Final Report

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Fiji Renewable Energy Power Project (FREPP)

Report on Feasibility of Resources and Sites For Waste-to-Energy Power Generation in Fiji

Waste to Energy Resource Assessment in Fiji

September - 2014

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Abbreviations & Acronyms

BOD	Biological Oxygen Demand
CDM	Clean Development Mechanism
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Di-oxide
COD	Chemical Oxygen Demand
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GWh	Gigawatt hours
H	Hydrogen
ha	hectare
FEA	Fiji Electricity Authority
FMIB	Fiji Meat Industry Board
FREPP	Fiji Renewable Energy Power Project
FSC	Fiji Sugar Corporation
IPPs	Independent Power Producers
Kg	Kilograms
kWh	kilowatt hour
MJ	Mega joule
MSW	Municipal Solid Waste
MT	Metric Ton
MW	Megawatt
MWh	Megawatt-hours
N	Nitrogen
PDD	Project Design Document
SCC	Suva City Council
SIDS	Small Island Developing States
SPD	South Pacific Distilleries
STP	Sewage Treatment Plant
TS	Total Solids
TSS	Total Suspended Solids
TWIL	Tropik Wood Industries Limited
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
VSS	Volatile Suspended Solids

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Overview of "Quantification and Assessment of Waste to Energy Resources in Fiji"

This report under the "Fiji Renewable Energy Power Project (FREPP[1]), focused on quantification and assessment of amount and types of waste resources available in Fiji for power generation. The report included quantitative and qualitative assessment of various potential wastes to energy resource generated in Fiji and major characteristics of waste resources for each identified waste streams in Fiji

The potential waste streams identified in Fiji with relevance to waste to power generation potential includes: Municipal Solid Waste (MSW); Sewage and Sludge (Domestic Waste Water); Livestock Waste; Biomass Waste; Non Hazardous Industrial Organic Waste and Agricultural Crop Residues. The quantification and assessment of potential waste streams in Fiji infer that some (MSW, biomass, livestock) of the waste streams identified have reasonable resource and potential available for power generation as stand-alone applications or for medium scale centralized power generation activities. This is the second report under the study assessing the feasibility of quantified waste resources under various waste streams and identified potential sites for waste to energy (power) generation.

Approach & Methodology

The "Resource Assessment Study for Waste-to-Energy Resources in Fiji"under the "Fiji Renewable Energy Power Project (FREPP) intends to quantify and assess the amount of waste resources available in Fiji for power generation and identify technology options for feasible implementation of waste to energy projects.

This report (Second under the Study) is a macro assessment focusing on estimating the theoretical potential for power generation from the identified waste streams and assessing the feasibility of the available resources for energy generation. The report also discusses on the identified potential waste to energy projects in Fiji including their estimated potential for power generation based on the site survey carried out. It is to be noted that the scope of the study does not involve carrying out a detailed techno-economic feasibility assessment for the identified waste streams or the potential projects. This report on "Feasibility of Resources and Sites for Waste-to-Energy Power Generation in Fiji" is developed based on stakeholder consultations and resource assessment site surveys carried out for identified potential projects.

The quantification and assessment of the amount and types of waste resources (First Report) including data and information collected on waste to energy resource availability and assumptions considered for projections of waste resource availability were also validated through meeting with the stakeholders during the development of this report.

Detailed on-site resource analysis including envisaged economic, social and environmental implications, issues and benefits for the identified potential waste to energy projects were also carried out using a waste to energy project survey template. The list of stakeholders met and consulted including the site surveys is provided in Annex 1.

[1] http://www.fj.undp.org/content/dam/fiji/docs/ProDocs/Fij_FREPP_00076656.pdf
http://www.fdoe.gov.fj/index.php/energy-planning/frepp

Feasibility of Waste to Energy Resources and Sites in Fiji

Municipal Solid Waste (MSW)

The composition of municipal solid waste (collected and dumped at site) mainly contains biogenic/organic, inorganic and inert components. The biogenic fraction in the MSW can be converted to electricity through thermo-chemical path (incineration/pyrolysis) or anaerobic digestion (landfill gas capture and utilization).The incineration of MSW mainly involves burning of organic materials in the waste at very high temperatures and pyrolysis burns waste in absence of oxygen. The heat generated during the combustion process can be used to generate electricity. A typical incineration plant generates about 550 kWh per tonne of waste combusted[2] with average power generation efficiency in the range 20-25%.

