Use of Biomass as Renewable Energy Source in Panay

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Consultant Mission on the Use of Biomass as Renewable Energy Source

Consultants:

Dr.-Ing. Andreas Ortwein, Leipzig, Germany

Engr. Jeriel G. Militar, Iloilo, Philippines

Customer: DFS Deutsche Forstservice GmbH, on behalf of GIZ Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH

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1 INTRODUCTION

1.1 Organizational Background

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH has been commissioned by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) to implement the project „Forest and Climate Protection Panay 2“. In the framework of this project a feasibility study has been prepared on the potential of bio-energy to replace fossil fuel (esp. coal and bunker oil) and reduce the carbon emissions. Of special interest is the potential of biomass (wood and agricultural residues) for the decentralized supply of communities and households with electricity, heat for drying rice, copra, abaca and lumber, and cooling.

The study has been carried out by German consultant Dr. Andreas Ortwein and Philippine consultant Jeriel G. Militar from Central Philippine University, Iloilo, Affiliated Renewable Energy Center (AREC). The study has been implemented in a mission in March 2015.

1.2 Regional Background

The Republic of the Philippines is one of the countries with a high degree of deforestation. For the region of the Western Visayas (Region VI) with its six provinces, the loss of forest between 1934 and 1988 has been as high as 72.9 %, reducing the forest area to 7.5 % of the land area [1].

In the Renewable Energy Act of 2008, the development, utilization and commercialization of renewable energy in the Philippines is promoted. The National Renewable Energy Board (NREB) has been created by this law, and as such is responsible and empowered to formulate and recommend policies for renewable energy sources development. A feed-in tariff (FiT) system was established, guaranteeing access to the grid, long-term contracts and stable purchase prices. The FiT for biomass is 6.63 PhP/kWh. Starting in January 2017, the FiT rate will be decreased every two years by 0.5%.

1.2.1 General Overview on the Island of Panay

The provinces of Aklan, Antique, Capiz and Iloilo are all located in the island of Panay which is one of the major islands in the Western Visayas Region (Region 6) in the central part of the Philippine archipelago. Panay is roughly triangular in shape with a long stretch of mountain range that runs across the western portion of the island from north to south and also a long strip of wide plain that stretches along the southeastern coast. The total land area of Panay island, excluding Iloilo City, is more or less 12,224 square kilometers distributed among the four provinces as follows: Aklan with 1,821, Antique with 2,729, Capiz with 2,595 and Iloilo with 5,079. Total population based on the latest published population data of 2010, is just a little over 3.6 million with Aklan at 535,725, Antique at 546,031, Capiz at 719,685 and Iloilo at 1,805,576 (See Table 1-1 and Figure 1-1).

Table 1-1: Population, land area and land classification of the provinces of Panay

Province	Population as of 2010	Total land area (in ha)	Alienable and disposable (in ha)	Forest land area (in ha)
Aklan	535,725	181,794	106,795	74,371
Antique	546,031	252,200	132,937	118,635
Capiz	719,682	263,317	110,594	93,770
Iloilo	1,809,443	466,342	344,744	113,995
Panay	3,610,884	1,163,653	695,070	400,770

Figure 1-1: Maps of the Philippines and Panay Island

1.2.2 Province of Aklan

The province of Aklan is located in the northwestern portion of the Panay Island. It is mountainous with over one-third of its land area sloping at 30 percent on the average. It is still one of the few provinces in the country to maintain a total of some 709 hectares of virgin forest. The province has no active volcano, therefore, earthquakes have not been severe, although three faults pass through it. There are five major river systems. The largest and longest is the Aklan River, which flows some 60 kilometers from Capiz to the mouth in Kalibo. Ibajay River flows over 30 kilometers from Madalag to its mouth at Ibajay. The Tangalan, Jalo, and Talon Rivers are much smaller. The highest waterfall in the province is the Dumalaylay which falls some 100 meters. The coastline of Aklan stretches some 155 kilometers along 10 municipalities and 73 barangays.

Aklan has a total land area of 181,794.64 hectares or 1,817.94 square kilometers; 73,993 hectares of which is forest land and the remaining 106,795 hectares is “alienable and disposable”, which, in the Philippine context, is referring to lands in public domain which are “declared as not needed for forest purposes” [2]. The total population of the province as of 2010 was 535,725. It is subdivided into 17 municipalities. Among the municipalities, the capital town of Kalibo, as expected, is the most populated with 62,438 and accounts for 13.83% of the total. It is followed by Ibajay, with 39,643 and New Washington with 33,981. Lezo, the smallest municipality, is the least populous with 12,393 or just 2.74% of the provincial population figure.

1.2.3 Province of Antique

The Province of Antique occupies the western portion of Panay island. About 82% of the province is classified as upland with rugged terrains and steep slopes. The Baloy-Madyaas (or Madia-as) Mountain Ranges virtually separates the province from its neighboring provinces of Aklan, Capiz and Iloilo, making it relatively isolated from them. Access to the province from these neighboring provinces is through circuitous coastal roads. The interior mountains are almost impassable except for the San Joaquin, Iloilo to Hamtic, Antique mountain road in the south and the Nabas, Aklan to Pandan, Antique mountain road in the north which are susceptible to landslides and road slippage during the rainy season.

Antique has a total land area of 252,200 hectares or 2,522 square kilometers; 118,635 hectares of which is forest land and the remaining 133,565 hectares is alienable and disposable. The total population as of 2010 was 546,031. The province is composed of 18 municipalities, mostly coastal, with one island (Caluya) and three inland (San Remegio, Sibalom and Valderrama) and a total of 590 barangays

Agriculture and fishing are the two major economic activities in the province with rice, coconut, sugarcane, banana and corn as the important agricultural crops; rice being on the top of the list with an annual production of 211,466 MT (metric tons) in 2010. Coconut comes next with an annual production of 67,492 MT (including husk), followed by sugar cane at 53,942 MT, banana at 17,870 MT and corn at 1,720 MT. Agro-forestry is also becoming an important economic activity in the province.

Among the 18 municipalities, Valderrama has the largest land area at 28,780 hectares, followed closely by San Remegio and Sibalom at 28,223 and 23,784 hectares respectively. San Jose and Belison are the two smallest with 4,450 and 1,978 hectares respectively.

The total population of the province as of 2010 was just over half a million at 546,031. San Jose de Buenavista, the second smallest in land area, is the most populated at 57,847. This is due to the fact that being the capital town of the province and the center of education, commerce and trade, San Jose is fast becoming an urbanized municipality. Sibalom, the third largest in land area and being adjacent to San Jose, comes in close second at a population of 56,058. Libertad, the northernmost municipality and the farthest from the capital together with Belison, the smallest in land area registered the lowest populations at 15,669 and 12,807 respectively.

1.2.4 Province of Capiz

The province of Capiz has a total land area of 263,317 hectares or 2,633.17 square kilometers; 93,769.73 hectares of which is forest land and the remaining 169,547.27 hectares is alienable and disposable. The total population of the province as of 2010 was 719,685. It is composed of 16 municipalities and one component city, Roxas City. It has 473 barangays and proportionately divided into two political districts: the first district covers six municipalities and one city namely: Maayon, Panay, Panitan, Pilar, Pontevedra, Pres. Roxas and Roxas City; and the second district covers the ten municipalities of Cuartero, Dao, Dumalag, Dumarao, Ivisan, Jamindan, Mambusao, Sapian, Sigma and Tapaz.

1.2.5 Province of Iloilo

The Province of Iloilo occupies the southern and the northeastern portion of the island of Panay. It is divided into two distinct geographic regions: the highlands on the western border and the lowland plains which account for a larger portion of the province. Small islands east of its northernmost tip also dot the Visayan Sea - of these Pan de Azucar and Sicogon are well-known. Iloilo is divided into 42 municipalities and one component city grouped into 5 legislative or congressional districts.

2 BIOMASS RESOURCES AND POTENTIAL

For this study, only sustainable wood from reforestation plantations and rice husk have been considered as solid biomass resources. Further agricultural residues, which could have been part of the study, include corn cobs, coconut shells and sugar bagasse. They are excluded from the study due to the low observed availability of those residues.

General findings on the biomass resource assessment and potential utilization of biomass, as well as the energy system of the island of Panay, including results from the visitations of regional and international consultants in 2015, can be found in the respective report by Engineer Jeriel G. Militar from the Affiliated Renewable Energy Center (AREC) of Central Philippine University, Iloilo City. The findings have been coordinated within this study.

The main findings include an annual availability of more than 14,000 tons of dry wood from reforestation and plantation areas and an availability of more than 185,000 tons of rice husk for Panay. Also, the study showed high expected increases in power demand and new installations for power production for the next years.

2.1 Previous Biomass Studies

During the ForClim Panay Project Phase I, in 2011 a biomass resource assessment has been conducted for the province of Antique, entitled “Biomass and Energy Supply and Demand in the Province of Antique, Philippines”. The study revealed that the province (Antique) being a majorly agricultural and forested province was found to have abundant supply of forest biomass and agricultural residues. Forest biomass was limited to lumber and fuel wood there being no commercial logging activities in the province to generate significant amount of forestry residues. Annual volume of lumber production at 3,085 cubic meters per 1,711 hectares of agro-forest plantation was found to be sustainable based on data from the provincial PENRO. For the agricultural residues, rice husk was found to be the most abundant with an annual production of 47,115 metric tons estimated from rice production values using the generally accepted grain to husk ratio of 0.2 and an assumed recovery factor of 50%. Coconut residues come in second with an annual production of 22,272 metric tons of husks and 10,124 metric tons of shells but these are mostly consumed by the producers themselves for domestic fuel, for drying copra and for other uses. Sugar cane residues, particularly bagasse, were also found to be of significant volume but like coconut residues were also mostly consumed by the producers for their own use mostly for cooking the cane juice in the production of muscovado sugar.

Another study in 2014 commissioned by GIZ under the Powering Agriculture Initiative, entitled “Study on Rice Husk Potential as Energy Source in Panay”, focused on the potential of rice husk as fuel in rice mills where they are generated. The significant result of this study is the listing of identified rice mills with more than 500 kW of estimated sustainable electrical power that could be generated from the mills’ own-produced rice husks and the recommendation that the power plants designed to utilize these rice husks as fuel are best situated in the rice mills where the rice husks are actually produced and piled on site as this will take out the cost of hauling and storage from the cost of installing and operating the power plant.

These previous studies revealed that although there are existing utilizations for rice husk, there are enough surpluses that could still be utilized for heat and electricity generation. The figures though are preliminary and need further validation for the implementation of specific projects.

Similarly, this study sought to assess the available supply of biomass and their existing uses in the four provinces of Panay for the purpose of identifying the energy potential as a possible alternative to fossil fuel. Special focus was placed on the two categories of biomass: wood and agricultural residues.

2.2 Forest Based Biomass

2.2.1 Fuelwood

Data from the 2013 Philippine Forestry Statistics published by the Forest Management Bureau of the Department of Environment and Natural Resources reveal the following facts in relation to forest resource utilization in Panay:

- There are no existing commercial sawmills
- There are no existing Tree Farm and Agro-Forestry Farm Leases
- Only one (1) Integrated Forest Management Agreement (IFMA) was issued in Iloilo with an area of only 541 hectares
- Only two (2) Special and Forest Land Use Permits and Agreements were issued, three (3) in Aklan with a total of 6 hectares and 2 in Iloilo with a total of 151 hectares
- No commercial timber licenses were issued
- There are no commercial wood processing plants

These facts explain why there is no significant amount of forest and wood residues generated in Panay there being no existing commercial wood processing activities. This means that the only available forest based biomasses are wood (lumber) and fuel wood. From the same source, Table 2-1 and Table 2-2 list the monthly volume of log and lumber production in cubic meters by province in 2013.

