the demand for hydrogen fuel cell vehicles on the West Timor. The design of hydrogen fueling station is determined by analysis of the nature thermodinamics, heat transfer, materials, fluid mechanics and high-pressure hydrogen gas. The design is expected to ensure that the incorporation of components function used properly.

2.5.1 Gaseous Hydrogen Delivery

In our draft, H₂ is sent using hydrogen gas truck fueling station to 6 units scattered on the West Timor. Placement fueling station will be described in siting part. Truck has capacity of 105 kg at a pressure of 250 bar hydrogen gas enough to meet demand for 60 cars for three days. We assume there is only Light Duty Fuel Cell Vehicles with a capacity of 5 kg / car and the average - average charging as much as 10 cars per fueling station, then at each fueling station capacity of 50 kg of hydrogen. This assumption is based on the number of car ownership in West Timor is not so much especially when the population switching to fuel cell vehicles. So, our designs will be able to provide up to 120 hydrogen fuel cell vehicles per week. The design we used a tube trailer of company Hexagon Lincoln. Delivery of hydrogen can charge to the fueling station is scheduled every day per two stations.

2.5.2 Dispensing

Filling the tank of fuel cell vehicles depends tankage initial condition of the vehicle. Based on TIR SAE J2601 standard, the ability of the dispenser to fill the tank of a vehicle depends on the ambient temperature and the initial pressure of the vehicle tank . High-pressure tank will fill up the tank of his vehicle filled with targets for 10 minutes charging time for charging 5 kg of hydrogen until the pressure of 700 bar (based on the specification guidelines). However, when hydrogen is released, the temperature increase will occur due to contact with the outside
temperature and thus potentially overheating will occur due to the higher charging pressure. To avoid that, hydrogen must be cooled first. Therefore, this project choose dispenser type A with a nozzle that require hydrogen gas at a temperature of -40 °C. In addition, there is a correlation between the ambient temperature and charging time (Schneider 2013) so that our designs will fill the tank until it is full no more than 3 minutes with the assumption that the initial conditions of the vehicle tank pressure 20 bar and a temperature ambient of 30 °C.

When charging, the vehicles using data communication through a wireless communication interface to determine the condition of the vehicle tank contents. When vehicles are required to be filled, the system will calculate the necessary amount of hydrogen based on the condition of the initial SOC (State of Charge) of the vehicle tank of the data sent by the nozzle (Richardson et al 2014). At the time of SOC HAS Achieve 98% - 100%, then the control system tells you wish to reduce the flow rate of hydrogen filling. This is done to avoid overpressure in the tank of the vehicle.

2.5.3 Storage, Compression, and Dispenser

In this design, delivery truck will fill the low-pressure storage tanks at a pressure of 50 bar with a volume of 3 m³. Then the gas will be compressed back with a two-stage compression process using a compressor in order to obtain gas pressure up to 827 bar. The pressure of hydrogen gas in the tank HP is 827 bar with a volume of 1.06 m³. Tank pressure of 827 bar have been selected for minimum pressure differential required in order to meet the needs of the vehicle charging rate of 5 kg for 3 minutes at 70 bar. Gas Booster Resiprocating Haskel with type AGT - 30/75 is used in our design. Compressor is chosen because it can suppress the hydrogen gas more than 770 bar.

![Figure 2. Hydrogen fueling station diagram](image)
Diagram of the charging process can be seen in Figure 2. The need hydrogen filling can be changed every day. This will bring a state where there is a fueling station that will quickly run out while in other places is not quickly exhausted. In anticipation of this, HP Tank made into two units at each fueling station unit that can store hydrogen in the current conditions of excess stock. In addition, there is a warning signal communication system when the stock is low or exceeds the capacity of the storage in a unit. Early warning if the capacity is low especially important on the unit away from the hustle of the city so infrequent users to fill hydrogen at this station. In these conditions, truck transporters must be scheduled to fill the unit. On the other hand, the control system will command the valve to the storage overload will open a fueling station when the condition of excess stock.

Before hydrogen into the high-pressure tank, hydrogen temperature heats up due to the compression process by the compressor. To return to the standard state hydrogen temperature, the required chiller to cool the hydrogen gas using the pool water is circulated. This design was chosen because of the use of water as a cooling fluid powerful enough for large specific heat can absorb more heat than any other fluid.

2.5.4 Safety Equipment

Our system requires equipment - safety to carry out complex operations. The nature of hydrogen that is odorless, colorless, reactive and explosive cause a degree of security that is made must be considered. Our system is equipped with several safety equipment on them like hydrogen detector, fire detector, pressure valve, Electrical shut-off switch, hydrogen leak alarm, fire alarm, fire suppression, HVAC, as well as the patron for the operator. The equipment is connected to a control panel to set the conditions when the operation took place. Hydrogen detector is used to send a warning signal when the found concentrations of hydrogen around this sensor. Fire alarms, fire detectors and fire suppression are needed to prevent and control fires. When the fire broke out at some point, the pressure valve serves to close relationships between components so that the fire did not spread widely. Hydrogen detector, hydrogen leakage alarm and HVAC systems is necessary to maintain the stability of the hydrogen gas in the storage conditions, especially in hydrogen storage plant and fueling station. This is because hydrogen is very responsive to changes in ambient temperature. Temperature sensors and pressure gage is needed to determine the condition of the nature of hydrogen gas in storage in real time on the control panel that does not pass through the normal range of temperature and pressure.

