

Renewable energy sources research report :



Think Pacific Foundation (Fiji)

Prepared for: The Think Pacific Foundation

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Action Project aim: Provide Research for Think Pacific on alternative, renewable sources of energy instead of petrol generators for rural villages of Fiji, considering benefits and possible negatives of different renewable energy sources.



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Section 1- Introduction

Think Pacific is an incredible Fijian charity who works to support and strive towards sustainable development of Fiji's rural communities. This charity is far more than just environmental sustainability, they also help in areas such as education, advocacy, sports development, health, business/management improvement, youth development and infrastructure development. The Think Pacific Foundation works with a variety of NGO's, charities and businesses to work towards positive changes in Fijian Communities.

In all of Think Pacific's projects they work with the 17 United Nations sustainable goals in mind, and in this action project I aim to do the same, in particular keeping in mind goal 7 (affordable and clean energy), goal 11 (sustainable cities and communities), and finally goal 13 (climate action). My research objective is to discover alternative sustainable forms of energy instead of petrol generators currently in use in rural communities of Fiji to provide Think Pacific with inspiration on changes that can be made.

I chose to undertake researching alternative renewable energy sources for rural communities for Think Pacific as I am aware that rural communities are at the heart of Fiji and these villages, and their people, deserve to have energy that is sustainable for their environment. I wanted to complete a project that aligned with the inclusive socio-economic development of Fiji, with no one being left behind in terms of a variety of factors such as gender, ethnicity and geographical location (of course including rural areas).

By researching alternatives for the petrol generators currently used in rural areas for stronger surges of electricity it is my hope that these findings will be implemented in the near future, or at least considered/used as inspiration. I have created this detailed research report word document, for detailed research notes, and completed a PowerPoint for a summary of these notes and an simpler platform for the delivery of my presentation at the end of my remote internship. I have also included a reference list of sources for my research in case further information is needed/wanted.



Section 2- Renewable sources already in use in Fiji

Fiji is an admirable country with the efforts they have already made towards the use of renewable energy sources with 50% of Fiji's energy source being hydropower, 5% biomass and wind. However, Fiji still relies on fossil fuels for 45% of their power source, therefore this project aims to give inspiration and new ideas surfacing on other alternative energy sources that Fiji can begin to start utilising to further reduce their reliance on fossil fuels.

Fiji already uses solar, wind, biomass, geothermal and hydropower forms of energy.

Section 2.1- How are these source used in Fiji and how useful are these sources?

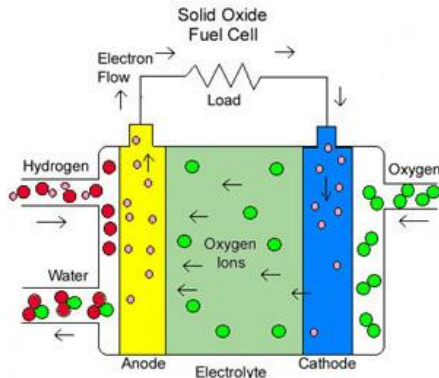
- **Hydro power-** In Viti Levu there is a 42- megawatt Nadarivatu hydropower station which is located in the remote central area of Viti levu in Fiji. This hydropower station reduces the countries dependence on expensive, imported diesel and provides 20% of the island's electrical needs.
- **Solar-** As explored in the decide phase of my internship, Fiji has companies such as solar Fiji which is helping towards cleaner renewable energy.
- **Geothermal-** There was an intensive study on the power generation options on Viti Levu conducted in 2009 by the Japanese government. Findings included:
 - ❖ 2 potential sites identified for geothermal energy production being Tavua and Sabato.
 - ❖ Estimated production of 6MW geothermal generation.
 - ❖ Further studies into sub-surface was suggested (drilling) to confirm definite geothermal energy generation.
 - ❖ 1MW saves 5,100 tons of CO2 emission.

Fiji is identified by the geothermal energy association as one of 39 countries that could meet their electricity demand solely by tapping the renewable energy from the underground heat.