Table 2-1: Log production by province in 2013

Province	Log Production (m^3)
Aklan	2,105
Antique	2,674
Capiz	4,432
Iloilo	3,009
Total Panay	**12,220**

Source: Philippine Forestry Statistics, 2013

This log production represents only a small part of the annual wood increment in forest plantations, however. The forest plantation area of Panay comprises at least 12,500 ha (only NGP and German assisted plantations, see Table 2-2). The annual wood increment is in the range of 120,000 m^3 per year (average increment 10 m^3 / ha / year), or 10 times as high as the present log production. It is estimated that only 50% of the reforestation area is accessible for wood harvesting. The average density for oven-dried wood is around 570 kg/m^3 [3]. It is assumed, that around 50 % of harvested plantation wood will be converted into sawn timber, and only the remaining 50 % can potentially be used as energy wood. Thus, on reforestation sites an average energy wood potential of 2.5 m^3/ha equivalent to 1.425 t/ha (dry matter) can be assumed. Table 2-2 provides the energy wood potential in Panay by province.

Table 2-2: Available woody biomass in plantations around the Panay Mountain Range

Province	German Assisted[1] (ha)	NGP (ha)	Total (ha)	Available Biomass[2] p.a. (t)
Aklan	685	1,594	2,279	3,248
Antique	1,572	3,220	4,792	6,829
Capiz	264	1,423	1,687	2,404
Iloilo	445	3,386	3,831	5,459
Total Panay	**2,966**	**9,623**	**12,589**	**17,940**

Source: Forest and Climate Protection Project Phase 2 – ForClim 2

According to Table 2-2, an annual amount of almost 18,000 tons of dry woody biomass from plantations would be available for energy purposes in Panay, concentrated in Antique and Iloilo. The average selling price for fuelwood in rural areas is in the range of 1,000 PhP/ton.

2.2.2 Charcoal

Aside from fuelwood, one other utilization of forest biomass that may be of significance and worth considering is for charcoal production. Current regulations of the DENR prohibits commercial production and large scale trading of charcoal but implementation is not strict because it is recognized, especially by local authorities, that a lot of rural folks are dependent on this activity for their livelihood. This being the case, there is no official figure as to the volume of production and trading of charcoal but observation at trading routes such as provincial vehicle and ferry terminals and even along road sides would confirm that charcoal production is prevalent and the volume could be significant. Currently, prevailing cost of charcoal which is usually sold by volume, ranges from 150 to 250 pesos per sack depending on the wood species used. This costing is equivalent to about 6.50 to 10 pesos per kilogram, again, depending on wood species used.

2.3 Agricultural Residues

2.3.1 Rice Husk Production

The amount of rice husk produced can be estimated from the volume of rice production. Usually for the production of 1 ton of milled rice, 0.23 tons of husks are produced. Annual rice production data in the four provinces of Panay from 2012 to 2014 were generated from the online database of the Bureau of Agricultural Statistics at *www.countrystat.bas.gov.ph*. The use of the average over the three year production data ensures that the skewing effect of factors, such as typhoon, drought or other factors affecting annual production volumes would be minimized. The resulting values are presented in Table 2-3.

1 Fuelwood and timber plantation areas are not yet complete

2 Available dry biomass is assumed at 1.425 tons per hectare per year

Table 2-3: Rice production in metric tons, by province and year, crop years 2009-2013

Province	2009	2010	2011	2012	2013	Average
Aklan	140,357	103,625	126,657	129,645	135,293	127,115
Antique	250,913	211,466	287,036	273,468	286,622	261,901
Capiz	373,982	335,608	349,094	360,914	322,388	348,397
Iloilo	944,050	659,970	959,239	995,402	822,452	876,223
Total Panay	1,709,302	1,310,669	1,722,026	1,759,429	1,566,755	1,613,636

Source: Bureau of Agricultural Statistics, www.countrystat.bas.gov.ph

The three-year average annual rice production for Panay was computed to be 1,613,636 metric tons. That of the province of Iloilo which stands as the third largest rice producing province in the country was the highest among the four provinces at 876,223 metric tons. Aklan posted the lowest average production at 127,115 metric tons.

This volume of production could further be increased, particularly in Iloilo Province, with the Jalaur River Multipurpose Project Stage II (JRMP II) which is expected to provide year-round irrigation to the existing 22,340 hectares of irrigated rice farms and increase it by some 9,500 hectares more. Completion is expected to take place within the next three years.

Based on the rice production data by semester from the same data source, rice production volume is about 60% more during the rainy season, which is from June to December, compared to the production during the dry season, which is from January to May. This means that the demand for mechanical dryers needed to dry palay prior to milling is higher during the rainy season compared to the dry season when the production is lesser and there are more sunny days which allow the farmers and millers to sun-dry their palay.

Milling one metric ton of rice produces about 200 kilograms of rice husk. This may be a reliable means of estimating the theoretical amount of rice husk produced in the area but in reality, not all of these could be available in the same area due to a number of factors affecting the recovery process. For one, not all of the rice produced in one area is milled in the same area. Rice trading may significantly affect the amount of rice actually milled in the area compared to the amount produced in the same area. Small scale milling using widely distributed stationary and ambulant mills spreads over a wide area the rice husks produced making the recovery of the same difficult.

Thus, the theoretical amount of rice husk computed from volume of rice production does not have practical importance in establishing the true potential of rice husk as an energy resource in the same area where rice was produced for the simple reason that not all of these amounts are actually generated in the same area. One adjustment that could be made to come up with a reasonable amount is by making an assumption of how much, in terms of percentage of these theoretical amounts, could actually be recovered and utilized. In the absence of study-based figures, some researchers arbitrarily assume a 50% recoverability factor, meaning, of the computed theoretical amount of rice husk, only 50% would actually be recoverable and available for utilization as fuel. The results of these calculations are listed in Table 2-4.

Table 2-4 Volume of rice husk by province and year, crop years 2009-2013, in metric tons

Province	2009	2010	2011	2012	2013	Average
Aklan	14,036	10,363	12,666	12,965	13,529	12,712
Antique	25,091	21,147	28,704	27,347	28,662	26,190
Capiz	37,398	33,561	34,909	36,091	32,239	34,840
Iloilo	94,405	65,997	95,924	99,540	82,245	87,622
Total Panay	170,930	131,067	172,203	175,943	156,676	161,364

at rice husk to grain ratio of 0.23 and assumed rice husk recovery rate of 50%

The efficiency of the energy conversion equipment used to burn the rice husk as fuel to generate electricity could be additionally factored in to further improve the accuracy of the estimate of the potential. A survey of published data on biomass power plants using rice husk as fuel reveal that these plants could attain system efficiencies in the range of 15% to 30% depending on the installed capacity. Large capacity plants, of say 5 MW and above could attain system efficiencies of up to 30%. Medium-scale plants, those with capacities of 1 MW to less than 5 MW could generally attain efficiencies up to 20%. For this study, 20% system efficiency is adopted.

Rice husk has a relatively higher heating value compared to other agricultural residues, making it a good fuel for energy generation. Published heating values range from 13 MJ/kg to 17 MJ/kg at 10% moisture content. Of these published values, 15 MJ/kg appears to be the most widely used hence was used in this study for computing the energy potential. Since electrical power is usually expressed in MW_{el}, it should be noted that 15 MJ is roughly equivalent to 4.167 kWh, thus the heating value of rice husk, expressed in electrical energy unit is 4.167 kWh/kg. This value was used to compute the equivalent energy potential of rice husk generated in the study area.

Using the preceding energy content equivalences and the adopted 20% system efficiency of the rice husk fueled equipment, the energy potential of the total rice husk production in the provinces of Panay are computed and the resulting values are shown in Table 2-5.

Table 2-5: Energy potential of rice husk produced in Panay

Province	**Rice husk production (t/a)**	**Total energy content in MWh** (at 4.167 MWh per ton)	**Total potential for electric power produc-tion in MWh** (at 20% electrical efficiency)	**Equivalent installed capacity in MW (at 8000 hours of annual operation)**
Aklan	12,712	52,969	10,594	1.21
Antique	26,190	109,134	21,827	2.49
Capiz	34,840	145,177	29,035	3.31
Iloilo	87,622	365,122	73,024	8.34
Total Panay	161,364	672,402	134,480	15.35

The transport and trading of paddy rice transfers the availability of rice husks from the areas of production to the areas where the mill sits are located. Therefore, the actual amount of rice husks available for utilization in a specific area is determined by the presence of stationary rice mills that buy and store paddy rice for milling and trading.

Rice husk, being a by-product of milling, is usually found piled up at mill sites. Very few mills haul their husks to another site because of its bulky and dusty nature which present challenges in hauling and storage. Previous study on the utilization of rice husk for energy generation found out that the most viable scheme is to put up the power plant at the mill site or near the mill site or a cluster of adjacent mill sites where the amount of rice husk generated is enough to sustain the fuel requirement of the plant. This is because hauling and storage incur significant added cost to the operation of the plant.

The previously cited "Study on Rice Husk Potential as Energy Source in Panay" also recommended that utilization of rice husk for power generation is best done at rice mill sites because these are where the rice husks are actually generated and are available for utilization. Mapping out of rice husk availability by municipality was not found to be practical for the purpose of determining the true potential of rice husk for power generation. Instead, a mapping of the rice mills in the study area was recommended and done to determine the amounts of rice husks generated by these rice mills, their locations within the study area and their current practices with regards to rice husk disposal and utilization as well as their preferences in relation to the possibility of utilizing their own-generated rice husks as power source for their drying and milling operations. A list of rice mills operating in the four provinces were obtained from the National Food Authority (NFA). Actual amounts of rice husks generated by these rice mills and their locations were gathered through actual interview of rice mill owners, but in most cases, of those in charge of the operation of the rice mills as their representatives. Other data gathered through the interviews included milling schedules, milling outputs, rice husk disposal practices, paddy rice drying practices and other data relevant to the objectives of the study. Amounts of rice husk generated, their equivalent energy potential and other rice mill related data were computed using generally accepted percentages, heating values and other applicable parameters as discussed in the preceding section, see Table 2-6.

Table 2-6: Rice mills with rice husk electric energy potential of 500 kWel and above

Name of Rice Mill	Name of Owner	Address	Milled Rice Output in t/a	Amount of rice husk generated in t/a	Potential electric power production in kW_{el} [1)]
Farmer's Milling & Supply Co., Inc.	Joy Moskal	Cogon, Panit-an, Capiz	46,800	13,455	1,402
D&D Rice Mill	Jett Rojas	Casamata, Ajuy, Iloilo	38,016	10,930	1,139
EN Rice Mill	Ernesto Eco	Supa, San Jose, Antique	22,464	6,458	673
M-1 Rice Mill	(Undisclosed)	Leganes, Iloilo	21,120	6,072	633
Grabato Rice Mill	Rey P. Grabato	Mina, Iloilo	17,820	5,123	534

[1)] at 4,167 kWh/t, 20% electrical efficiency, 8000 h/a of full operation

Although there are already a number of megawatt-scale utilization of rice husk for electricity and heat generation in Luzon, its utilization outside Luzon as in Panay, is still limited and mostly confined to small scale fuel applications for cook stoves, ovens, kilns and dryers either by direct combustion or gasifying. There are also reported non-power uses, e.g. as soil conditioner in its raw state or carbonized.