WEH® TK 17 hydrogen fueling nozzle with a data interface selected for fuel dispensing. This is because capable of providing hydrogen when it is connected to the fuel cell vehicle up to 700 bar pressure and in accordance with SAE J2600 and SAE J2799 TIR. The nozzle is fitted with a breakaway coupling and hoses to ensure that users are safe and minimize the danger.

2.5.4.1 HVAC

Hydrogen gas is highly reactive gas. Flammable hydrogen gas is at a concentration of 4% - 74%. For safety reason, the hydrogen storage area designed to be in the bunker located below ground level. This is done to reduce the impact in the event of an explosion. To prevent fire and explosion, it is necessary ventilation and air conditioning was good. Hydrogen is stored in storage tanks in the bunker has a volume of 172.5 m$^3$ at a pressure of 250 bar. To prevent an increase in
the hydrogen concentration quickly, the bunker was designed with a fairly large volume, which has a volume of about 18 times the volume of the storage tank. In addition, the bunkers are natural ventilation and fan located at the top of the bunker. This is due, because the density of hydrogen is very low compared to the air, the hydrogen leaking gas will be collected on the top. Thus, in this way the expected disposal of hydrogen by the fan can be more effective. Bunker was designed to have six pieces of fan with a total discharge of 180 m³/s. The concentration of hydrogen can be kept below 4%, if the leakage discharge is under 7 m³/s. If more than that, then the CO2 gas will be sprayed automatically to reduce fire risk.

2.6 COMMUNICATION

Data communication is a form of communications that are specifically related to the transmission or transfer data between computers, computers with other devices in the form of digital data transmitted over the data communications media. Micro grid processing system uses the concept of combining multiple generators and a group of users in a specific region or in a specific grid. Generator is an initial variable as input provider of energy while the end user is a variable grid as consumers of energy. The role of communication is one of the major factors that are transforming the traditional grid into a set of microgrids. An important aspect of concern in microgrids is that they have variability in their power generation. This influence the two primary issues for the power distribution operation, i.e. voltage control and power flow management.

The communication infrastructure may make use of multiple technologies such as wireless, Ethernet, fiber and power line communications. The effectiveness of the communications between the microgrid components/agents is mostly based on the structure of microgrid and its control system. Generally, there are two approaches for communication infrastructure in a microgrid. It can be centralized, i.e. there is a main controller in the microgrid that collects the required data from agents and performs necessary actions, or it can be decentralized, where every agent has its own controller that will take actions according to their policies. The microgrid components are mostly controlled using a decentralized decision-making process approach in order to balance demand and supply coming from distributed sources and the main grid.

The microgrid will be design based on the smart grid system. The systems alleviate the problems faced by many of the current electrical grid. First, it reduces the amount of power generation is required, because the electric utility network knows exactly how much electricity is required at a particular time. This will not only save money for consumers, but also reduces the amount of harmful air emissions from power plants. To achieve this, the smart grid requires a two-way flow of communication between meters where the energy flows, the control center at a substation to direct the flow of electricity to where it's needed, and power plants to provide electricity. Second, smart grid integrating renewable energy sources into the network by communicating how much input of renewable energy resources will add a variable grid and adjust the system, such as the voltage and the amount of electrical power. Smart grids will also reduce the burden on energy consumption during peak hours. Peak hours are when utility companies are the most expensive to produce energy. The introduction of smart meters allows consumers to monitor electricity consumption per hour and offers the possibility of raising the price peak hours due to increased energy demand and lowered prices of peak demand. Consumers would then
become more aware of the energy they use, to encourage them to save energy at a certain time and run the equipment at night. Smart grids, in theory, can reduce peak loads by encouraging consumers to use less energy during peak hours, flatten the top, and create a more even production of energy to generate electricity and reduce electricity costs.

Grid infrastructure consist of production section, transmission and distribution, and customers section. The smart infrastructure provides the bidirectional energy and data flow depending its energy, intelligence, and communication. The improvement of smart grid does not only promoted by smart energy infrastructure and power electronics, but also by the high-level information infrastructure, monitoring, measurement, and metering operations that provide a widespread communication. The smart measurement requirements such as sensors, networks, and Phasor Measurement Units (PMUs), while smart metering solutions such as Advanced Metering Infrastructure (AMI) [4]. For the communication, cellular technology based on Global System for Mobile (GSM) are used because it’s optimal coverage areas comparing other wireless networks, support million device, low power consumption of terminal equipment and provide high data rate (LTE: 326 Mbps download/86 Mbps upload).

To generate electricity on the grid used generator from the grid macros derived from fossil fuels and micro grid derived from solar energy through photovoltaic technology, the electrolyzer and a fuel cell. In the normal state in the daytime power needs of the user are read by AMI, then the information will be sent wirelessly over the Internet GSM to a server or central control and automatic control center will process the data and ordered makrogrid to supply the demand from users in real time, At the PV solar energy will be converted into electricity and then stored in the form of hydrogen through the process electrolisis. When the demand for electricity in the users is smaller than the capacity of the grid meal macro control center will provide a macro command on the grid to drain excess electricity to the electrolyzer, thereby reducing energy loss and increase energy reserves in the form of hydrogen.