The theoretical potential for electricity generation from MSW in Fiji through the thermo-chemical path is estimated to be 38 GWh per year.

Table 1: Estimated Electricity Generation Potential in Fiji from MSW through Thermo-Chemical Conversion

Location of Landfill/Dump	Estimated Annual Biogenic (Organic) MSW Received (Ton)[3]	Estimated Annual Electricity Generation Potential (MWh) (Thermo-chemical conversion)
Naborao Landfill	42,344	23,290
Lautoka Dump	16,220	8,921
Ba Dump	1,950	1,072
Sigatoka Dump	4,745	2,610
Rakiraki Dump	975	536
Savusavu Dump	650	358
Labasa Dump	1,625	894
Levuka Dump	845	465
Total	**69,354**	**38146**

Anaerobic digestion is another option for treatment of the biogenic waste fraction in the MSW. The organic matter in the MSW that's dumped in a landfill anaerobically decomposes over a period of time. This leads to generation of landfill gas which normally contains 55 – 60% methane (CH_4). It is also observed that the MSW generally has 65% of organic matter and 50% moisture content.

The landfill gas can be captured through a network of gas collection pipes and used to generate electricity. Some of the key factors that influence the generation and collection of landfill gas from a MSW landfill site include the amount, type, and age of waste; moisture content; temperature; pH; and site conditions.

Based on the experiences with landfill gas recovery projects that are generating electricity in other developing countries, on an average, it is observed that around 60m^3 of landfill gas can be produced for a ton of MSW. This rate of generation is estimated to sustain for around 10 to 15years with a collection efficiency of 75% and methane content of 50%. The estimated gas generation rate may vary but is very conservative and provides a reliable estimate of the current situation.

[2] US EPA - http://www.epa.gov/solidwaste/nonhaz/municipal/wte/basic.htm
[3] Based on Suva City Council MSW characterization study – 65% organic matter including green waste

Table 2: Estimated Electricity Generation from MSW through Landfill Gas Recovery and Utilization

Location of Landfill/Dump	Estimated Annual Quantity of Biogenic (Organic) MSW Received (Ton) [4]	Estimated Annual Landfill Gas Generation (m^3)	Estimated Annual Electricity Generation Potential (MWh) (Landfill Gas Recovery)[5]
Naborao Landfill	42,344	254,064	8000
Lautoka Dump	16,220	97,320	3060
Ba Dump	1,950	11,700	370
Sigatoka Dump	4,745	28,470	900
Rakiraki Dump	975	5,850	180
Savusavu Dump	650	3,900	120
Labasa Dump	1,625	9,750	310
Levuka Dump	845	5,070	160
Total	**69,354**	**416,124**	**13,100**

The theoretical potential for electricity generation from MSW in Fiji through landfill gas recovery is estimated to be 13 GWh per year. The identified potential projects for electricity generation under the MSW stream are discussed below.

Naboro Landfill

The Naboro Landfill is a project of the Fiji Government, funded by the European Union and the Government of Republic of The Fiji Islands. The site is designed to accept municipal solid waste (MSW) from the Suva (city), Nasinu (city), towns including Nausori, Lami and Navua and other neighboring rural areas. The landfill site is envisaged to operate for 50 years. The current contractor M/s HG Leach from New Zealand have been managing the landfill since 2005 and the contract is being renewed every 5 years.

Figure 1: Naboro Landfill, Suva (Source: M/s HG Leach)

The Naboro Landfill is engineered to a high standard to contain leachate which is the liquid residue produced by decomposing organic fraction of municipal solid waste. The compacted clay liner and leachate collection system prevents leachate permeating into the underlying

[4] Based on Suva City Council MSW characterization study – 65% organic matter including green waste
[5] Based on 70% landfill gas recovery rate; 45% fraction of methane in landfill gas and caloric value of methane 10 kWh/m3

ground water or nearby rivers or the sea as was the case at Lami. A high standard day to day operation ensures proper placement and compaction of the waste, along with daily cover and intermediate capping layers which minimise the fire risk and helps minimise odour issues, windblown refuse and vermin along with uncontrolled discharge of landfill gas.