The use of rice husk for traditional and improved cook stoves is the most widespread application in terms of the number of users although the combined consumption is still insignificant because the usual consumption of these devices is very minimal in the range of 1 to 2 kilograms per hour only. Use for dryers come in second in terms of unit numbers, but the combined consumption is greater than those for cook stoves. Based on the Flatbed Dryer Program database from the DA, 333 batch type flatbed dryers had been distributed to farmer groups all over Panay from 2009 to 2014. Most of these dryers could dry an average of 120 sacks of rice per batch consuming an average of 30 sacks of rice husks per batch. As per monitoring of the DA, the average number of sacks of rice dried per year by all these dryers, from 2009 to 2013 was 140,574. Using the ratio of 30 sacks of rice husks to 120 sacks of rice dried, the amount of rice husk consumed by the 333 dryers per year is approximately 35,143.5 sacks. The equivalent weight of one sack of rice husk ranges from 7 to 10 kg depending on the moisture content. Using the middle value of 8.5 kg/sack, the total rice husk consumption of all the dryers is more or less 298,719.75 kg/year about 300 tons per year.

2.3.2 Rice Straw

Rice straw is another residue of rice with significant quantity generated each year. The generally accepted straw to grain ratio ranges from 0.25 to 0.30 depending on the manner of harvesting the rice paddy. However, a major portion of this is being left on site (in the farms where the paddy rice is harvested), burned, or left to decompose to serve as soil conditioner and maintain soil productivity of the farms. A smaller fraction is used as fuel in cooking earthen pots using the traditional open firing method. This residue has very little potential as an energy resource as of now owing to the prevailing practices and preferences of farmers. Table 2-7 shows the amount of rice straw generated computed at straw to grain ratio of 0.29 from the rice production values of Table 2-3.

Table 2-7: Amount of rice straw generated by province (in tons)

Province	2012		2013		2014		Annual Average
	Sem. 1	Sem. 2	Sem. 1	Sem. 2	Sem. 1	Sem. 2	
Aklan	16,826	20,771	16,849	22,386	13,326	17,040	35,733
Antique	21,311	57,995	22,829	60,291	21,776	59,448	81,217
Capiz	39,171	65,494	38,103	55,390	30,739	53,697	94,198
Iloilo	93,054	195,612	65,775	172,736	92,318	153,206	257,567
Total Panay	170,363	339,872	143,557	310,802	158,159	283,392	468,715

2.3.3 Coconut Residues

Panay is also a coconut producing region, particularly the province of Aklan. The main crop produced is the coconut nut which is processed to produce copra and ultimately coconut oil. Table 2-8 shows the coconut production by province as of December 31, 2014 as provided by the Philippine Coconut Authority office in Region 6.

Table 2-8: Coconut statistics by province, as of Dec. 2014

Province	Area planted (ha)	Number of existing palms	Total nut production	Copra equivalent (in metric tons)	Amount of residues (in metric tons)
Aklan	39,358	3,935,869	281,622,564	53,735	90,198
Antique	24,317	2,431,707	143,837,992	27,445	46,068
Capiz	40,586	4,007,613	127,697,524	24,365	40,898
Iloilo	27,700	2,627,202	72,251,722	13,786	23,141
Total Panay	131,961	13,002,391	625,409,802	119,331	200,305

Source: Philippine Coconut Authority

Aklan province tops the provinces in Panay in coconut production with a total nut production of 281,622,564, almost double that of Antique which comes in second at 143,837,992 nuts. According to the Philippine Coconut Authority (PCA), the typical composition of the whole nut is as follows: meat 30%, water 22%, cocoshell 12%, and husk 35%. Based on these ratios and the total annual production, the quantity of coconut residues (shell and husk) generated per year are shown in Table 2-8.

The other coconut residues that are of potentially significant quantities but have no data available and does not have any established means of estimating the quantities are the coconut leaves (including the midrib or the frond) and the spadix which is the inflorescence stem that holds a bunch of nuts (from PCA documents).

Copra drying is a significant heat activity in the province. According to the PCA, there are three methods used in drying copra. These are:

1. Sun drying – split nuts, either husked or de-husked are laid open face up to dry under the sun. Done properly, it produces white copra after about 5-7 days.

2. Direct fire drying – split nuts, usually de-husked, are laid open face down on the slats of a smoke kiln which has a fire hearth underneath without chimney (popularly called “tapahan”). Coconut husks and shells are usually used as fuel. This method usually produces a very inferior heavily smoked copra.

3. Indirect fire drying – a hot air dryer called Kukum Dryer is used, where the burning fuel and fuel gases do not come in contact with the coconut meat being dried, producing high grade copra.

There is, however, no data available as to the quantity of copra being dried using coconut residues. However, because of the rainy season, it is safe to assume that a significant quantity of copra is being dried using this fuel type.

2.3.4 Sugarcane Residues

Sugarcane production data from 2011 to 2013, by province, as reported in the online database of the Bureau of Agricultural Statistics are shown in Table 2-9. It is interesting to note that no production is reported for the Province of Aklan. Bagasse, the residue produced during milling/crushing of cane to extract the juice, is computed at bagasse to cane ratio of 0.3 or 30% and also shown in the said table. Other residues generated upon harvesting are leaves and young tops but these residues are left in the fields to decompose or just burned on site. In the Province of Antique, these sugarcane are mainly milled to produce brown sugar called *Muscovado*.

Table 2-9: Sugarcane and bagasse production by province from 2011-13 in tons

Province	2011	2012	2013	Annual average	Bagasse generated [1)]
Aklan	-	-	-	-	-
Antique	55,296	55,874	55,066	55,412	16,624
Capiz	607,704	503,260	375,656	495,540	148,662
Iloilo	1,258,358	1,149,658	970,447	1,126,154	337,846
Total Panay	1,921,358	1,708,792	1,401,169	1,677,106	503,132

[1)] at bagasse to cane ratio of 0.3
Source: Online Database of the Bureau of Agricultural Statistics

In 2005 and 2006, CPU-AREC conducted a survey of existing muscovado mills in the province as part of an inventory of biomass systems installed in Region VI. A total of 107 muscovado millers in Antique were surveyed. The survey revealed that all of the millers use their own bagasse and some bamboo residues as their fuel for cooking the cane juice to produce muscovado. Bamboo residues are usually used as starters and sometimes as supplementary fuel. The total annual bagasse consumption of the 107 millers that were surveyed amounted to 12,974,500 kg or 12,974 metric tons, while the bamboo residues totaled 2,682,600 kg or 2,682 metric tons. All but one of the millers interviewed use motor driven roller mills to mechanically extract the cane juice. Only one miller still uses a traditional rotary mill driven by a *carabao* (water buffalo). There is however no available data as to how much power is consumed by these mills. As things stand at present, there is no surplus of bagasse in the province that could be used for extra power generation.

In the Provinces of Capiz and Iloilo, most of the sugarcane produced is brought to large sugar mills where these are milled to produce raw and refined sugar. Bagasse residue from these mills are used as fuel for heat and electricity generation to supply the energy requirement of the mills. Of the four sugar mills in Panay, only the Central Azucarera de San Antonio Cogeneration Power Plant in Brgy. Cadilang, Passi exports excess power of about 2-7.5 MW to the grid depending on the milling capacity and schedule.

3 ENERGY SYSTEM ANALYSIS

3.1 National Energy Supply and Demand Situation

The Philippine Energy Plan 2012-2030 prepared by the Department of Energy pegs the total energy use in the country at 39.29 million tons of Oil Equivalent (MTOE) in 2010 and 39.40 MTOE in 2011. One ton of oil equivalent is equal to 11.63 megawatt hours (MWh) more or less, thus 39.40 MTOE is roughly equivalent to 458,222,000 MWh or 458.222 terawatt hours (TWh).

In the Philippine primary energy mix, oil provides the highest share to the mix at 31%, followed by geothermal at 22%. Coal come close next at 20%, biomass at 12%, natural gas at 8%, hydro at 6% and bio-fuels at 1%. Wind and solar come last, contributing a relatively insignificant quantity but as of the last three years, developments in the local energy sector have shown that solar and wind are among the fast growing renewable energy sources being developed.

The national power grid is under the management of the National Grid Corporation of the Philippines (NGCP). Source: DOE's Philippine Energy Plan 2012-2030

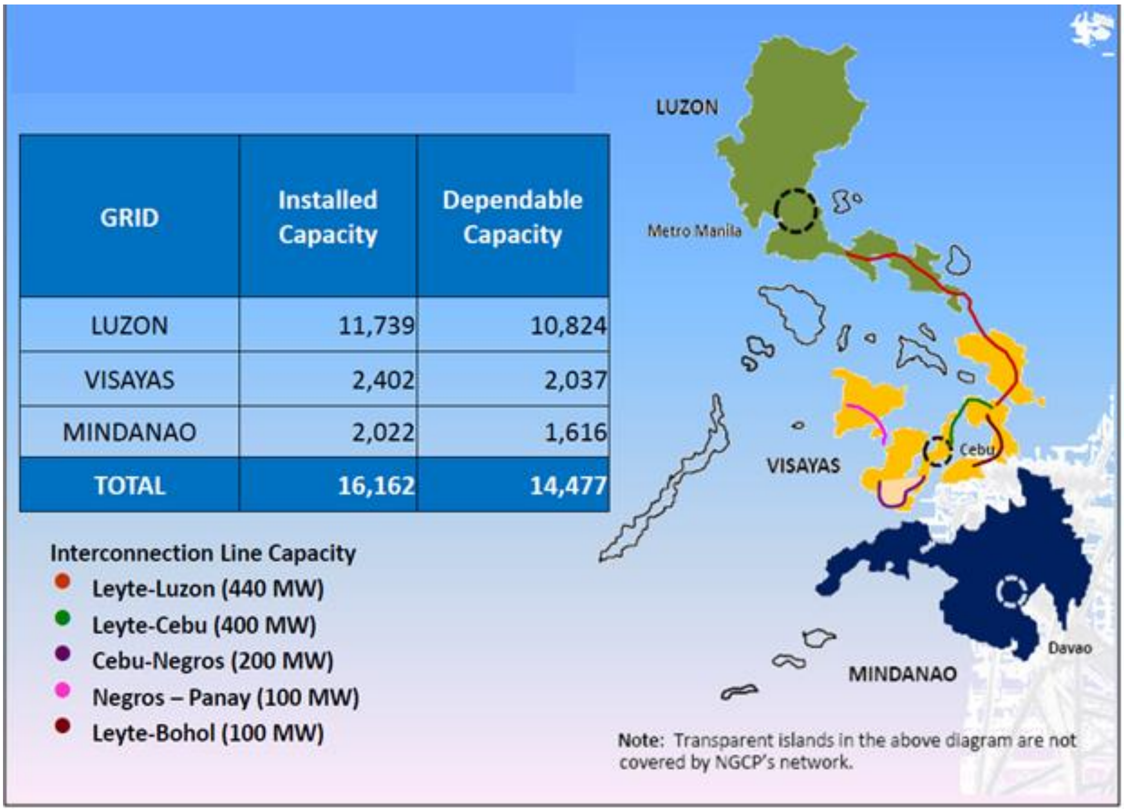
Figure 3-1, taken from the Philippine Energy Plan 2012-2030, shows the national power system grid setup as of 2011. The total installed capacity of the national grid stands at 16,162 MW and the dependable capacity at 14,477 MW broken down as follows: Luzon grid with 11,739 MW and 10,824 MW; Visayas grid with 2,402 MW and 2,037 MW; and Mindanao grid with 2,022 MW and 1,616 MW of installed and dependable capacities respectively.

The Luzon and Visayas grids are connected via the 440 MW capacity Leyte-Luzon interconnection while the Mindanao grid remains unconnected to the national grid. The Visayas grid, being composed of six major islands, has four interconnections: the 400 MW Leyte-Cebu, 200 MW Cebu-Negros, 100 MW Negros-Panay and 100 MW Leyte-Bohol interconnections. The transparent or uncolored islands are not connected to the NGCP operated national grid but the transmission and distribution of electricity are managed either by the National Power Corporation - Small Power Utilities Group (NPC-SPUG) or the distribution utilities covering the islands.