On the state of the evening, electricity and hydrogen production process by PV can not be done because there is no solar radiation. So the production process is done by makrogrid for the needs of the grid in accordance with the capacity of macro grid. If there will be peak demand legible by AMI in the user, the control center will instruct storage and fuel cell preparing to produce electricity. When peak demand occurs then automatically storage1 and fuel cell will operate as well as a number of energy flows with peak needs. Peak demand can be addressed by storage1 is some 15% of peak demand. If the conditions of peak runs above average (peak time > 5 hour) and a pressure sensor on storage1 has shown the limits to be discharged is 10 bar, the system will send information to the control center and the control center will instruct storage2 for preparing to open the valve to the fuel cell and valve will be opened when the pressure in storage1 reached 1 bar. When normal circumstances the information received from AMI, the control center will instruct the fuel cell to stop and close the valve storage2.

On the principle of smart grid, the weather was overcast and rainy season can be predicted by working with a system such as a weather observer and Geofisikia Meteorology Agency (BMKG) so that action can be done early preparations. If the control system receives information tomorrow will be dark or raining then the control system will instruct storage and fuel cell to be
vigilant. However, if natural disasters such as earthquakes, hurricanes, or tsunamis have occurred, corrective action must be done. The corrective action can be done if there is damage to some power transmission is through information received from the user as reports installed sensors or messages sent via the android app either be text, voice calls and video that can be accepted by the control system and the control system will soon change the energy transmission lines and immediately begin to address the damage to the site. However, if the damage is occurring on the system macrogrid so it cause black out the control system will automatically instruct the backup power system through storage2 to drain the fuel cell and hydrogen to generate energy as needed based on the recording of the data AMI. Black out conditions that can be solved for two days, on this occasion can be done to improve the system attempts macrogrid.

Through the application of smart grid, allowing users to manage the use of electrical energy through android-based application so that the user can arrange finance. Additionally in an effort to save energy and lower the chances of excessive peak time then created rules for different prices during peak and off peak time. When peak time occurs then the prices go up and the user is expected to reduce the burden of energy. Peak time data information can be obtained from the use of grid applications.

Figure 3. The microgrid communication network
3 COST AND ECONOMIC ANALYSIS

The feasibility of a project must consider the economic analysis of the design that have been made. This is because the economic aspect is useful to determine the breakeven point between the cost and benefit of cash in this project. In our design, the estimated price based on previous studies is used to determine the capital costs, operating costs and maintenance costs is required by the system. The cost of capital for the projects that we have designed can be seen in the following table 2.

Table 2 Installation Cost

<table>
<thead>
<tr>
<th>Installation</th>
<th>Qty</th>
<th>Units</th>
<th>cost of units</th>
<th>Total (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV</td>
<td>7,500,000 kW</td>
<td>0.7</td>
<td>5250000</td>
<td></td>
</tr>
<tr>
<td>Electrolyzer</td>
<td>33750 kW</td>
<td>460</td>
<td>15525000</td>
<td></td>
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<td>fuel cell</td>
<td>66000 kW</td>
<td>434</td>
<td>28644000</td>
<td></td>
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<tr>
<td>Fueling station 100 kg/day</td>
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<td>1375000</td>
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<tr>
<td>fueling station 150</td>
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<td>fueling station 50</td>
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<tr>
<td>salt cavern</td>
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<td>1355004</td>
<td></td>
</tr>
<tr>
<td>water pond</td>
<td>2 units</td>
<td>5956</td>
<td>11912</td>
<td></td>
</tr>
<tr>
<td>Delivery truck</td>
<td>1 Units</td>
<td>500000</td>
<td>500000</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>55390916</strong></td>
<td></td>
</tr>
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</table>

Table 3 Equipment cost

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Qty</th>
<th>Cost (USD)</th>
<th>Total (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor 276 bar</td>
<td>1</td>
<td>277000</td>
<td>277000</td>
</tr>
<tr>
<td>Compressor 827 bar</td>
<td>10</td>
<td>259282</td>
<td>259282</td>
</tr>
<tr>
<td>Composite storage 100 bar</td>
<td>3</td>
<td>70000</td>
<td>210000</td>
</tr>
<tr>
<td>Composite storage 300 bar</td>
<td>1</td>
<td>2247000</td>
<td>2247000</td>
</tr>
<tr>
<td>Composite storage 827 bar</td>
<td>6</td>
<td>1100000</td>
<td>660000</td>
</tr>
<tr>
<td>Mass Flow rate meter</td>
<td>3</td>
<td>3222</td>
<td>9666</td>
</tr>
<tr>
<td>Temperature sensor</td>
<td>9</td>
<td>33</td>
<td>297</td>
</tr>
<tr>
<td>Pressure sensor</td>
<td>9</td>
<td>250</td>
<td>2250</td>
</tr>
<tr>
<td>Block and bleed valve</td>
<td>9</td>
<td>500</td>
<td>4500</td>
</tr>
<tr>
<td>Isolation hand valve</td>
<td>6</td>
<td>500</td>
<td>3000</td>
</tr>
<tr>
<td>Check valve</td>
<td>6</td>
<td>400</td>
<td>2400</td>
</tr>
<tr>
<td>Hydrogen pre-cooler</td>
<td>3</td>
<td>4000</td>
<td>12000</td>
</tr>
<tr>
<td>HVAC</td>
<td>3</td>
<td>2100</td>
<td>6300</td>
</tr>
<tr>
<td>Breakaway connection</td>
<td>3</td>
<td>3953</td>
<td>11859</td>
</tr>
</tbody>
</table>
The input parameters that we did on this analysis that maintenance costs will increase by 10% from the previous year, the interest rate 6.75% per year and operating costs are considered fixed, but on the other side of this project took a price for hydrogen fuel of 22 USD / kg and the cost of electricity during peak time of $ 0775 / kWh, then the cash flow in the next 10 years can be seen in the table below.