- **Wind-** Fiji has a grid-connected 10 MW wind farm situated in the Butoni hills of Sigatoka. The wind farm consists of 37×275kW Vergnet wind turbines, which are connected to the EFL grid network.
- **Biomass-** use of biomass for steam and electricity generation in Fiji include the sugar mills, copra oil mills, soap factories, several large and small sawmills (Malau, Drasa) and some small power generation systems, such as the one in Wainiyaku in Taveuni. Total production of biomass was estimated at 72.67 PJ, 24% from food, 44% of agricultural residues, 10% dung and 22% from forestry. Only 11% was used as fuel, 12% as industrial wood and 24% as food. Biomass is very useful to Fiji as It is the most important energy source for most of the Pacific Island Countries, with its contribution to the total energy supply ranging up to 63%. Fiji, PNG, Samoa, Solomon Islands and Vanuatu depend heavily on biomass for over half of their total energy needs. Biomass does release CO₂ but at a considerably lower rate than burning fossil fuels.

There has been great progress/use of renewable energy sources and Fijis draft National energy plan 2014 hopes to create stronger institutional framework, reducing risk perceptions surrounding renewable energy development among investors and lenders. Despite this, the Renewables Readiness Assessment (RRA) report calls for closer coordination among government ministries and donors to particularly deploy off-grid renewable energy technologies to achieve faster progress on rural electrification.

Section 3- Hydrogen fuel cells as an alternative renewable energy source. How does it work?



As stated in the project details, rural villages currently use solar energy for small scale charging and stronger surges of electricity are created using petrol generators. Due to these petrol generators being expensive, loud and a pollutant to the environment research needs to be conducted to explore sustainable alternatives to petrol generators.

Hydrogen fuel cells are a current renewable energy source being used as an alternative to petrol generators. These Hydrogen fuel cells generate electricity from an electrochemical reaction and is considered to be environmentally friendly. Hydrogen is a carrier of energy, which can be produced from various resources. Molecular hydrogen is a fuel containing approximately six times more energy per kilogram (2.20 pounds) than gasoline and twelve times more energy

per kilogram than coal.

Fuel cells = they operate like a battery but does not run down or require charging, it will produce energy in form of electricity and heat as long as fuel is supplied. consists of two electrodes sandwiched around an electrolyte. Oxygen passes over one electrode and hydrogen over the other, generating electricity, water and heat. Hydrogen fuel is fed into the "anode" of the fuel cell. Oxygen enters the fuel cell through the cathode. Encouraged by a catalyst, the hydrogen atom splits into a proton and an electron, which take different paths to the cathode. The proton passes through the electrolyte. The electrons create a separate current that can be utilised before they return to the cathode, to be reunited with the hydrogen and oxygen as a molecule of water. A fuel cell system, which includes a "fuel reformer", can utilise the hydrogen from any hydrocarbon fuel - natural gas, methanol, and even gasoline. Since the fuel cell relies on chemistry and not combustion, emissions from this type of a system would still be much smaller than emissions from the cleanest fuel combustion processes.

- **Hydrogen production from water=** Electrolysis of water is the most common method of hydrogen production. An electrical current is passed through electrodes emersed in electrolytic solution separated into two chambers by semi-permeable membrane. Electrical energy splits water molecules into hydrogen and oxygen gases. This creates no sir pollution with energy efficiencies generally exceeding 80%. Electricity needed cane be created by renewable energy sources. There are various methods to produce hydrogen directly from renewable energy without electricity some include:
 - Direct Photoelectrochemical conversion= where sunlight hits the electrolytic solution in which photosensitive semiconductors and catalysts are suspended. The energy absorbed by catalysts creates electricity which triggers splitting of the water molecule into O₂ and H.
 - Thermal decomposition= Concentrated solar thermal energy can get to temperatures exceeding 2760 degrees Celsius (5000 Fahrenheit). Water thermally decomposes into hydrogen and oxygen in these conditions. However, the separation of gases before they spontaneously recombine is one problem facing this technology.