The estimated annual quantity of organic material received at the landfill including the electricity generation potential on site has been provided in Tables 1 and 2 above. Fiji Electricity Authority (FEA) has informed that it has conducted a detailed feasibility study of Naboro landfill to explore the possibility of generation electricity through thermo-chemical and landfill gas recovery techniques. However, details of the study were not available mainly due to confidentiality issues. It is understood that the study has estimated a potential installed capacity of around 8-10 MW through the thermo-chemical route and around 4 to 5 MW through landfill gas recovery.

Lautoka (Vanutu) Dump

The Vanutu dump in Lautoka is managed by the Lautoka City Council, a statutory body under the Ministry of Local Government. The dump on an average receives around 69 tonnes/day of MSW which includes garbage, street sweepings, market waste, green waste etc. The dump caters to MSW generated from Nadi, Lautoka town limits and resorts located in the outer islands. The waste characterization data for the Vanutu dump has been provided in the table below.

Table 3: Vanutu Dump Waste Composition Data (Source: Lautoka City Council)

Category of Waste	2008 (%)	2012 (%)	2017 (%)
Kitchen Waste (organic)	36.9	37.7	38.9
Paper	15.3	15.9	16.4
Textile	2	2.1	2.2
Plastic（PET)	1.9	1.8	1.7
Plastic（Film)	8.4	8.4	8.4
Grass and Wood	21.4	20.2	18.8
Rubber and Leather	0.4	0.3	0.3
Combustibles Sub-total	86.4	86.5	86.7
Metal	3.5	3.6	3.6
Bottle and Glass	2	2.1	2
Ceramic & Stone	3.4	3.1	2.9
Others	4.8	4.7	4.8
Non-Combustibles Sub-total	13.6	13.5	13.3
Total	**100**	**100**	**100**

Figure 2: Vanutu Rubbish Dump (Source: Lautoka City Council)

The estimated annual quantity of organic waste received at the landfill including the electricity generation potential on site has been provided in Tables 1 and 2 above. However, there are some key issues associated with the location and available area for the Vanutu dumpsite. The site is believed to be have evolved from a mangrove site during 1960's and is situated on a water table. There is very limited scope for converting the dumpsite into a sanitary landfill due to the limited land area available for expansion including envisaged impact on the local environment due to the location of the site.

Suva Market Waste

Suva City Council (SCC), a municipal entity under the Local Government Act is responsible for collection and disposal of MSW from Suva city limits including the wastes generated by Suva agricultural produce market. On an average the Suva market generates around 7 tonnes of waste per day.

Figure 3: Segregation and Collection of Suva Market Waste (Source: Suva City Council)

About 8% of the generated market waste is currently being segregated and converted to compost at the SCC depot in Samabula area. The rest of the waste is being collected and dumped at the Naboro landfill. The data from waste characterization study carried out by SCC for the MSW generated in Suva is provided in the figure below. Although, a specific characterization study is not available for the Suva market waste, it is understood that most of the waste generated are highly organic in nature.

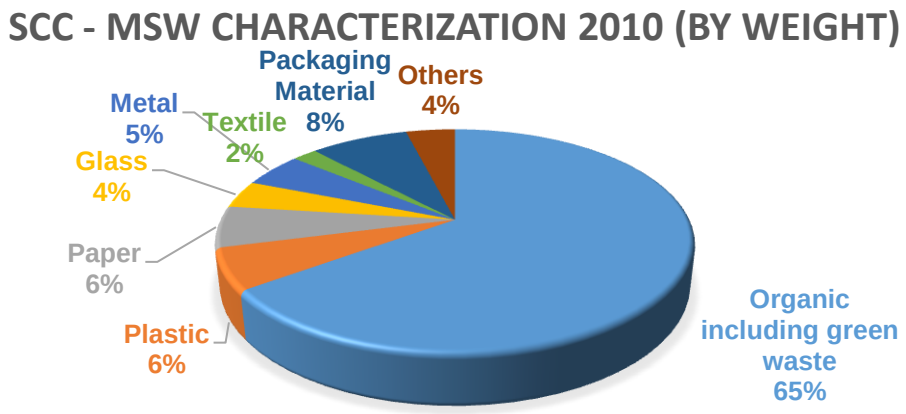

Figure 4: Waste Composition Data for Suva MSW (Source: Suva City Council)

It is estimated that around 560 cubic meters[6] of biogas could be generated per day by anaerobic decomposition of Suva market waste. The generated biogas can be utilized to produce around 2800KWh[7] per day of electricity which could result in approximately 1000 MWh of electricity generation annually.