Table 4 Cash flow in 2017 - 2027

<table>
<thead>
<tr>
<th>Years</th>
<th>Cost</th>
<th>Investment</th>
<th>Operation</th>
<th>Maintenance</th>
<th>Revenue</th>
<th>R-V</th>
<th>DF (6.75%)</th>
<th>Riil Now</th>
<th>PV Cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>64828694</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-64828694</td>
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<tr>
<td>2</td>
<td></td>
<td>0</td>
<td>1812754.404</td>
<td>636.12</td>
<td>20191375</td>
<td>18377984</td>
<td>0.87753</td>
<td>16127316</td>
<td>-44602139</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>0</td>
<td>1812754.404</td>
<td>699.732</td>
<td>20191375</td>
<td>18377921</td>
<td>0.82205</td>
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</tr>
<tr>
<td>4</td>
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<td>0</td>
<td>1812754.404</td>
<td>769.7052</td>
<td>20191375</td>
<td>18377851</td>
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</tr>
<tr>
<td>5</td>
<td></td>
<td>0</td>
<td>1812754.404</td>
<td>846.67572</td>
<td>20191375</td>
<td>18377774</td>
<td>0.72137</td>
<td>13257251</td>
<td>-2085209</td>
</tr>
<tr>
<td>6</td>
<td></td>
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<td>931.343292</td>
<td>20191375</td>
<td>18377689</td>
<td>0.67576</td>
<td>12418913</td>
<td>10333704</td>
</tr>
<tr>
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<td>1024.477621</td>
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<td>8</td>
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<td>1126.925383</td>
<td>20191375</td>
<td>18377493</td>
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<td>32865197</td>
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<tr>
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<td>18377257</td>
<td>0.52038</td>
<td>9563169</td>
<td>52637119</td>
</tr>
</tbody>
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<td>2</td>
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<td>20191375</td>
<td>18377257</td>
<td>0.52038</td>
<td>9563169</td>
<td>52637119</td>
</tr>
</tbody>
</table>
With these cash flows, Net Present Value of the project in 2026 of USD 8,623,359 and Net Benefit - Cost Ratio (B / C Ratio) were obtained for 1.099. These values prove the feasibility of this project will be safe when the price is chosen by the business owner at 22 USD / kg H2 and electricity at $ 0.775 / kWh at peak time. Cost of electricity is more expensive than the other because it takes a lot of energy when converting hydrogen into electric energy. In addition, the investment required mainly the cost of PEM fuel cell and electrolyzer is expensive because our system must to ready to supply the energy in the event of power outages for two days.
4 SAFETY ANALYSIS

According to OSHA regulations (occupational safety and health administration), hydrogen included in the category of hazardous, so in general do placements reactor / tank can refer to the system:
1. Upperground
2. Underground

Underground system selected for considering the ease in temperature and environmental control. Underground ambient temperature is lower possible to create that safe storage conditions and avoid the occurrence of self-ignition due to the high temperature of the environment as well as the short circuit. The main building is a place to save storage will be constructed using concrete components so that the temperature underground environment remained low and stable over the possibility of landslides caused by the earthquake.

4.1 MATERIALS AND EQUIPMENT

In general, method of placements reactor / tank can refer to the underground system and upperground. The results conclude that the required two draft laid underground storage. Underground storage system selected by considering the ease in temperature and environmental control. Underground ambient temperature is lower possible to create that safe storage conditions and avoid the occurrence of self-ignition due to the high temperature of the environment as well as the short circuit.

Our team analyzed that there are two storage required. The first storage is devoted to storing hydrogen needs for 2 days so requires space and input pressure. For safety reasons it was designed for the first storage in salt cavern. Salt cavern using rock salt which is very low in porosity, impermeability, chemical neutrality and good mechanical stability. It makes an excellent medium for storing gas. Salt cavern geologically possible to be developed in NTT because most of the rock structure constituent of limestone and geographic location close to the sea. The second storage is devoted to address the needs during peak hours and also to be distributed to the fueling station. It has a smaller volume and lower pressure than the first storage. However, for security reasons storage remains placed in the soil, but not as deep as the concept of the bunker. The main building is a place to save storage will be constructed using concrete components so that the temperature underground environment remained low and stable over the possibility of landslides caused by the earthquake.

Hydrogen reactor design would be prone to leaks, especially on the nozzle, pipe and weld joints on the storage tank. Hydrogen leak detection is done by installing a sensor H2 at some point that allows the leakage in accordance with the FMEA analysis that our team has done. However, when the sensor detects a leak can be ascertained that the concentration of hydrogen in the storage environment is already high due to high pressure inside the hydrogen storage tank and buoyancy properties of hydrogen is high. Therefore, in addition to detecting leaks, jg control system will be designed as a trigger to turn on the alarm, turn off the switch to cut off the electricity, as well as open air vents to channel the hydrogen out of the system and turn off the electrical connections to avoid the occurrence of ignition and explosion.