New generating capacities need to be put on line to meet the increasing demand for power as the economy and the population grow. Source: DOE's Philippine Energy Plan 2012-2030

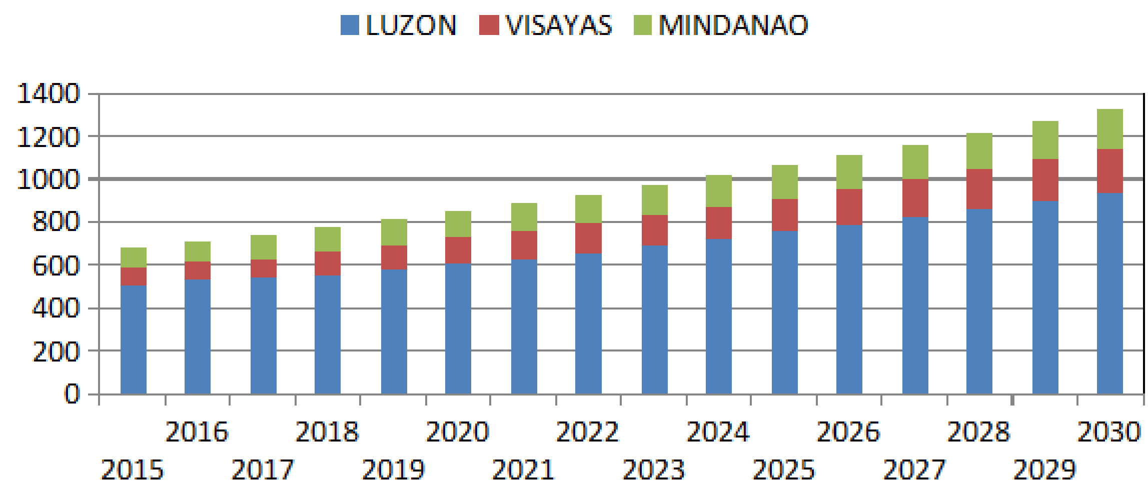
Figure 3-2 presents the DOE's forecast of new capacities needed by the country for the planning years 2015 through 2030. Disaggregation by Luzon, Visayas and Mindanao grids are provided to help in coming up with a more focused power development plan. The figure shows a steadily increasing demand with the Luzon grid surpassing even the combined demands within the Visayas and Mindanao grids.

The DOE has presented a sustainable low-carbon scenario for the years ahead as stated in the Policy Thrusts of the PEP 2012-2030. With this scenario, there is created a sustained requirement for the development of additional generating capacities that are clean, renewable and sustainable for the whole country.



Source: DOE's Philippine Energy Plan 2012-2030

Figure 3-1: Philippine power system infrastructure as of 2011



Source: DOE's Philippine Energy Plan 2012-2030

Figure 3-2: New capacity additions (in MW) at country level

3.2 Panay Energy Situation

3.2.1 Electrical Energy Supply and Distribution

Grid electricity supply for the four provinces of Panay is distributed by six electric distribution utilities (electric cooperatives), namely:

- Aklan Electric Cooperative, Inc. (AKELCO),
- Antique Electric Cooperative, Inc. (ANTECO),

- Capiz Electric Cooperative, Inc. (CAPELCO),
- Iloilo I Electric Cooperative, Inc. (ILECO I), Iloilo II Electric Cooperative, Inc. (ILECO II) and Iloilo III Electric Cooperative, Inc. (ILECO III).

Table 3-1 lists these cooperatives and their corresponding franchise areas, total number of connections, total annual consumption and electricity rates.

Table 3-1: Electric distribution utilities serving Panay island

Coop	**Area served (Franchise area)**	**Total number of connections**	**Total annual consumption in kWh**	**Electricity rate in PhP/kWh [1)]**
AKELCO	Whole province of Aklan plus 2 municipalities in Antique (Pandan and Libertad)	Residential: 105,202	249,438,797	10.8436
		Low Voltage: 7,705	249,438,797	9.8973
		High Voltage: 30	249,438,797	8.5637
ANTECO	Whole province of Antique, except Pandan & Libertad (see AKELCO)	Res.: 78,927	88,489,847	NonVAT: 11.3847
		Com'l & Ind'l: 2,165	88,489,847	
		Pub. Builds. Etc.: 1,787	88,489,847	VAT: 11.7152
CAPELCO	Whole province of Capiz	Res.: 114,383	164,745,032	R: 11.6110
		Com'l & Ind'l: 3,861	164,745,032	C&I: 10.8489
		Others: 1,786	164,745,032	Others: 10.8489
ILECO I	Iloilo province, 1st and 2nd district	R: 114,949	212,881,298	R: 11.1497
		LV: 4,258	212,881,298	LV: 9.8530
		HV: 49	212,881,298	HV: 9.1464
ILECO II	Iloilo province, 3rd and 4th district	R: 94,492	138,289,452	R: 10.1532
		C&I: 4,049	138,289,452	C&I: 9.7657
		Others: 297	138,289,452	Others: 8.1165
ILECO III	Iloilo province, 5th district	R: 55,207	65,485,789	All: 9.36
		LV: 2,015	65,485,789	
		HV: 8	65,485,789	
		SPUG[3]: 334	65,485,789	*No data*

[1)] The rates presented are the distributed price (final electricity price) which include the generation, transmission, distribution, taxes, etc. The net generation cost have not been disclosed.

The main sources for the supply of these power coops include:

- the 164 MW coal fired power plant of Panay Energy Development Corporation (PEDC) in Ingore, Lapaz, Iloilo City,

3 SPUG – Small Power Utilities Group, a group of NPC to electrify areas not connected to the main transmission grid

- the 294 MW geothermal power plant of Green Core Geothermal, Inc. (GCGI) in Valencia, Negros Occidental,
- the 139.2 MW diesel power plant of Salcon Island Power Corporation (SIPC) in Tinocuan, Dingle,
- some smaller diesel fueled power plants and other power sources

3.2.2 Energy Demand in the Households

In the absence of data on household energy consumption for the island of Panay, it is deemed applicable to infer the national figures in the results of the Household Energy Consumption Survey (HECS) conducted by the DOE and NSO in 2004. The said survey revealed that 87.6 % of the sampled households nationwide used electricity, to fuel their homes. Lighting was the main use of electricity in the household, with household recreation such as use of televisions and players (VHS, DVD, CD, stereo, etc.) coming in second and space cooling (use of electric fans and air conditioners), third.

Other types of fuel used in the households, particularly for cooking, include liquefied petroleum gas (LPG), kerosene and traditional types of fuels such as fuel wood, charcoal and other biomass residues. About 52 % of the sampled households used LPG while 56 % utilized kerosene. Users of traditional fuels such as fuel wood, charcoal and other biomass residues were observed at 55 %, 34 %, and 18.9 % of the total number of households sampled, respectively. 10 % and 3.3 % of the sampled households used gasoline and diesel respectively, which were consumed primarily for transportation. These data from the survey reveals that the use of biomass, including charcoal, as source of heat energy for household cooking is still widespread (55 % fuel wood, 34 % charcoal) throughout the country particularly in the rural areas like most of the rural communities in the Panay.

3.2.3 Energy Demand in the Agricultural and Industry Sectors

Drying, milling and other post-harvest activities are all energy consuming activities in the agricultural sector. Almost all agricultural crops undergo drying upon harvesting to help preserve quality and extend shelf life. Crops and products that undergo drying include rice (see sections about rice husk as biomass source and the following texts on rice drying in the concept development section), copra, corn, abaca, coffee and fish. Most of the drying activities, especially during the summer months, use direct sunlight to dry the crops or products by simply laying the same in an open space under the sun.

Cooking, drying, milling and other food and handicraft processing are among the energy consuming activities in the industrial sector. Cooking tops the list as this process requires a lot of heat such as in the production of muscovado sugar from sugar cane. Drying and milling are also significant energy consuming activities but most of the drying activities like drying of wood, abaca, coffee and other food products are mostly done using the heat of the sun either by laying the products in an open space under the sun or by using solar dryers.

Copra drying is also a significant energy consuming activity in the agriculture sector. It is usually accomplished by direct sun drying during summer months or by using the traditional fire hearth locally called “tapahan” fueled by coconut husks, shells and other coconut residues. Significant milling activities are also done on sugar cane. Milling of sugar cane and cooking of the resulting cane juice are two of the major energy consuming processes in the production of muscovado sugar which is an important small and medium scale industry mostly in the province of Antique but also found in the other two provinces of the study area.

Other food processing activities involve mostly cooking and cold storing. Wood, metalcraft and handicraft processes usually involve the use of power tools for welding, cutting, machining, grinding and drilling which draw power from the electricity grid or from diesel/gasoline generator sets. Lumber and other wood and bamboo materials that need to be dried are usually sun dried.

3.3 Conclusions

Considering the current energy supply in Panay as well as the current mix in primary energy for power production, any further supply of renewable energy is necessary. This conclusion is not only referring to carbon dioxide reduction but also to a stable power supply. The expected increase in power demand for the Philippines justifies the installation of renewable power from all different sources, including biomass, wind, hydro, geothermal and solar power.

4 DEVELOPMENT OF CONCEPTS

4.1 General Aspects

The use of solid biomass for energy purposes usually includes several separated or linked process steps. It commonly starts with one or more thermo-chemical conversion steps, including drying, pyrolysis gasification and combustion. Afterwards, final power conversion takes place to make use of it. This may include simple heat transfer (e.g. for drying), inclusion of one or more thermodynamic cycle (e.g. for power generation or for cooling), or further usages (e.g. fuel cells), depending on first conversion steps.

4.2 Conversion Chains

Identification of possible conversion chains takes place by considering the following aspects:

- biomass availability
- market for products (e.g. power, heat/cooling, charcoal)
- technology readiness level

For sustainable plantation wood from reforestation areas, the following conversion chains have been identified:

- gasification, gas engine (products: power and heat)
- pyrolysis (products: charcoal)
- pyrolysis, gas engine (products: power, heat and charcoal)

For rice husk, four more conversion chains have been identified:

- combustion (products: heat)
- combustion, water steam cycle (products: power and heat)
- combustion, organic Rankine cycle (products: power and heat)

In the following sections, the different conversion chains are described in detail. This includes general information, a technical description, typical operating data (if available) and implementation examples (if available).

4.2.1 Sustainable Wood Gasification and Gas Engine

Generating power from sustainable wood, e.g. from plantations, is considered to be an eligible possibility within forest land use plans (FLUP). Wood can be made available as logged wood or as chipped wood (which requires an additional wood chipper). Although it is possible to produce pellets from wood, this requires additional investments (pellet press, mill), which might make it unfavorable in terms of economy and ecology under the Philippine context (scaling effects, transport conditions).

In gasification, a carbon based fuel is converted to a low calorific gas e.g. by partial oxidation. The product gas consists of carbon monoxide and hydrogen as combustible components, but also of carbon dioxide, water (steam), nitrogen, methane and smaller amounts of trace components and contaminations (e.g. tar). There are several gasification technologies, including moving bed gasification and fluidized bed gasification. [4]

The combination of such a gasification process with an internal combustion engine has been demonstrated and is available on the market. Here, the product gas from gasification is fed to a gas engine, which is connected to a power generator.

There are several producers of CHP systems for biomass gasification. In Germany, the most common systems are from Spanner and Burkhardt [5]. While the Burkhardt model is suitable for pellets only, the Spanner models are designed for wood chips as fuel. There are two standardized models with 30 kW_{el} and 45 kW_{el} (with an additional 19 kW_{el} currently brought to the market). In the following Table 4-1, the most important technical data for both models is listed [6].