Sewerage Sludge

Domestic wastewater (sewage) normally comprises of waste organic matter, some inorganic solids, heavy metals, sand and grit, and floating debris. The organic matter in the sewage (suspended or dissolved solids) can be settled through appropriate treatment process. The settled sludge has very high organic content which could be converted to biogas through anaerobic digestion of the sludge. In this process, a large fraction of the organic matter (cells) is broken down into carbon dioxide (CO_2) and methane (CH_4), and this is accomplished in the absence of oxygen. About half of the amount is then converted into gases, while the remainder is dried and becomes a residual soil-like material. The production of biogas provides an easy possibility of energy recovery through generation of electricity.

Table 4: Estimated Electricity Generation Potential at Major Sewage Treatments Plants in Fiji

Centre	Volume of Sewage Treated (m^3/day)	Average TSS in Raw Effluent (mg/l)	Estimated Methane Generation Potential (m3/day)[8]	Estimated Electricity Generation Potential (MWh/year)[9]
Suva	24,500	300	4,630	8,450
Nasouri	600	220	83	152
Pacific Harbour	691	170	74	135
Lautoka	6,750	275	1,170	2,134
Nadi	3,000	249	470	858
Sigatoka	600	195	73	134
Ba	975	138	85	155

[6] Based on 1 tonne of vegetable waste yields 80m3 of biogas

[7] Based on 1 m3 of biogas generates around 5KWh of electricity

[8] Based on 70% Volatile Suspended Solids (VSS) and 0.9m3 of methane production per KG of VSS destroyed

[9] Based on 1 m3 of biogas generates around 5KWh of electricity

Labasa	900	165	93	170
AdiCakobau School	150	285	27	49
Wailada	150	180	17	31
Naboro	300	190	36	65

The theoretical potential for electricity generation from sewage sludge in Fiji is estimated to be 12.33 GWh per year.

As observed from the above table, only Kinoya Sewage Treatment Plant (STP) appears to have potential to generate reasonable quantity of electricity. However, the Kinoya project is currently registered under the Clean Development Mechanism (CDM) of Kyoto Protocol and is eligible for carbon credits[10]. The technology implemented on site for GHG emission reduction is methane capture and flaring. As per the CDM modalities and procedures, the Project Proponent is not allowed to deviate from or change the design of the registered project that has been indicated in the registered Project Design Document (PDD). In case the Project Proponent decides to install biogas generators for electricity generation during the CDM crediting period (10 years i.e.2012 - 2022), the project might face constraints in terms of issuance of carbon credits by UNFCCC.

Livestock Waste

Livestock farming in Fiji mainly consists of dairy and beef cattle, sheep, goats, pigs and poultry. Waste/manure generated by livestock is generally used as an organic fertilizer and energy source. The livestock waste can be burnt directly (after drying) or anaerobically digested to produce biogas[11].

Generating biogas is considered to be more efficient than using the waste as raw manure or direct burning. Apart from biogas, the bio-digesters also produce slurry which can be used as a fertilizer. Small-scale household level digesters can provide thermal energy for cooking and water heating needs. Large scale digesters can generate large volumes of biogas for electricity generation. The quantity of waste/manure produced by livestock varies and depends on the animal type. The methane generation potential can be evaluated based on the type of waste/manure generated and the type of animal.