The system works using a leak detection sensor that is as follows:
1. The sensors will be placed in the space / leaking like a prone position on the storage space, compressor, dispensing station and pipeline installation along which there is a connection.
2. In the event of a leak, the sensor will sound an alarm and indicate the location of the leak on the display / monitor in the control room so that the operator can immediately perform a partial power outage accompanied by the opening of the air vent.
3. In addition to utilizing sensor, jg operator will be assigned to conduct an inspection system for detecting leaks by bringing H2 handheld scanner type. Inspection of leakage is very dangerous (due to high pressure) so that the operator should wear personal protective equipment.
4. After that, fire suppression will conduct an inspection to the site to check the level of leakage and the possibility of potential damage
5. Repair component

4.2 EVENT TREE ANALYSIS

Our team do the analysis of how disaster mitigation, especially in case of a leak like this

![Event Tree Analysis](image)

Figure 4 Analysis of disaster mitigation

4.3 FAILURE MODE AND EFFECT ANALYSIS (FMEA)

FMEA is done to identify the possibility of disaster that could occur and their causes, effects, and prevention. In determining the failure modes that should be addressed, our team has done the calculation set forth in the RPN. The higher RPN value indicates failure mode more dangerous and should be addressed. RPN value is obtained by considering factor, severity of potential damage (Severity), frequency of event (frequency), and the ease to be detected (Detection). These three factor are expressed in scale of 1 – 10.
<table>
<thead>
<tr>
<th>Equipment</th>
<th>Function</th>
<th>Failure</th>
<th>Effect</th>
<th>Causes</th>
<th>Severity</th>
<th>Frequency</th>
<th>Detection</th>
<th>Mitigation</th>
<th>RPN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen Storage vessel</td>
<td>To store high pressure hydrogen in gaseous phase</td>
<td>Leakage</td>
<td>Release hydrogen to the environment and cause potential fire hazard</td>
<td>leak at the weld joint</td>
<td>10</td>
<td>4</td>
<td>8</td>
<td>Design according to regulations</td>
<td>320</td>
</tr>
<tr>
<td></td>
<td></td>
<td>material fracture</td>
<td>Release hydrogen to the environment and cause potential fire hazard, explosion</td>
<td>excess hydrogen supply pressure</td>
<td>10</td>
<td>2</td>
<td>10</td>
<td>Install a pressure regulator on the storage vessel</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>corrosion</td>
<td>reduced ability to accommodate the hydrogen storage</td>
<td>environment</td>
<td>8</td>
<td>5</td>
<td>8</td>
<td>design hydrogen environment</td>
<td>320</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crash / collision</td>
<td>explosion, potential fire hazard, building destruction and personnel death</td>
<td>clash of heavy equipment or vehicles</td>
<td>8</td>
<td>2</td>
<td>6</td>
<td>installing protective around storage, put up signs vehicles</td>
<td>96</td>
</tr>
<tr>
<td>Valve and Pipe</td>
<td>to transfer hydrogen to the vehicles</td>
<td>leakage</td>
<td>Release hydrogen to the environment and cause potential fire hazard</td>
<td>weak connection, overpressure</td>
<td>10</td>
<td>4</td>
<td>8</td>
<td>Install pressure regulator</td>
<td>320</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Corrosion</td>
<td>the reduced strength of the material composing the pipe</td>
<td>environment</td>
<td>8</td>
<td>5</td>
<td>8</td>
<td>design hydrogen environment</td>
<td>320</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fracture</td>
<td>hydrogen leak causing explosion or fire hazard</td>
<td>natural disasters such as landslide, earthquake</td>
<td>8</td>
<td>2</td>
<td>10</td>
<td>design hydrogen environment</td>
<td>160</td>
</tr>
<tr>
<td>Dispensing Station</td>
<td>transfer hydrogen to the vehicles</td>
<td>leakage</td>
<td>potential fire hazard</td>
<td>instrument functional failure, operator carelessness</td>
<td>10</td>
<td>4</td>
<td>8</td>
<td>installation of fire suppression, H2 scanners, and alarm and system design according to regulations</td>
<td>320</td>
</tr>
<tr>
<td></td>
<td></td>
<td>accident (collisions with cars)</td>
<td>explosion, potential fire hazard, building destruction and personnel death</td>
<td>driver error</td>
<td>8</td>
<td>2</td>
<td>8</td>
<td>installation of barrier to avoid direct collision, installation of signs vehicles</td>
<td>128</td>
</tr>
<tr>
<td></td>
<td></td>
<td>fire</td>
<td>explosion, potential fire hazard, building destruction and personnel death</td>
<td>operator error, their short circuit</td>
<td>8</td>
<td>3</td>
<td>10</td>
<td>installation of fire suppression, installation of a power outage switch in case of short circuit</td>
<td>240</td>
</tr>
<tr>
<td>Compressor</td>
<td>Pressurized hydrogen</td>
<td>Fracture</td>
<td>hydrogen leak causing explosion or fire hazard</td>
<td>the pressure generated during the compression process exceeds the ability of the compressor</td>
<td>8</td>
<td>3</td>
<td>8</td>
<td>design of materials according to regulations, to control the pressure using a hydrogen analyzer</td>
<td>192</td>
</tr>
<tr>
<td></td>
<td></td>
<td>leakage</td>
<td>potential fire hazard</td>
<td>The weak joints between pipes</td>
<td>10</td>
<td>6</td>
<td>10</td>
<td>installation of fire suppression, H2 scanners, and alarm and system design according to regulations</td>
<td>600</td>
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<tr>
<td></td>
<td></td>
<td>corrosion</td>
<td>decreased ability of the compressor</td>
<td>environment</td>
<td>5</td>
<td>4</td>
<td>8</td>
<td>design hydrogen environment</td>
<td>160</td>
</tr>
</tbody>
</table>
4.4 REGULATIONS, CODES, AND STANDARDS
The following are some regulations, rules, and existing standards and that can be used:

**Hydrogen Safety Regulations**
OSHA 1910.103 Subpart H Hazardous Materials

**Building and Construction**
ANSI/IEEE 1547-2003 Standard for Interconnecting Distributed Resources with Electric Power Systems
FSM Division 10.03 Fire Apparatus Accessibility includes NFPA1 Fire Prevention Code, NFPA241
FSM Division 13.01 Fire Alarm Systems
FSM Division 13.02 Fire-suppression and protection system
FSM Division 13.03 Fuel Storage Tanks
FSM Division 13.04 Wet Chemical Fire Extinguishing Systems
FSM Division 15.06 Plumbing – Gas Lines and Piping
FSM Division 16.03 Outdoor Power Transmission and Distribution
FSM Division 16.04 Basic Electrical Materials and Methods
FSM Division 16.05 Emergency Power
FSM Division 16.06 Fire Protection System
FSM Division 16.12 Uninterruptible Power System
FSM Division 17.01 Central Control and Monitoring System CCMS
EPA Title 40 CFR parts 260-268 includes hazardous waste management systems.
FERC Order No. 2006-B "Small generator” interconnection standards for distributed energy resources up to 20 megawatts (MW)

**Fire Protection**
NFPA 70 National Electric Code, Article 692 Fuel Cell Systems
NFPA 72 National Fire Alarm Code
NFPA 101 Life Safety Code
NFPA 110 Standard for Standby Power Systems
NFPA 170 Fire Safety Symbols

**Design and Maintenance**
IEC 62282-3-1: Fuel Cell Power Systems – Safety
IEC 62282-3-100 – Stationary Fuel Cells - Safety
ANSI/INHPA 853 Installation of Stationary Fuel Cell Power Plant
ANSI/CSA America FC1-2400 Fuel Cell Power Systems
NFPA 50A – Standard for Gaseous Hydrogen Systems at Consumer Sites
NFPA 52 – Compressed Natural Gas (CNG) Vehicular Fueling System Standard
NFPA 54 – National Fuel Cell Code
NFPA 55, ISO-TC 58 – Hydrogen Storage routine checking of mechanical stress
NFPA 55, ISO-TC 58 – Hydrogen Storage maintain safe external conditions
NFPA 55, ISO-TC 58 – Hydrogen Storage adjustable valve at outlet; temperature sensor
NFPA 55, ISO-TC 58 – Hydrogen Storage utilize tanks with high pressure capacities
NFPA 55, ISO-TC 58 – Compressors temperature sensors
NFPA 55, ISO-TC 58 – Compressors routine checking of inflow and outflow
NFPA 55, ISO-TC – Compressors routine checking of inflow
NFPA 55, ISO-TC 58 – Compressors adjustable valve at outlet
NFPA 55, ISO-TC 58 – Compressors routine checking of mechanical stress
NFPA 55, ISO-TC 58 – Compressed Gas Cylinders routine checking of mechanical stress
SAEJ2600 – Hydrogen Dispensers
SAE J2601 – Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicle
ISO 9001: 2000 – Vapor-Liquid Separator Adjustable valves at inlet and outlet
ISO 9001: 2000 – Pressure Swing Adsorption Unit routine checking of valve function
ANSI B31.3 – Piping Design Standards
ASME B31.1, B31.3, B31.9 – Piping/Valves routine checking of mechanical stress
ASME B31.1, B31.3, B31.9 – Piping/Valves routine checking of mechanical stress
ASME B31.1, B31.3, B31.9 – Piping/Valves proper and gradual closing of valves
ASME BPV Code, Section IX – Welding and Brazing Qualifications
ASME BPV Code, Section VIII, Division I – Rules for Constructions of Pressure Vessels
ASME PTC 50 Test procedures, methods and definitions for the performance characterization of fuel cell power systems.
5 SITTING

Proper placement microgrid system and fuel system aims to develop a system of power production efficiently and effectively so as to achieve a production process with the most economical cost. The location is also greatly affect the cost, fixed or variable costs. The location greatly affects the overall risks and benefits. In lokasi yang microgrid projects planned is in the province of East Nusa Tenggara. The choice of location is based on the peak load on the city of Kupang is 59.95 MW. The main microgrid system will be put on the area Oelpuah. This location is a strategic location because it is put on the ground a huge empty is 7.5 hectares (Figure 5). The location is also not far from the sea is 4 km. The sea water will be supplied to the site and going through the process of distillation. At this location there is also a storage that stores fuel cell. The location is also close to 4.2 ha PV project built by the government.

![Figure 5 Micro grid location](image)

The project will also produce a fuel cell and three fueling station will be built on the Kupang, Kefamenanu, and Atambua area who coined distance of 289 km (Figure 6).

![Figure 6 Fueling station location (white point)](image)
The first location is at the fuel station Yos Sudarso Kupang City. This location is very strategic because of the fuel station is located on the main traffic road and located in the middle of town so easy to reach. Fuel station capacity is 150 kg. This is because the number of shares based many car users are assumed to be in this city (Figure 7).