Table 4-1: Technical data for Spanner gasification CHP models

Name of model	**HK 30**	**HK 45**
Electrical power	30 kW	45 kW
Heat power	73 kW	108 kW
Wood chip consumption (estimated)	30 kg/h	45 kg/h
Wood chip quality	Size G30 to G40, 13% moisture content (better: < 8%), max. 30% of fines (< 4mm)	
Heat output	Max. 85 °C (at 60 °C return temperature)	
Dimensions wood gasifier (LxBxH)	5272 mm x 1540 mm x 2300 mm	
Dimensions CHP unit (LxBxH)	2600 mm x 924 mm x 2196 mm	

In the following Figure 4-1, the general principle of the system is given. Wood chips are fed to the gasifier via a lock (or sluice). From here, they are transported to the actual reformer, where the gasification process takes place. The product gas is cleaned from residual charcoal and ash with the help of a filter, before being fed to the gas engine.

In Asian countries (e.g. India) gasification techniques from Ankur and Husk Power Systems are better known and wider distributed. Ankur has developed a dry filter system which improves the control and the end-of-life management of tar particles. This reduces a significant environmental risk and enables the sustainable operation. More information can be obtained from the GIZ sector project HERA at head office.

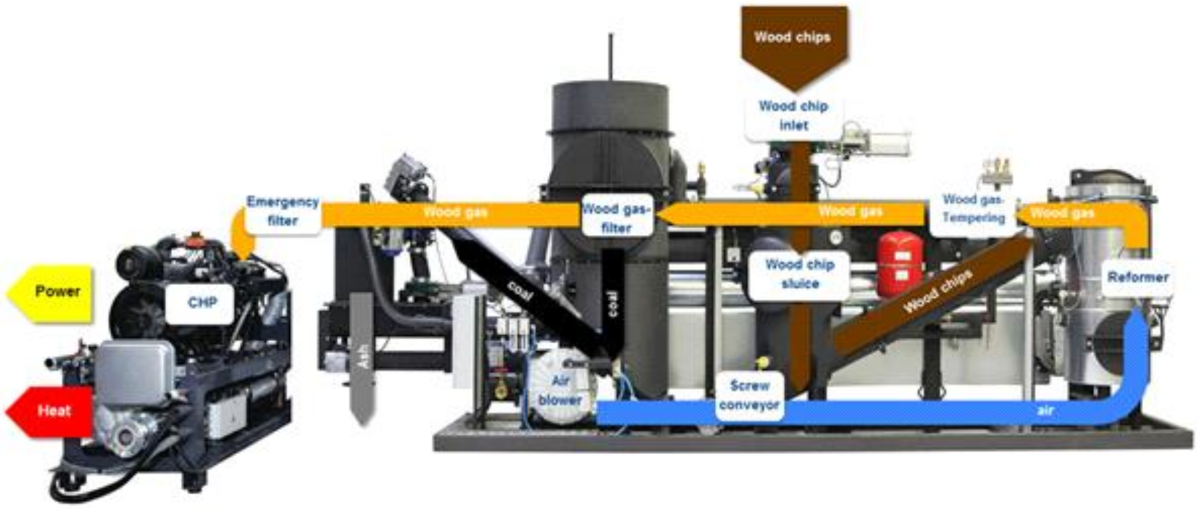


Figure 4-1: Functional diagram for Spanner gasification + CHP system [6]

There are several examples for the implementation of wood gasification in combination with CHP systems. In Figure 4-2, a plant in Austria with a nominal power of 30 kW_{el} is shown which is in operation since 2010.

Figure 4-2: Spanner gasification system in Austria [5]

The economics of small plants in the mentioned range of 30 to 45 kW are not as good as compared to larger plants of up to 200-250 kW. The investment cost of larger plants are much higher (above 50 million PhP), however, and the wood requirement would exceed the regional available supply. For this study only smaller plants shall be considered, therefore.

4.2.2 Sustainable Wood Pyrolysis for Charcoal Production

Charcoal is used as a combustion fuel in several contexts, including cooking. Traditional production of charcoal, e.g. in earth kilns, is considered to be very inefficient and environmentally problematic. Although the usage of wood for such purposes is often prohibited, it is sometimes tolerated as a cultural practice.

Generally, charcoal is produced by a thermo-chemical conversion of biomass with very limited access to oxygen. Due to increased temperature, organic components are cracked. Since most of the hydrogen and oxygen contained in the original biomass are driven out during the process, the remaining coke has a very high carbon content. [4]

Traditional charcoal production usually finds conversion rates of 11.8% for pit mounds, 25.7% for surface earth mounds, and 16.8% for Casamance (modified) surface earth mounds [7].

There are several technical options to improve charcoal efficiency while reducing emissions. For this study, the so-called Adam retort (see Figure 4-3 and Figure 4-4) is considered [8] [9].

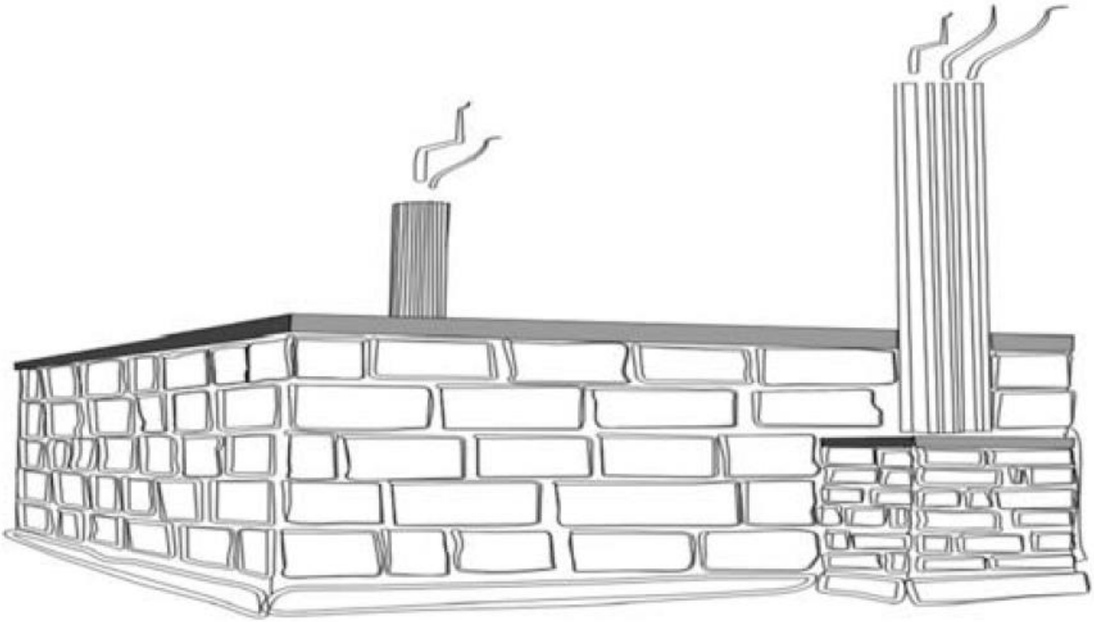


Figure 4-3: “Adam retort” or Improved Charcoal Production System (ICPS) [8]

This retort results in conversion rates of more than 30%. Emissions are strongly reduced by returning the pyrolysis gases to the so-called fire box, where they are flared and the heat content is recycled [9]. Typically, the retort has a feedstock capacity of 3 m³. It requires a certain amount of wood for start-up (typically 50 kg), and has a charring time of 10-20 h [9].

Figure 4-4: Adam retort in operation [9]

There are many positive experiences with Adam retorts, but also critical reports. The pyrolysis process is rather complex and problems may arise during maintenance and operation. Before embarking on this technology further research may be recommended. Besides, as long as charcoal is not sold at a real market price and has to compete with illegal production, investments in improved wood-to-charcoal production/ conversion are economically not attractive. Additional information can be obtained from the GIZ HERA project and the Energypedia website https://energypedia.info/wiki/Charcoal_Production.

4.2.3 Sustainable Wood Pyrolysis plus Gas Engine

Generally, it is possible to use the gases from wood pyrolysis in the charcoal production process to produce additional power. This can be done by using them as a fuel for either a gas engine or a gas turbine. Demonstration projects on this principle have been reported in literature, but the technology is currently not considered matured [10] [11].

An example for a demonstration system for combined charcoal, heat and power production is given in Figure 4-5.

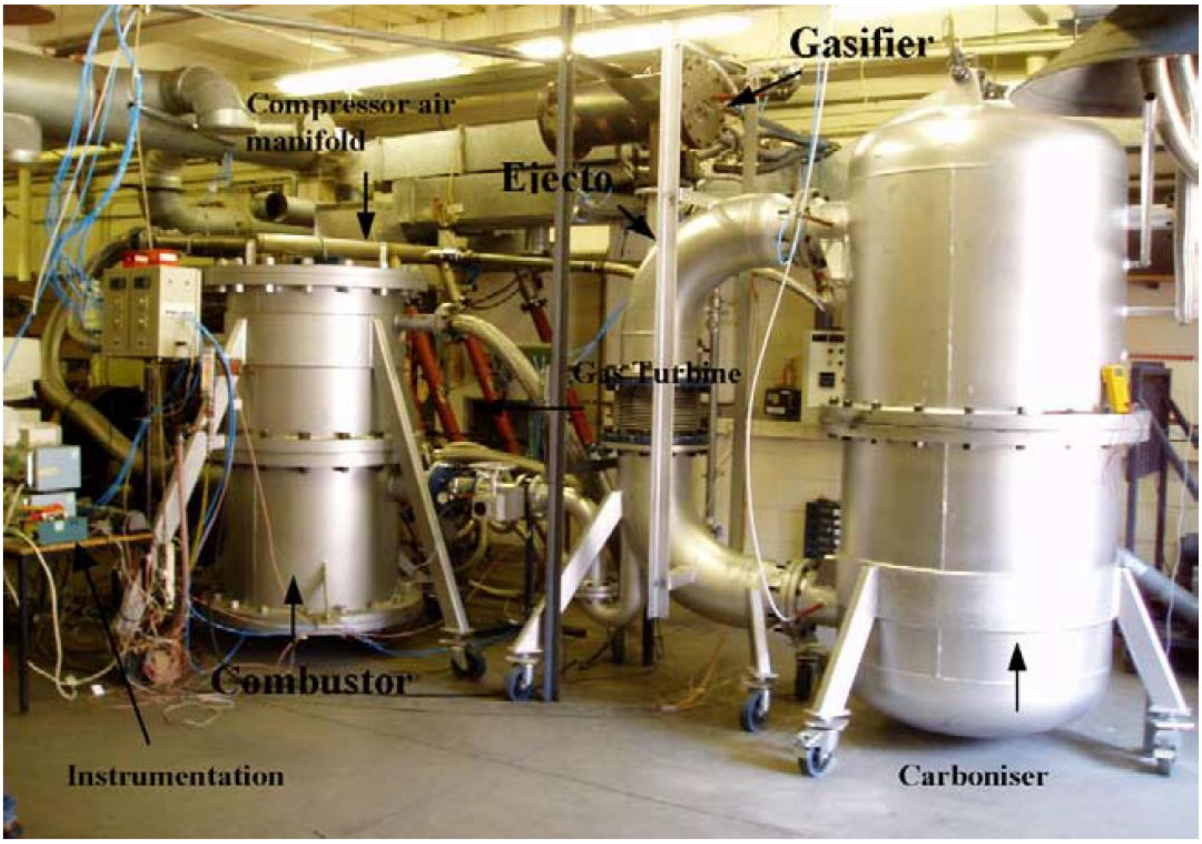


Figure 4-5: Combined charcoal, heat and power demonstration system [10]

4.2.4 Rice Husk Combustion for Rice Drying

Rice drying is an important part of the value chain for rice production. Fresh rice with rice husk (paddy, or *palay* in the Philippines) usually comes with a moisture content in the range of 28% (weight-based), while rice mills (where the rice husk is separated from the rice for food) require a moisture content of 13.5-14.0% for optimized operation. Traditionally, the palay is dried in the sun. Due to area consumption and the reliability on weather conditions (especially during rainy season), but also due to the losses in rice during the sun drying (which can be as high as 8 to 10% according to NFA), technical rice drying is considered to be of increasing importance for the food security in the Philippines.