Table 5: Estimated Electricity Generation Potential from Livestock Waste

Type of Livestock	Estimated Quantity of Waste Generated (ton/day)	Estimated Biogas Yield (m3/t) [12]	Estimated Electricity Generation Potential (MWh) [13]
Cattle	1,472.46	40	295
Pigs	110.5	70	39
Poultry	373.4	60	112
Sheep	28.02	50	7
Goat	202.4	50	51
Total	**2,186.78**		**504**

[10] http://cdm.unfccc.int/Projects/DB/TUEV-SUED1299488431.41/view

[11] Biogas is the gaseous product of the anaerobic digestion (decomposition without oxygen) of organic matter. The composition of biogas varies depending upon the origin of the anaerobic digestion process. Typical composition is CH4 (50% to 70%), CO2 (30% to 50%), and traces of gases such as H, CO, and N.

[12] Based on USAID Report - http://www.nrel.gov/docs/fy09osti/44808.pdf

[1313] Based on 1 m3 of biogas generates around 5KWh of electricity

Although the combined potential for electricity generation from livestock waste in Fiji seems to be large, in reality, only a part of this can be achieved. This is mainly due to the fact that waste generated by poultry and pigs can only be utilized wherein these animals are raised in closed facilities allowing the collection of the manure. The manure from cattle although has the highest potential to generate electricity (295 MWh), due to the grazing pattern adopted in Fijian cattle farms, it is difficult (economically and technically) to collect the cattle manure and transport it to a centralized location for processing. However, the cattle farms could make use of the manure produced during milking of cattle (during when they are brought into a common shed) for biogas generation at household scale for thermal energy needs. The situation is very similar to cattle manure with waste/manure generated by sheep and goats.

Figure 5: Piggeries at Vuda and Naboro Correctional Facility (Source: Vuda Piggery)

The projects having potential for electricity generation under the livestock waste stream has been discussed in the below table.

Table 6: Potential Livestock based Electricity Generation Projects, Fiji

Project	Type and Quantity of Waste Generated (ton/year)	Biogas Yield (m3/year)	Electricity Generation Potential (MWh/year)
Naboro Correctional Facility Piggery	Pig Manure 401.5	28,105	140
Vuda Piggery	Pig Manure 1,825	127,750	639
Naboro Leyland Piggery	Pig Manure 913	63,910	320
Ram Sami & Sons	Poultry Litter 3,650	219,000	1,095
Crest Poultry	Poultry Litter	Data and information to estimate the potential for electricity generation was not available.	
Rooster Poultry			

Biomass Waste

Bagasse (Sugarcane Waste)

Sugar mills around the world normally use bagasse, the residue of sugarcane generated after crushing to generate steam and power through cogeneration. The simultaneous production of both electrical power and a useable form of thermal energy, such as steam, is termed cogeneration. This may be achieved by generating high pressure steam in a boiler, which would then be passed through a turbine generator for power before being used as exhaust steam in drying or process heating.

The electricity generated is used for captive consumption within the sugar industry and the surplus is fed into the grid. The sale of surplus electricity to the grid in fact is a key source of additional revenue which could assist in long term sustainability of the sugar industry.

Fiji Sugar Corporation (FSC) is a government-owned sugar milling company in Fiji having monopoly on production of raw sugar in Fiji. The Government of Fiji is a major shareholder that owns 68% of shares while statutory bodies, local companies and individuals own the remaining shares. FSC owns and operates four sugar mills located at Lautoka, Ba and Rakiraki on the main island of Viti Levu while Labasa mill is located on the second largest island of Vanua Levu.

Table 7: Installed Capacity and Electricity Production by FSC Sugar Mills

Name of Sugar mill	Installed Capacity (MW)	Power Export During Crushing Season (MW)	Total Power Generated (2013) kWh
Lautoka	12	6	17,474,151
Rarawai	9	3	8,990,508
Labasa	24	14	15,208,450
Penang	3	0	3,738,200
Total	**48 MW**	**23 MW**	**45,411,309 kWh**

The four sugar mills owned by the Fiji Sugar Corporation (FSC) Limited have a collective electricity generating capacity of around 48 MW during the sugar cane crushing season. The boilers in these mills are fuelled by bagasse. Wood chips/Firewood is used to supplement bagasse in some mills during off-season when there is shortage of bagasse or when the open-air-stored bagasse is in an advanced stage of decay. The bagasse is generated on site while whatever Wood chips/Firewood used is purchased locally. FSC mainly depends on electricity from Fiji Electricity Authority (FEA) grid during off-season.