- **Hydrogen Production from Hydrocarbons=** This requires a fuel reformer which will carry out the extracting process. Cheapest way is usually by natural gas. To split the hydrogen from the carbon in natural gas (mainly methane, CH₄), the methane is mixed with high temperature steam under pressure, and with a catalyst present, produces carbon monoxide (CO) and hydrogen, a process called steam reformation. Another reaction known as “a shift reaction” is then applied to produce more hydrogen and some water from the carbon monoxide. Transforming other hydrocarbons such as biomass into hydrogen can be achieved by partial oxidation.

Section 3.1- Positives

- Molecular hydrogen, consisting of two bonded hydrogen atoms, contains an estimated 6 times more energy per Kilogram than the unrenewable energy source gasoline, and 12 times more energy per kilogram than coal. Not only would this be a renewable source it would allow for much more power per kilogram than current fossil fuels in place, therefore more environmentally and economically friendly in the long run.
- The product of the electrochemical reaction from the chemical combination of hydrogen and oxygen is water. No carbon dioxide, hydrocarbons, carbon monoxide, sulphur compounds or any toxic pollutants are released therefore little or no pollution is produced compared to petrol generators which emit nitrogen oxides, carbon monoxide particulate matter and sulphur. All of which are incredibly damaging to not only the environment but also to humans, pets and the beautiful biodiversity of Fiji.
- Introduction of Fuel cells into the pacific region will relieve the regions dependency on fossil fuel, which have been creating growing strain on small islands, such as Fiji's, economy. Fuel cells would dramatically decrease air pollution, fossil fuel imports and reduce trade deficit.
- The article “Hydrogen Fuel cells to power rural areas?” by Arnes Biogradlija explored the work of Sofia Pelaez who conducted a feasibility study of a photovoltaic systems, fuel cells and hydrogen and their application in isolated areas showed promising results in relation to hydrogen fuel cells being used in rural areas of Leon. The found that research offers solutions to the problems of obtaining energy in off-grid areas. This is especially useful in rural areas in provinces such as León and is based on “mixing” a photovoltaic system with a hydrogen system, which consists of an electrolyser and a fuel cell. “A photovoltaic system has certain limitations, since it needs to be in a usable area and depends on the climate. The one I propose uses hydrogen cells, which store three times more energy than fossil fuels such as oil or natural gas,” And in relation to costs another researcher Vegazana Campus stated promisingly, “One of the main conclusions I have drawn is that in a few years, with the advances in these electrolyser and fuel cell technologies, it will be much cheaper and then they will be economically viable.”
- The implementations of renewable energy sources such as solar, hydro, biomass and wind shows clear, strong and promising indication of Fiji being ready for the introduction of more new energy resources like hydrogen fuel cells.
- Some pacific island countries are/have seriously considered hydrogen technology with hope to meet their energy requirements and minimise import of petroleum products. The establishment of small scale demonstration projects in the Pacific region perhaps would be something to consider so as give the region a “feel” of the technology.

- Storage and transportation of hydrogen= H is light and consists of small molecules, can make it difficult to store but there are three main ways in which it can be stored cost effectively if used for transport or power generation. These include:
 - **Compressed form**= compressed to 20-25 mega-Pascals for storage in cylindrical tanks up to 50L.
 - **Liquid form**= needs to reach -253 degrees Celsius to liquefy. The advantage of liquid hydrogen is its high energy to mass ratio, three times that of gasoline. It is the most energy dense fuel in use (excluding nuclear reactions).
 - **Bonded hydrogen**= The safest methods for bonding hydrogen chemically are either with metal and liquid hydrides, or absorbed carbon compounds, as no hydrogen will be released in the event of an accident. A recent advancement in the bonding of hydrogen is the announcement of carbon nanofiber technology, which has the capacity to store up to 70% of hydrogen by weight. Note that a typical metal hydride can store between 2 to 4% by weight. Thus, if the new technology proves to be correct then this may make it possible for a hydrogen fuel cell vehicle to travel for 5 000 km before refuelling.
- Hydrogen has a variety of applications=
 - **Transport**= Hydrogen, like petrol, diesel and natural gas burns well in an internal combustion engine. Groups such as BMW, Mazda and the Musashi Institute of Technology have successfully designed engines to run on liquid and gaseous hydrogen.
 - **Electricity generation**= In terms of energy transmission, it becomes cheaper to transport energy by hydrogen pipeline than by electric cable, as there is a 7.5% transmission loss along its length. The economics of electricity generation by hydrogen fuel cells is currently not as cheap as generation by fossil fuels however, it is believed to be in the future.
 - **Marine sectors**= Fuel cells are currently being demonstrated on small passenger boats such as the “Hydra”, a 22-passenger boat developed by Etaing GmbH of Germany, which features a 5 kW alkaline fuel cell.