Rice dryers have already been implemented on several levels in the Philippines, including the provinces of Panay island. There is an existing program of the Department of Agriculture (DA) for the implementation of flatbed dryers e.g. by cooperatives or associations. Additional programs include the installation and operation of rice processing centers (RPC) with circulating rice dryers. Also, many rice millers are operating rice dryers independently to dry the rice directly at the mill.

The basic principle of biomass fueled rice dryers is the combustion of rice husk and the conversion of the produced heat to the paddy to reduce moisture content. The combustion takes place in a furnace, which has usually a brick lining. Depending on the technology, the flue gases are led directly through the palay (especially in flatbed dryers) or transfer the heat to air within heat exchangers, so the hot air can be used to dry the paddy.

Flatbed dryers can dry an amount of 1-3 tons of paddy per day, with a drying time of 6-12 hours [12]. The general principle of flatbed dryers is given in Figure 4-6. In Figure 4-7, one of the flatbed dryers distributed by the Department of Agriculture (DA) is shown, which was granted to an Irrigators Association under a specific contract.

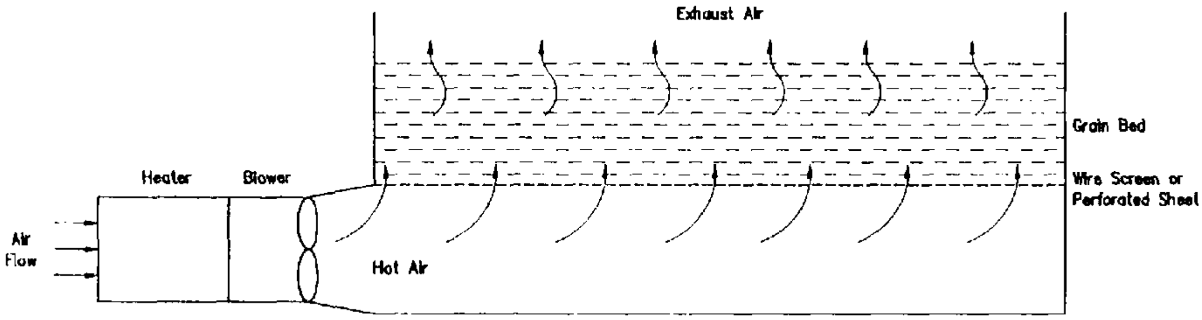


Figure 4-6: Flatbed dryer principle [12]

Figure 4-7: Flatbed dryer at an Irrigators Association in Brgy. Cansadan-Tubudan, San Jose, Antique

In Figure 4-8 several circulating rice dryers at the site of the National Food Authority (NFA) in San José, Antique, can be seen. At the site, farmers can sell their palay to a price set by the government. The rice is then dried and milled at the site, with the final product to be stored at the NFA warehouse and sold in times of rice shortages. The general principle of circulating batch dryers is given in Figure 4-9.

Figure 4-8: Circulating rice dryers at the National Food Authority (NFA) in Brgy. San Fernando, San José de Buenavista, Antique

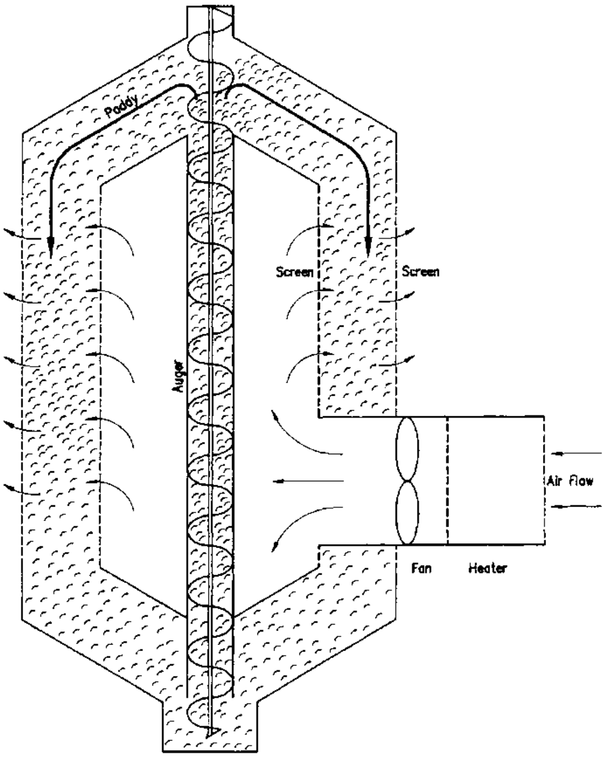


Figure 4-9: Circulating batch dryer [12]

4.2.5 Rice Husk Combustion and Water Steam Cycle

With increasing population and energy demand, any further supply in power is important for the Philippines. Currently, there are still several brown outs on the island of Panay. Thus, industries rely on diesel power generators in cases of grid problems to continue working. This includes rice mills, to whom it would be of high advantage to have their own power supply from rice husks. If the power plant is designed in an appropriate way, rice millers can be their own suppliers.

Typical combined heat and power (CHP) systems with steam cycle start at a nominal power of $1MW_{el}$.

At first, the fuel (here: rice husk) is burnt within a furnace (see Figure 4-10). There are several combustion technologies, including a variety of grid furnaces as well as fluidized bed combustion systems. Also, there might be a staging of the air to decrease emissions. The heat from the flue gas is transferred to pressurized water within a boiler (which might have several stages) to produce superheated steam. Within a steam turbine, the energy from the steam is transferred to a generator to produce power. Heat from the steam can be used, e.g. for thermal processes. In bleeder type steam turbines, steam can be extracted in several stages of the turbine. Before closing the cycle, the steam has to be condensed so it can be pressurized again.

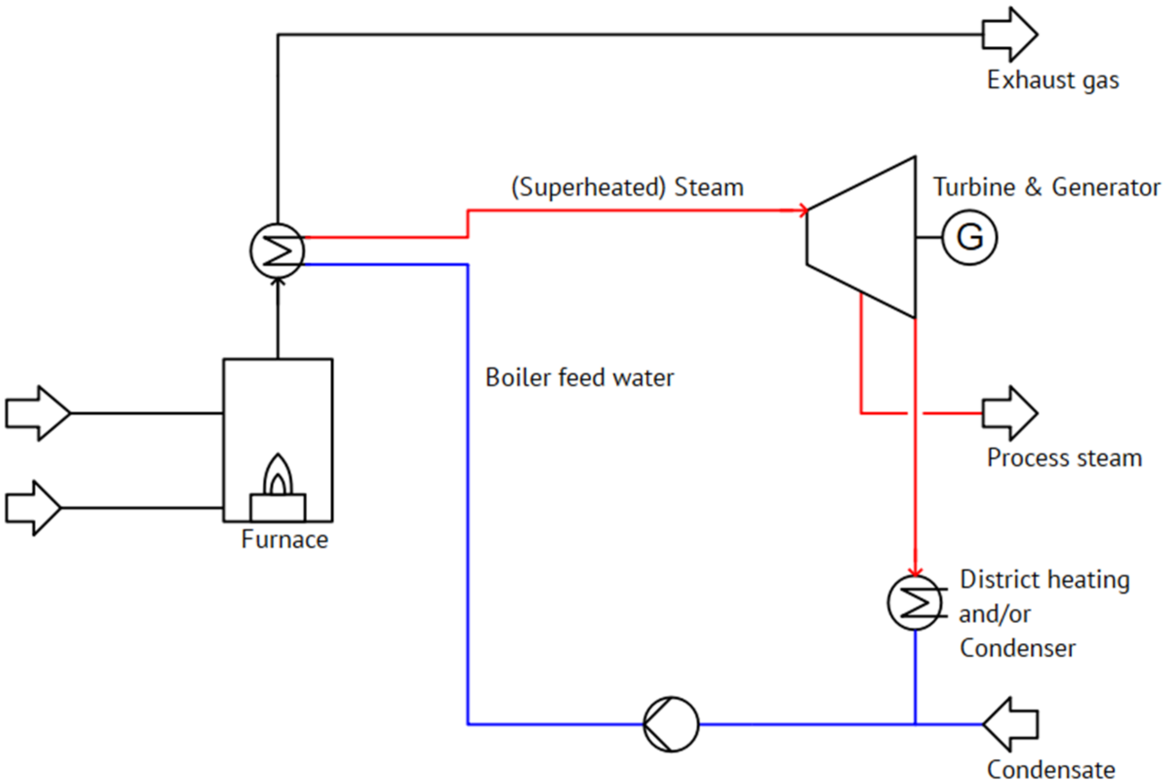


Figure 4-10: Simplified flow scheme of a steam cycle based power plant

An existing power plant based on rice husk (Family Choice) has been visited by consultants of the ForClim II project in March 2015 (see Figure 4-11 [13]). It has a nominal power of 1.5 MW_{el}, requiring 2.25 t/h of rice husk. It has a extraction-condensing turbine, with 350°C steam temperature and 24 bar as inlet parameters. Biomass is burnt in a step grate boiler, producing 11.5 t/h of steam at 26.5 bar in a water tube steam boiler. The rice mill is using all of the produced power. No major problems have been reported for the last years.

Fuel cost for rice husks is a very important topic. Worldwide, biomass projects in developing countries have struggled with a significant increase of prices as soon as the demand from power plants materialized, often rendering the initial business plan obsolete. The assumed cost in this study of 1,000 PhP per ton of rice husks takes the increased demand already into consideration (now often the rice husks are just dumped on empty spaces near the rice mills). But maybe just a pilot installation can really show what will happen. In this study a rice-husk based steam cycle is only recommended for rice mills with sufficient own supply of husks and a substantial power demand.

Figure 4-11: Family Choice Rice Husk Power Plant [13]

4.2.6 Rice Husk Combustion and Organic Rankine Cycle (ORC)

Typical combined heat and power (CHP) systems with Organic Rankine Cycle (ORC) start at a nominal power of 0.5 MW_{el}. Organic Rankine Cycles (ORC) make use of some specific features of certain thermal and silicon oils. While the thermal oil can be used to transfer heat from a furnace at a specific temperature, the silicon oil has some advantageous properties in regard of the thermodynamic Rankine cycle.

In an ORC plant, biomass is burnt within a furnace. Afterwards, heat is transferred to thermal oil, e.g. via coils. By this way, the heat can be transferred at low pressure level since the oil has a higher boiling temperature which will not be reached in the process. Depending on process design, there can be one or two thermal oil cycles (compare Figure 4-12 and Figure 4-13) [14].

Within the so-called turbogenerator, heat from the thermal oil is transferred to a specific silicon oil (the type of which is depending on the temperature of the hot thermal oil). The silicon oil will boil and drive a power generator. In a further heat exchanger, the oil is cooled down and condensed.

Typical electrical power outputs are in the range of 400 to 2,200 kW, with an efficiency of 15-20 %.