Rarawai Cogeneration Project

FSC is planning to implement a 40 MW cogeneration plant in its sugar mill at Rarawai on Viti Levu. The feasibility study for the cogeneration plant has been completed and the project is expected to be operational during early 2016.

The Rarawai plant is proposed to have two 110 ton per hour boilers and two 20 MW extraction condensing turbo-generators. The plant is expected to supply all the steam and power to the 300 tons cane per hour capacity sugar mill during the sugar cane crushing period. The surplus power is planned to be exported to the FEA grid. During off season, the plant is expected to operate in a power generation mode supplying power only to the FEA's grid.

The plant will use the entire bagasse generated in the sugar mill. FSC is also planning to supply about 50,000 MT of bagasse per year from its other sugar mills to the Rarawai cogeneration plant. In addition to bagasse it is also proposed to use wood chips and cane trash as fuels as fuel source.

Labasa Cogeneration Project

FSC is also in advanced stages of establishing a 10 MW bagasse/biomass based cogeneration plant at Labasa sugar mill in Vanua Levu. The cogeneration facility is being planned to operate even during off-season using surplus bagasse and wood chips procured from third party sources. The plant is expected to be commissioned during late 2014.The power generated from the 10 MW turbo-generator is expected to meet the internal power requirements and the surplus power will be exported to Fiji Electricity Authority.

Logging and Forest Industries

Even though large volume of forest residues are generated during logging in Fiji which has a potential to be used as fuel source for electricity generation, collection and handling costs are the key barriers in utilizing the resource effectively. The residues left to decompose in the forests also play a key role as soil nutrients. Practicing appropriate collection techniques during logging could help in terms of collecting the residues including maintaining the soil nutrient level by leaving behind leaves, barks and thinnings.

Table 8: Theoretical Potential for Electricity Generation from Logging and Forest Industry Residues in Fiji

Activity Type	Estimated Volume Biomass Residues Generated (t/year) [14]	Electricity Generation Potential (MWh/year) [15]
Logging		
Natural Forests	25,737	38,605.50
Pine	163,061	244,592
Mahogany	15,858	23,787
Wood Chips	18,900	28,350
Saw Milling	7,240	10,860
Wood Veneer Sheets	4,335	6,502
Plywood	1,200	1,800

Considering the low calorific value and the distance to be covered to transport the residues to a centralized location, transportation costs are another prohibitive factor in using forest residues for power generation. Due to the high capital and operating costs involved, densification (briquetting or pillarization) tends to be the only financially viable option when the biomass waste needs to be transported over long distances. The briquettes and pellets

[14]conversion of volume to mass is based on average density of 792 kg/m3 for logging residues and 300 kg/m3 for wood waste and saw-milling residues with a moisture content of 20%

[15]Based on assumption that a tonne of dry biomass generates on average 1.5 MWh with the efficiency in the range of 20 – 40%

have wide range of application and usage right from rural households as cooking fuel up to commercial and industrial fuel requirements.

The biomass residues and wood waste generated from logging activities in the outer islands are currently being left in the forests or at the processing facilities. This is mainly due to the exorbitant transportation costs involved in moving the residues to the main island for utilization as an energy resource. Further, apart from Viti Levu, the grid coverage in Vanua Levu and other outer islands are not extensive or totally nonexistent. The in-adequate grid facility available in Vanua Levu to evacuates the generated electricity from logging and forestry industry residues are making the proposition unattractive to Independent Power Producers (IPPs).

Tropik Wood Industries Limited (TWIL), one of the biomass waste based IPP's in Fiji, maintains around 46,000 hectares of pine forests and currently process around 300,000 ton/year of logs as part of sawmilling and wood chipping operations. The waste barks and fines (14% of the logs processed) from wood processing operations are currently being used as feedstock for power generation through direct combustion of biomass at the two power plants (3 MW & 9.3MW). According to TWIL, most of the biomass waste generated currently is being consumed by the existing power plants and no excess or surplus biomass waste is available.

Figure 6: TWIL Biomass Waste Power Plant at Drasa (Source: TWIL)

The proposed and planned power generation projects utilizing the logging and forestry industry wood residues in Fiji has been discussed in the below table.