Section 3.2- Negatives and potential challenges

- Hydrogen fuel cells need an original primary source of energy. This original source of energy can be from renewable sources or non-renewable sources. If implemented in Fiji and the choice was made to use non- renewable sources such as coal, natural gas or oil then some environmental impacts would be associated with this technology, making it not a fully environmentally friendly source of energy.
- Research on hydrogen fuel technology arguably is still on going and has not been fully commercialised. It could be seen as too premature of a technology. Until commercially proven and its appropriateness to areas like Fiji it would be realistic to monitor development of this technology as a future option for the region.
- Toxic metals are used as catalysts or electrodes in **some** advanced hydrogen production technologies and fuel cells.
- Potential challenges include the vulnerability of Fiji to climate change and environmental impacts and changes such as Fijis large amount of rainfall caused by air rising over warm water where winds converge causing sometimes extreme thunderstorm activity, as seen with cyclone Winston.

Rising sea levels is another environmental factor that would need to be considered when thinking about the consequences of having hydrogen fuel plants/generators in certain rural areas of Fiji.

- Costs= Could be found to be expensive which is a massive aspect to consider before implementing this technology...In relation to hydrogen fuel cells in transport, Hörmandinger and Lucas's paper on the evaluation of the economics of fuel cells in urban buses states that with the current state of the technology and the general assumption that the fuel cell stack cost is \$300 per kW, the hydrogen fuel cell bus was found to be around 30% more expensive than its diesel counterpart.

Section 3.3- Companies/Countries using Hydrogen/Hydrogen fuel cells

Although not a company in Fiji, British Oxygen Company (BOC), has created a clean, silent, affordable Hydrogen Fuel cells generator for off grid applications.

This is an example of a company that has successfully created a commercially viable, low-carbon, hydrogen fuel cell which is a flexible alternative to small petrol and diesel generators. It has a wide range of commercial and industrial off-grid applications such as task-lighting (for railway and tunnel maintenance work), security cameras, environmental monitoring and process control systems and the leisure sector. It is stated to work at -10 degrees and in temperatures up to 40-degrees (good for Fiji!), only exhaust water vapour so is ideal for environmentally sensitive areas such as near water, in tunnels or in close vicinity to protected wildlife (perfect for rural places in Fiji) and that it is almost silent in operation, which would be good to reduce sound pollution in rural areas of Fiji.



Section 4- Other alternative energy sources

- **Solar- powered generators=** As stated in the action project brief rural villages that are isolated on an island or in the highlands use solar energy for small scale charging and then the petrol generators for stronger surges of electricity. A solar powered generator consists of two key parts- a set of solar panels and an internal storage system made up of photovoltaic cells, which catch, convert and store sunlight as electricity. This would be a good fit for rural areas of Fiji as they already use solar power. Solar generators do not emit any fossil fuels, are quieter, cleaner and safer than petrol generators. Up front cost of one of these may be large but maintenance cost of course of their life cycle are lower. They have fewer moving parts and wont require loads of upkeep for the duration of the solar cells lifecycle (25-30 years). They also come in a range of sizes, they do however take longer to power than diesel generators and are dependent on consistent sunny days.
- **Battery-powered generators=** These are greener, quieter alternative, rather than burning fossil fuels, these plug into an external power source (the electrical grid, a vehicle, or a solar power for instance, to collect and store electricity. Seeing as it can be connected to the electrical grid this could be a good alternative to rural areas in Fiji that are close enough to bigger towns or cities to be connected to mains electricity. These generators don't use fuel so don't produce carbon monoxide or other emissions. They are typically portable and convenient and safe for indoor use. They are convenient and portable however they can take a while to charge, especially when plugged into a solar energy source. This is something to keep in mind.

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