An ORC based CHP fueled by rice husk has been reported for Italy [15]. In Mortara (Region Lombardy, Province Pavia), an ORC plant with an electric power of 600 kW and a thermal power of 2.8 MW has been installed and started in July 2008. It is fueled by rice husk from rice mill Parboriz Spa. Thermal power is used fo the production of parboiled rice. The ORC part has been delivered by Turboden (now part of Mitsubishi Heavy Industries), while the boiler was supplied by Classen Apparatebau Wiesloch GmbH (see Figure 4-14, [16]). It is reported to be running with 99% availability [15].

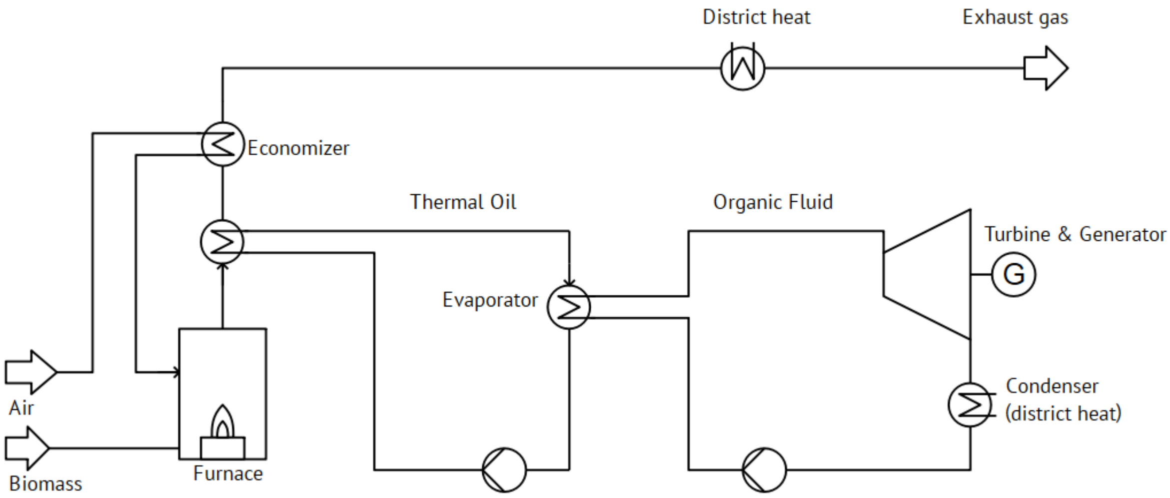


Figure 4-12: General principle of an ORC based power plant with one cycle

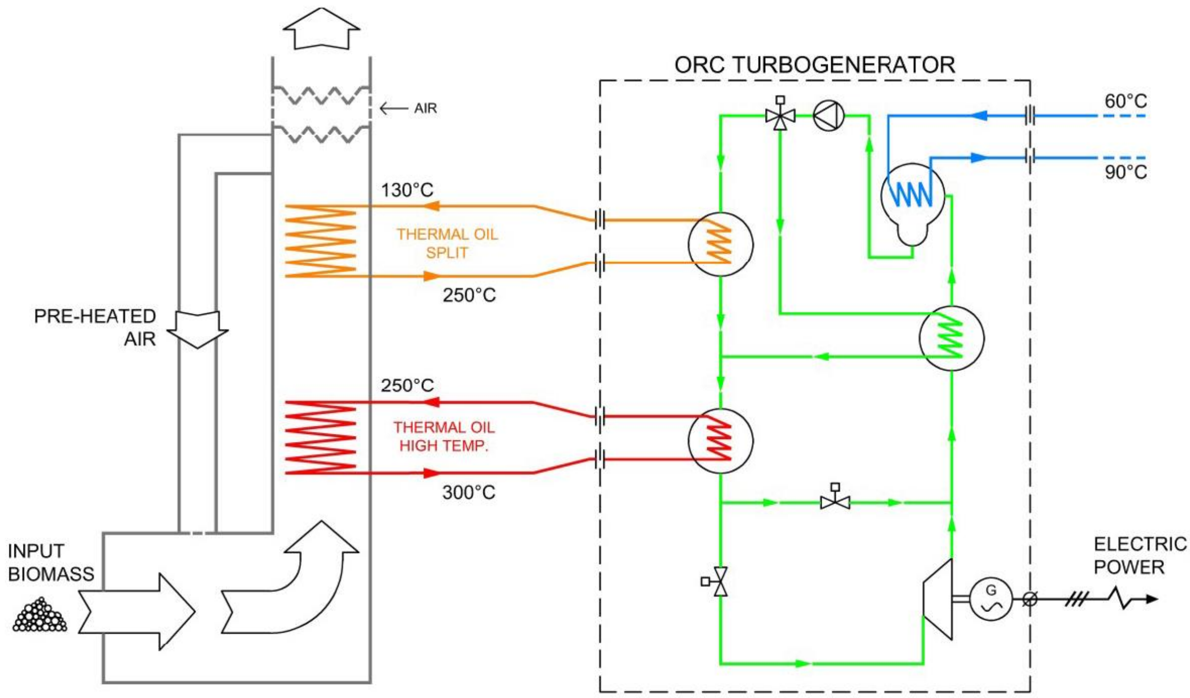


Figure 4-13: Flow scheme for an ORC based power plant with two thermal cycles [14]

Figure 4-14: Rice husk fueled ORC power plant [16]

5 FEASIBILITY ASSESSMENT

The feasibility assessment for the evaluated process chains will include economic and ecologic aspects. The basic methodology will be explained in the next section. The assumptions that have to be made will be given and, where necessary, explained in the following section.

5.1 Calculation Methodology for Power Production Technologies

Economics for this study are based on calculating equivalent annual costs (EAC) [17]. They can be defined as

$$EAC_{total} = EAC_{invest} - annual\ income + annual\ costs$$

with EAC_{inv} being the equivalent annual costs of the investment:

$$EAC_{inv} = IC * \frac{(1 + i_k)^n * i_k}{(1 + i_k)^n - 1}$$

Here, *IC* are the actual costs of the investment, i_k is the nominal interest rate, and *n* is the depreciation or recovery period (in years).

Annual income is calculated as the sum of all monetary cash flows to the operator (including absolute earnings from power sale, feed-in tariffs, byproduct sale, but also additional earnings e.g. from lower rice losses during drying) and of prevented spending (e.g. for electrical power from the grid, diesel fuel).

Annual costs include labor costs, maintenance (e.g. spare parts) and operation (e.g. lubrication oils), insurances, administration and unexpected costs.

5.2 General Assumptions

For economic calculations, the following assumptions are being made (reasonable variations are stated in the specific assumptions for the specific feasibility calculations).

- depreciation or recovery period: n = 10 years
- nominal interest rate: i_k = 8%
- reference electricity costs: c_r = 11.7 PhP/kWh
- rice husk lower heating value: $H_{i,RH}$ = 15 MJ/kg
- feed-in tariff for biomass: FiT = 6.63 PhP/kWh [1)]
- exchange rate US-$ → PhP: 1 US-$ = 44.53 PhP (as of May 1st, 2015)
- exchange rate € → PhP: 1 € = 50,13 PhP (as of May 1st, 2015)
- annual service and maintenance [18] c_{sm} = 8%
- annual administration, insurances and unexpected costs [18]:
  c_{aiu} = 2 %

[1)] The feed-in tariff (FIT) rate for biomass will be degressed by 0.5% every 2 years starting January 2017

Depending on the type of job, different monthly wages are assumed within the concepts. These monthly wages are based upon the 2014 Yearbook of Labor Statistics [19] and, of course, can only give a rough estimate. According to this data, an agricultural or forestry worker is assumed to have a monthly wage of 12,000 PhP, while a power plant operator or engineer is expected to have a monthly salary of 28,000 PhP.

For ecologic calculations, the assumptions are as following:

- reference carbon dioxide emissions from coal fired power plants: 246.8 g_{CO2}/MJ_{el} = 888.5 g_{CO2}/MWh_{el} [18]

In the Visayas, and especially in Panay, there is a large share of coal and oil fired power stations. Considering the base load capability of biomass fired power plants, it can be assumed that electrical power from solid biomass will substitute power from coal fired plants.

It should be noted, that this assumption is only of very general nature and does not conform with calculation methods for funding from the Clean Development Mechanism (CDM).

5.3 Results

5.3.1 Sustainable Wood Gasification and Gas Engine

For the evaluation of the combination of wood gasification and gas engine, assumptions as stated in Table 5-1 are made. Taking these assumptions into account, the results listed in Table 5-2 can be achieved. Due to high investment costs for reliable gasification technology, the economics of these technologies are not very favorable if only the feed-in tariff (FIT) is considered as an income. With its rather low output of 30 kW this technology may not be eligible for FIT anyway. The FIT system in the Philippines is designed for large utility scale projects. This small project can instead fall under the net-metering scheme. Net-metering is for RE systems with capacity up to 100 kW and installed within the premises of the owner-user. The generated electricity is used by the owner with the excess sold to the distribution utility.

Since the production cost per kWh of a wood gasification plant are below the reference electricity cost, the avoided cost for buying electricity from the grid would make it a positive investment for the owner.

Table 5-1: Assumptions for evaluation of wood gasification and gas engine

Parameter	Assumption for reference case	Explanation
Number of employees	1 power plant operators/engineers	- daily control and refill
Annual operation hours	7,500 h	- typical annual operation time for gasification CHP
Investment	5,000 €/kW$_{el}$	- typical investment for gasification CHP, see e.g. [5]
Fuel costs	960 PhP/t	- see report on first study for Antique
Carbon dioxide emissions	67 kg$_{CO2}$/kWh$_{el}$	- different values in literature: • 17.16 kg/MWh [5] • 22-35 kg/MWh (for wood biomass) [6] • 67 kg/MWh [7], chosen to be on safe side
Nominal power	30 kW$_{el}$	- typical available size
Overall electrical efficiency	20 %	- typical value for plant of this size
Annual service and maintenance	8 % of capital investment	- complex technology, might need relatively high maintenance costs

Table 5-2: Results for wood gasification and gas engine

Parameter	Value
Investment	7.5 Mio. PhP
Equivalent annual cost of investment	11.18 Mio. PhP
Annual labor force cost	0.336 Mio. PhP
Annual service and maintenance	0.6 Mio. PhP
Ann. administration, insurances and unexpected	0.15 Mio. PhP
Annual fuel input	270 t
Annual fuel costs	0.27 Mio. PhP
Overall annual costs	2.474 Mio. PhP
Annual electricity production	225 MWh
Annual income from FiT [1)]	1.492 Mio. PhP
Annual profit (with FiT)	-0.982 Mio. PhP
Power production costs	10.994 PhP/KWh
Average cost for buying electricity from the grid	11.7 PhP/KWh
Avoided cost for buying electricity (11.7 PhP – 10.994 PhP) x 225 MWh	0.159 Mio. PhP
Annual carbon dioxide savings (compared to coal)	185 t

[1)] FIT rate for biomass will be degressed by 0.5% every 2 years starting January 2017, so the annual income will be slightly reduced after this date.

5.3.2 Sustainable Wood Pyrolysis for Charcoal Production

The following calculations refer to an Adam retort for charcoal production. The relevant assumptions are given in Table 5-3. The results from the evaluation are given in the following Table 5-4.

According to the data, there is an annual benefit under the assumptions made. It should be noted, that under the same assumptions concerning fuel costs and labor force costs, but with no investment, the charcoal production costs are even higher (>14.9 PhP/kg) due to the lower efficiency. Most of the annual costs can be accounted to fuel costs and labor force costs in this calculation. Thus, current production can only be lower in costs by saving significantly in these categories (e.g. by very low priced fuel wood, or by not hiring staff but doing all work as an entrepreneur himself).