![Fueling station location in Kupang](image)

**Figure 7 Fueling station location in Kupang**

Second location is in kabupaten Kefamenanu. This is to facilitate motorists heading east NTT place this location is 202.4 km from the city center mussel. At these locations will be built fuel station with a capacity of 50 kg of fuel cell. This is to facilitate motorists who want to make a trip to the Atambua or Timor Leste. (Figure 8)

![Fueling station location in Kefamenanu](image)

**Figure 8 Fueling station location in Kefamenanu**

And the last location is Atambua that located 126 km from Kefameanu. The location is very strategic for riders who want to go to or leave the state of Timor Leste (figure. 9).
Figure 9. Fueling station location in Atambua

For each fuel filling will be done in the schedule for 3 days. Using the first trucks carrying fuel cells is 105 kg. Scheduling is shown in the following table:

Table 6 Schedule fuel filling station

<table>
<thead>
<tr>
<th>Location</th>
<th>Previous location</th>
<th>Distance (km)</th>
<th>Time</th>
<th>Contain Capacity (kg)</th>
<th>Fill scheduled (hari)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kupang City</td>
<td>Oelpuah</td>
<td>22.7</td>
<td>42 min</td>
<td>100</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>City Kupang</td>
<td>Oelpuah</td>
<td>22.7</td>
<td>42 min</td>
<td>50</td>
<td>II</td>
</tr>
<tr>
<td>Kefamenanu</td>
<td>Kota Kupang</td>
<td>202.4</td>
<td>4 h 39 min</td>
<td>50</td>
<td>II</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atambua</td>
<td>Oelpuah</td>
<td>263</td>
<td>5 h 40 min</td>
<td>100</td>
<td>III</td>
</tr>
</tbody>
</table>
6 ENVIRONMENTAL ANALYSIS

Based on the calculations have been done, it can be seen that the land required for the production of hydrogen is an area of 4.2 hectares, while the total area of the province of NTT on the island of Timor is 1.43943 million hectares. Making a production uses only 0.0003% of the island of Timor. This indicates that the making of a hydrogen production can still be done because there is land availability.

The use of land on the island of Timor only form of utilization as agriculture, moor, residential, industrial, forestry, plantation and fisheries. Hydrogen power will be built in 10°08’01.2”S 123°44’05.55”E, where the coordinates of the location of the only form of open ground. That is, the development of hydrogen power does not lead to land clearing but what happens in the form of land use.

Based on from the annual data local government, it can be seen that the number of visitors coming to NTT in 2012 reached 181 856 people. Kupang, including from NTT, is included prospective terms of tourism and thus require considerable energy supply. As is known, the eastern part of Indonesia is still minimal in the supply of the power source. The application of hydrogen fuel as a source of renewable electrical energy for electricity and vehicles in Kupang, NTT, greatly help local communities in meeting electricity needs while preserving the beauty of the environment in Kupang, NTT.

6.1 RESOURCE ANALYSIS

The energy source that used in the manufacture of hydrogen energy is solar energy. Electrical energy is used covers 15% macrogrid during off peak of 170.8 MWeh, PV (Photo Voltaic) Government of 25 MWeh, and additional new PV power plant of 37.5 MWeh. Hydrogen can be produced by electrolysis of 3732.78 kg H2 / day, divided into H2 3110.78 kg / day (8.99 MWeh) for peak demand, 100 kg H2 / day for the fueling station, and 522 kg H2 / day is stored to address blackout (figure 1).

Figure 1 Hydrogen production planing
The need for pure water for hydrogen production is 63.12514 m³ / day. There are two water resources that can be used: sea water and lake water. The City Kupang is the coastal area with rainfall of 2140 mm per year (climate.data.org). In the dry season, Kupang communities rely on Tilong dam raw water to meet the needs of 4.5 million m³ / year (SOE 2002). Rainwater can be accommodated in the dam Tilong of 3.3 million m³ / year. Kupang communities tend to lack water. Fulfillment of water for hydrogen production will intersect with the fulfillment of the raw water and irrigation farming in the mussel. Therefore, seawater selected as Feedstock in the manufacture of hydrogen. Pemurinian sea water electrolysis using a desalinator RUIAN HONETOP with an output capacity of 3000 liters / hour. Needs sea water with pure water yield of 80% is 375,000 liters of sea water / hour.

![Figure 2 Energy balance for producing hydrogen](image)

Energy balance in the production of hydrogen include desalination process, electrolysis, and compression. All these processes using electrical energy from PV. Electrical energy needs desalinization process of 0.00183 kW·h / l pure water, electrolysis of 0.057 MWeh / kg H₂, and Compression of 2.349 kW·h / kg H₂ (figure 2). Compression is done through a 2 stage is 35-620 bar and 620-827 bar. These compressors have isentropic efficiency of 80%. While the electrolyzer has a 49% efficiency.

6.2 EMISSION ANALYSIS

Electrical energy lost from the micro grid during off peak can be reached 170.8 MWh. The energy loss can be overcome by using energy during off-peak for producing hydrogen. Hydrogen can be produced amounted to 2732.8 kg / day. Hydrogen can be stored for use during peak hour. In addition, to cope with peak hour, hydrogen produced from solar PV is also used. Electricity used to produce 400kg / day of hydrogen is 25 MWh.

Hydrogen production from solar PV generating emissions of 30.6gCO₂ per MJ, GCO per MJ 0.0210, 0.0251 gNOx per MJ, and gVOCs 0.00195 per MJ (Dincer I, Veziroglu TN 2010). Thus, emissions from hydrogen production from solar PV and hydrogen production from macrogrid of 153.933 kgCO₂. Based on the assumption that typically, large subcritical
coal-fired utility plants today produce around 900 kgCO$_2$ / MWh or 250 gCO$_2$ / MJ (International Energy Agency, 2010). If the peak electricity comes from coal macrogrid energy, emissions during peak reached 176,220 kgCO$_2$ (Figure 3). So with the same energy, hydrogen can produce smaller emissions with a difference of 22,288 kg CO$_2$.