Table 9: Proposed Biomass based Power Generation projects, Fiji

Project	Company/Organization	Type and Quantity of Biomass Residues Required (ton/year)	Proposed Installed Capacity (MW)
Nabouwalu Biomass Power Project	Tropik Wood Industries Limited in collaboration with GIMCO (Korea)	Pine Chips180,000	12
Debua Biomass Power Plant	Fiji Electricity Authority	Mahogany Residues26,000	3
Savusavu Biomass Power Plant	Fiji Electricity Authority	Saw mill Waste and Coconut Waste22,000	2

Non Hazardous Industrial Waste Water

Press mud is a by-product from sugar industry and generally contains around 75-80% organic matter. Press mud is highly biodegradable and is a very good source for generation of biogas through anaerobic digestion. It is estimated that 1 MT of press mud could yield around 80-140 m3/day of biogas.

The sugar mills are estimated to generate the waste water in the ratio of 1:2 quantity of sugarcane crushed to waste water generated. The sugar mill effluents are having high amount of organic matter (BOD and COD) which could be potentially used to generate electricity through anaerobic digestion.

FSC as part of its sugar production process generates wastewater and press mud. However, FSC is not very keen in terms of utilizing the waste resources as the organization is working towards zero waste and effluent generation. It is understood that several initiatives are being already implemented by FSC in order to achieve the goal of zero waste and effluent[16].

Fiji Meat Industry Board (FMIB) is the main abattoir in Fiji. The waste generated includes bones, organs, hooves, and other inedible animal parts leftover after all the edible parts of the animal have been removed. It is estimated that on average 15 liters water wasted in each slaughtering.

The characteristics of the slaughter house waste are almost similar to that of domestic sewage but with very high organic content. The effluent generated contains about 45% soluble and 55% coarse suspended organics.

Due to the high organic nature of waste, there is a good potential to generated biogas and in turn electricity.

Table 10: Theoretical potential for electricity generation from FMIB Waste

Animals Slaughtered	No. of Animals Slaughtered /Day	Average Weight of Animals (kg)	Average Quantity of Waste Generated (kg/day)17	Estimated Energy Generation Potential (MJ/)18
Cattle	50	225	5,625	87,750
Pigs	120	55	1,980	30,888
Sheep	10	25	125	1,950
Goat	10	30	150	2,340

Paradise Beverages (Fiji) Limited located in Suva manufactures and sells beer, ready-to-drink alcoholic beverages, and soft-drinks in Fiji. The South Pacific Distilleries (SPD), a sister concern of Paradise Beverages (Fiji) Limited, located in Lautoka uses the molasses from sugar industry to make the Fiji brand of rums.

[16]Based on inputs FSC staff

[17] Inputs from Ministry of Agriculture Staff

[18] Average calorific value of 15.6MJ/kg of waste

Effluent treatment is currently not being done at both the plants. The effluent is being blended with sewage and discharged into main domestic sewers. Paradise Beverages (Fiji) Limited is keen to explore potential options to utilize the waste at both the plants to generate energy.

Waste water generated by breweries and distilleries generally contains high organic loading (BOD, COD & TS) levels. A part of the brewers' grain, a by-product from the breweries is currently being used as animal feed and rest disposed-off at the landfill.

Table 11: Theoretical potential for electricity generation from SPD and Paradise Beverages Wastewater

Plant	Quantity of Wastewater Generated (m3/year)	Average COD (t/m3)	Biogas Yield (m3/year)[19]	Electricity Generation Potential (MWh/year)[20]
South Pacific Distilleries	30,000	0.025	300,000	1,500
Paradise Beverages	72,000	0.00096	27,648	138

Agricultural Crop Residues

In contrast to other regions and developing countries, wherein agricultural and food crops are grown at a commercial scale and result in large quantities of residues, most of the Fijians depend on subsistence agriculture for own consumption or local markets.

Further, cultivation of the agricultural and food crops are scattered and dispersed across the islands.

Due to small land holdings and dispersed nature of the agricultural residues significantly increases the collection and transportation costs of agricultural residues to a centralized location for electricity generation.

Furthermore, large storage and treatment facilities are required for residues generated from seasonal crops as they become available at same time of the year.

Similar to any other developing country, large quantities of agricultural crop residues discussed in this study are already being used by urban and rural households as animal feed, manure for farms, cooking and water heating.

Hence, it is difficult to come up with a realistic estimate of agricultural residues available for electricity generation. These resources are site specific and a detailed analysis needs to be carried specifically for individual project sites.

[19] Based on specific biogas yield of 400 m3 CH4/t COD

[20] Based on 1 m3 of biogas generates around 5KWh of electricity

Table 12: Theoretical Potential for Electricity Generation from Agricultural Crop Residues in Fiji

Crop Type	Production (Tons)	Residue (Dry) (Tons)	Electricity Generation Potential (MWh/year)[21]
Cassava	58,772	2,997	4,495
Dalo	56,645	2,889	4,333
Yaqona	6,067	310	465
Coconut	10,634	6,476	9,714
		4,020	6,030
	17,757	42,617	63,925
Rice	4,288	1,684	2,526
		1,015	1,522
Pawpaw	335	71	106
	220 ha	19,580	29,370
Banana	3,392	721	1,081
	1,087 ha	96,743	145,114
Pineapple	445 ha	35,600	53,400

There is a good potential to utilize the root crop, fruit and vegetable wastes at household and community level wherein small biogas plants could be installed to make use of these organic wastes and generate biogas for thermal energy requirements. Normally coconut waste (husk & shells) are used as a source of energy for cooking and heating. These residues could also be used for copra drying which are used rather inefficiently, resulting in large amounts being required to achieve the desired able reduction in moisture content. Coconut shell also can be utilized to produce high quality activated carbon and charcoal by pyrolysis process, for used also in cooking and heating.

Given the issues and constraints with using agricultural residues as feed stock for electricity generation, it is suggested that briquetting or pelleting of agricultural residues could be a potential option to make use of large unused quantities of residues. The residues can be recycled and can provide a renewable source of energy by converting waste into high density fuel briquettes or pellets. These are a very good substitute for firewood and offer several advantages which include: reduction of fuel wood and deforestation; easy handling, transportation& storage due to high fuel density; cheaper than fuel wood and consistent quality, high burning efficiency.

[21]Based onassumption that a tonne of dry agricultural residue (biomass) generates on average 1.5 MWh with the efficiency in the range of 20 – 40%

Conclusion & Next Steps

A macro assessment has been carried out to estimate the theoretical potential for power generation from the identified waste streams in Fiji and the feasibility of the available resources for energy generation has been assessed. Based on the site survey carried out, potential waste to energy projects in Fiji has been identified including their estimated potential for power generation. Based on the assessment, in terms of theoretical potential for electricity generation, it appears that biomass waste stream (bagasse & logging and forestry industry residues) has the highest potential followed by MSW and livestock waste.

The two IPPs, Fiji Sugar Corporation (FSC) and Tropik Wood Industries Ltd (TWIL) currently involved in biomass waste to energy generation (bagasse & wood residues) are consuming most of the economically available biomass waste generated by using them as fuel at the existing power plants. Currently there is no excess or surplus biomass waste is available which could be economically collected and transported to the existing project sites. As discussed in the report, collection, handling and transportation costs are the key barriers in utilizing the available biomass resource effectively.

Under the MSW stream, Naboro landfill and Navutu Dump in Lautoka seems to have a reasonably good potential to generate electricity. The appropriate technology and approach needs to be decided based on the detailed techno-economic feasibility studies. Also as discussed in the report, for the Vanuatu dump in Lautoka, the sensitivities and issues related to location of the dump site and available area for waste processing needs to be considered whilst deciding on the appropriate waste to energy technology.

All the potential projects identified for the piggery and the poultry waste under the livestock stream have good potential to generate electricity. The power generated could be used for captive consumption and the excess fed to grid. The manure from cattle although has the highest potential to generate electricity, due to the grazing pattern adopted in Fijian cattle farms, it is difficult to collect the cattle manure and transport it to a centralized location for processing.

The next steps under the study will include research and identification of relevant technologies available globally (particularly in developing country context) for waste to energy power generation in Fijian context and recommendation of appropriate technology options for waste to energy power generation in Fiji considering similar experiences in other developing countries.

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Annex 1: List of Key Stakeholders Consulted

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