Figure 3 Emission comparison of peak hour backup energy source

Furthermore, solar PV is used to save additional energy by 6,466 MWh used to meet the needs of electricity when blackouts for a two-day total. Electricity from solar PV is used to produce hydrogen that can be stored in the storage. The hydrogen will be used as a source of electrical energy when blackouts for a two-day total. Emissions generated in the production of hydrogen from solar PV is equal to 54,961 kgCO$_2$. It is much smaller than emissions from macrogrid with the same amount of electricity. Emissions from macrogrid sourced from coal amounted to 5,819,400 kgCO$_2$ (figure 4).

Figure 4 Emission comparison of 2 days blackout backup energy source

The production process for hydrogen fueling station, a power source that is used is the solar PV of 18.75 MWh so that emissions from the production for 3 days amounted to 159 kgCO$_2$. Fueling station designed hydrogen can provide as much as 300 kg every three days for three fueling stations. The amount is equivalent to filling 60 units of fuel cell cars to travel distances as far as 156.25 miles. That means, the use of hydrogen energy in automobiles to reduce emissions of 60 units of gasoline-fueled cars. Based COPERT II emission factor and transport research laboratory of data, combined with real road testing the data, produces petroleum small vehicles 0.28 kgCO2/mile. Therefore, the emissions generated by 60 units of small car with a distance of 156.25 miles petroleum amounted 2,625 kgCO$_2$. 
Table 5. Default distance based emission factors for different types of mobile sources
(Tables 5.1 to 5.5 are from Environmental Reporting – Guidelines for Company Reporting on GHG Emissions, DEFRA, UK)

Table 5.1: Passenger Road Transport Conversion Factors: Petrol cars

<table>
<thead>
<tr>
<th>Size of car and distance units</th>
<th>Total units travelled</th>
<th>Units</th>
<th>$x$</th>
<th>kg CO$_2$ per unit</th>
<th>Total kg CO$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small petrol car Max 1.4 litre engine</td>
<td>miles</td>
<td>$x$</td>
<td>0.28</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>km</td>
<td>$x$</td>
<td>0.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium petrol car From 1.4 – 2.1 litres</td>
<td>miles</td>
<td>$x$</td>
<td>0.36</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>km</td>
<td>$x$</td>
<td>0.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large petrol car Above 2.1 litres</td>
<td>miles</td>
<td>$x$</td>
<td>0.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>km</td>
<td>$x$</td>
<td>0.27</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Average Petrol car</td>
<td>miles</td>
<td>$x$</td>
<td>0.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>km</td>
<td>$x$</td>
<td>0.20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: COPERT II emission factors and Transport Research Laboratory data, combined with real road testing cycle data

Table 5.2: Passenger Road Transport Conversion Factors: Diesel cars

<table>
<thead>
<tr>
<th>Size of car and distance units</th>
<th>Total units travelled</th>
<th>Units</th>
<th>$x$</th>
<th>kg CO$_2$ per unit</th>
<th>Total kg CO$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small diesel car 2.0 litre or under</td>
<td>miles</td>
<td>$x$</td>
<td>0.19</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>km</td>
<td>$x$</td>
<td>0.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large diesel car Over 2.0 litre</td>
<td>miles</td>
<td>$x$</td>
<td>0.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>km</td>
<td>$x$</td>
<td>0.14</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Average diesel car</td>
<td>miles</td>
<td>$x$</td>
<td>0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>km</td>
<td>$x$</td>
<td>0.12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: COPERT II emission factors and Transport Research Laboratory data, combined with real road testing cycle data

Table 5  The amount of CO$_2$ emission from delivery truck to fueling station

<table>
<thead>
<tr>
<th>fueling station(FS)</th>
<th>Distance from hydrogen plant (km)</th>
<th>Distance from hydrogen plant (mil)</th>
<th>Total of truck (unit)</th>
<th>Total CO$_2$ emissions (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS 1</td>
<td>22.7 x 2</td>
<td>16.1 x 2</td>
<td>1</td>
<td>36.456</td>
</tr>
<tr>
<td>FS 2</td>
<td>202.4</td>
<td>111.3</td>
<td>1</td>
<td>162.527</td>
</tr>
<tr>
<td>FS 3</td>
<td>203 x 2</td>
<td>163.8 x 2</td>
<td>1</td>
<td>326.018</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td>525.001</td>
</tr>
</tbody>
</table>
6.3 NOISE ANALYSIS

Fuel cells are used in the hydrogen production process has a noise level of 75 dB per unit. Planning for the long term will provide 60 units of fuel cells as a replacement for all current electrical power outages, because the fuel cell provides a maximum of 1 MW. However, the current electricity production is running normally, the fuel cell is used only as much as 9 units per day. Therefore, the noise is only 75 dB per day. The tools were in the room so as not to impact on the surrounding environment. Employees who are inside can also be overcome by using earmuff to drown out the noise.
Hydrogen for backup power and dispensing

Zero Emission %

Hydrogen energy for backup power in smart grid system and dispensing that use renewable energy for a better environment
Reference


APPENDIX

Site Plan

Fueling Station