Table 5-3: Assumptions for advanced charcoal making

Parameter	Assumption for reference case	Explanation
Number of employees	1 forestry worker	- operation
Annual operation hours	150 times	- up to two days per batch, three batches per week, 50 weeks per year
Investment	1,200 € per kiln	- as reported from the inventor
Fuel costs	960 PhP/t	- see report on first study for Antique
Fuel input per batch	750 kg	- 600 – 900 kg per batch have been reported [8]
Charcoal selling price	10 PhP/kg	- research shows wide span of prices, ranges from 100 – 300 kg/bag - each bag has 11 – 18 kg [20]
Charcoal production efficiency	0.32 kg/kg	- reported values for Adam retort [9]
Traditional charcoal production efficiency	0.15 kg/kg	- reasonable average value for traditional kilns [7]
Annual service and maintenance	8 % of capital investment	- complex technology, might need relatively high maintenance costs

Table 5-4: Results for advanced charcoal making

Parameter	Value
Investment	60,156 PhP
Equivalent annual cost of investment	8,965 PhP
Annual labor force cost	144,000 PhP
Annual service and maintenance	4,812 PhP
Ann. administration, insurances and unexpected	1,200 PhP
Annual fuel input	112.5 t
Annual fuel costs	180,000 PhP
Overall annual costs	267,000 PhP
Annual charcoal production	36,000 kg
Annual income from charcoal sale	360,000 PhP
Annual profit	93,000 PhP
Charcoal production costs	7.417 PhP/kg
Wood saving per kg charcoal compared to traditional charcoal making	3.5 kg wood / kg charcoal

5.3.3 Sustainable Wood Pyrolysis plus Gas Engine

Currently, the technology for the pyrolysis of sustainable wood plus the usage of the gas in a gas engine or gas turbine is still on a demonstration level. Currently, there are no reliable data on costs, efficiencies and carbon dioxide reduction. Under the assumption, that 10 % of the fuel heat content can be transferred to power with such a technology, a unit of the size comparable to the one in the previous section on charcoal production could produce an average of 5-10 kW_{el}. Although this amount is not very large, it can already supply a number of households e.g. in an isolated barangay. Under the condition of using only sustainable wood from reforestation, this technology has the potential to provide electrical power plus charcoal as salable product.

5.3.4 Rice Husk Combustion for Drying

Since the technology for rice drying by using rice husk as a fuel is already implemented in several versions (flatbed dryers, circulating dryers), no feasibility considerations have been made within the frame of this study.

5.3.5 Rice Husk Combustion + Water Steam Cycle

For this technology, the following specific assumptions have been made (see Table 5-5). For the reference case of this technology, the results as listed in Table 5-6 have been calculated. According to the results, the power production costs are relatively low. Even under the assumption of relatively high costs for fuel (1,000 PhP/kg), the power production costs are below the FiT.

Table 5-5: Assumptions for rice husk combustion and water steam cycle

Parameter	**Assumption for reference case**	**Explanation**
Number of employees	22 power plant operators/engineers	- 5 shifts with 4 operators each - 2 administrative persons
Annual operation hours	8,000 h	- annual operation of more than 8000 hours has been reported from Philippine rice husk power plants
Investment	2,000 US-$/$kW_{el}$	- experience from comparable rice husk fired power plants in the Philippines
Fuel costs	1,000 PhP/t	- power plants in proximity increase rice husk prices - rice husk power plants have been reported to buy rice husk for 1 PhP/kg
Carbon dioxide emissions	67 kg_{CO2}/kWh_{el}	- different values in literature: • 17.16 kg/MWh [21] • 22-35 kg/MWh (for wood biomass) [22] • 67 kg/MWh [23] - highest value chosen to reduce risk
Nominal power	1.0 MW_{el}	- biomass availability for municipality of Sibalom and surrounding

Table 5-6: Results for rice husk combustion and water steam cycle

Parameter	Value
Investment	89.06 Mio. PhP
Equivalent annual cost of investment	13.27 Mio. PhP
Annual labor force cost	7.39 Mio. PhP
Annual service and maintenance	7.12 Mio. PhP
Ann. administration, insurances and unexpected	1.78 Mio. PhP
Annual fuel input	12,000 t
Annual fuel costs	12.00 Mio. PhP
Overall annual costs	41.57 Mio. PhP
Annual electricity production	8,000 MWh
Annual income from FiT [1)]	53.04 Mio. PhP
Annual profit	11.47 Mio. PhP
Power production costs	5.1963 PhP/kWh
Annual carbon dioxide savings (compared to coal)	6,570 t

[1)] FIT rate for biomass will be degressed by 0.5% every 2 years starting January 2017, so this might be slightly lower

5.3.6 Rice husk combustion + Organic Rankine Cycle (ORC)

For the reference case of this technology (see assumptions in Table 5-7), the results as listed in Table 5-8 have been calculated.

Table 5-7: Assumptions for rice husk combustion and ORC

Parameter	**Assumption for reference case**	**Explanation**
Number of employees	7 power plant operators/engineers	- 3 shifts with 2 operators each - 1 administrative person
Annual operation hours	8,000 h	- high availability has been reported for a rice husk fueled ORC plant in Italy
Investment	4,290 €/kW_{el}	According to ORC producing company [23]
Fuel costs	1,000 PhP/t	- power plants in proximity increase rice husk prices - rice husk power plants have been reported to buy rice husk for 1 PhP/kg
Carbon dioxide emissions	67 kg_{CO2}/kWh_{el}	- different values in literature: • 17.16 kg/MWh [5] • 22-35 kg/MWh (for wood biomass) [6] • 67 kg/MWh [7] - highest value chosen to reduce risk
Nominal power	1.4 MW_{el}	- equals 50% own supply for larger rice mills
Overall electrical efficiency	14 %	- evaluation of several plant efficiencies
Annual service and maintenance	3 % of capital investment	- 1.5 % service and maintenance have been reported for ORC biomass CHP plants, value doubled for rice husk specific maintenance and additional oversea costs

Table 5-8: Results for rice husk combustion and ORC

Parameter	**Value**
Investment	300.8 Mio. PhP
Equivalent annual cost of investment	44.83 Mio. PhP
Annual labor force cost	2.35 Mio. PhP
Annual service and maintenance	9.02 Mio. PhP
Ann. administration, insurances and unexpected	6.02 Mio. PhP
Annual fuel input	19,200 t
Annual fuel costs	19.2 Mio. PhP
Overall annual costs	81.42 Mio. PhP
Annual electricity production	11,200 MWh
Annual income from FiT [1)]	74.26 Mio. PhP
Annual profit (with FiT)	-7.16 Mio. PhP
Power production costs	7.2697 PhP/kWh
Annual carbon dioxide savings (compared to coal)	9,200 t

[1)] FIT rate for biomass will be degressed by 0.5% every 2 years starting January 2017, so this might be slightly lower

From the table it can be seen that there is a negative benefit under the assumptions made. It must be noted, that those amounts can be influenced positively by considering income from heat usage (e.g. for drying or cooling) and by using the electricity instead of buying power.

Taking into account that for the two largest rice mills (see section 2.3.1) at least 50% of fuel could be supplied by themselves, fuel costs could be reduced by 50%. Under these assumptions, power production costs could be reduced to 6.4125 PhP/kWh, leading to a positive benefit of 2.44 Mio. PhP per year. If all rice husk could be obtained for free (e.g. by cooperation of rice mills), power production costs could be reduced to 5.5554 PhP/kWh with an annual benefit of 12.0 Mio. PhP.

6 RECOMMENDATIONS AND POTENTIAL INVESTORS

6.1 Implementation of CHP from Rice Husk

Evaluation of rice husk availability in Panay showed that there are several locations with the potential to install medium-scale power plants with more than 500 kW_{el} (see section 2.3.1).

One rice miller near Roxas City had already put up some effort to invest into a combined heat and power plant from rice husk. His favored technology was the combination of combustion and ORC. The main obstructions for the investment was the necessary amount of proprietary capital required for the necessary loan.

The municipality of Sibalom has already been identified as a potential place for a rice husk fired CHP plant. Sibalom is considered the rice granary of the province of Antique, and has an ideal location near to further rice producing municipalities and close to the provincial capital San Jose. The mayor of Sibalom expressed interest in having such a power plant in his municipality and was willing to give political support to such an investment.

The decision for one technology (water steam) or the other (ORC) strongly depends on the local situation (e.g. concerning rice husk supply) and the preferred ratio of capital investment and operational costs. Steam cycle power plants require lower specific investments, but higher operational costs compared to ORC. Although economics of Organic Rankine Cycles for rice husk usage are not as favorable as steam turbine based power plants, especially due to the higher specific investment, it is an interesting option due to its low maintenance and staff requirements. The technology has been proven to work with rice husk as a fuel, and could work as an interesting option for power production. Since private investors have shown explicit interest in such technology, they should be supported

The implementation of a small rice husk power plant (1-2 MW_{el}) in the municipality of Sibalom should be supported by political and financial measures.

Discussions with the LBP Lending Center Iloilo showed that LBP has a special loan window for renewable energy projects. The ForClim project will facilitate a meeting between the potential investors and LBP, to further assess the terms and conditions for a loan.

6.2 Implementation of CHP from Sustainable Reforestation Wood

Commercial systems for gasification based CHP available in Germany have been optimized for Central European conditions. Currently, the first approaches to Asian markets are being made by German companies. A demonstration system could show the application of the technology to Philippine conditions (e.g. with high humidity).

Much of the reforestation area is situated in remote areas, especially close to the mountain ranges. Considering power and industrial infrastructure in Panay, the most promising operators of a CHP system for sustainable reforestation wood are cooperatives or the like. The same option should be preferred for the production of charcoal from reforestation wood.

Central Philippine University has some experience in biomass gasification and should be considered as a local scientific and education partner when a demonstration plant is put up in Panay.

Even under the rather conservative assumption of 1.425 t/ha/yr dry biomass available for energy use in forest plantations around the Central Panay Mountains (50% of the expected increment, net of logs to be used for sawn timber), about 18,000 t of dry woody biomass would be available for power generation. A small gasification plant in the range of 30 kW_{el} would require roughly 270 tons/yr of dry wood. With the available energy wood from 12,589 ha plantations, around 66 small gasification plants with combined 2 MW_{el} could be sustainably fueled.

6.3 Implementation of Improved Charcoal Production

Generally, the production of charcoal is not the most efficient way for the usage of wood for energy. But since charcoal production is an existing practice, and can be expected to last for the next years, it should at least be improved in terms of efficiency and emissions. The implementation of Adam retorts or similar technologies requires a regulatory framework which allows for the sustainable usage of plantation wood on one hand, but strictly restricts logging of natural forest for these purposes.

6.4 Implementation of Rice Dryers

Most of the rice mills contacted already conducted some investments into rice dryers fueled by rice husk. This included not only flatbed dryers, but also circulating grain dryers. Still, there are rice mill operators without rice husk fueled rice dryers, which are potential investors in such systems and shall be advised by the project.

Also, cooperatives and farmer associations have been identified as potential operators of rice dryers. There are already several organizations operating a rice dryer, usually financed by the Department of Agriculture, but there are still many farmer groups interested in additional rice dryers.

For the implementation of rice dryers by private investors, no major action is considered to be necessary. Private investors, especially rice mill owners, have invested and are still investing in rice husk fueled rice dryers. A brochure of best practice examples, including the dryers from Rice Processing Centers (RPC) and National Food Authority (NFA), could provide additional information to potential investors.

For public investors, the continuation of the existing programs for flatbed rice dryers by the Department of Agriculture (DA) is recommended. Cooperatives and associations should be supported by further information of the advantages of such systems to classical rice drying.

Further support of rice dryer implementation should include the improvement of efficiency of existing rice dryers. Also, considering health and rice quality, emissions of the combustion process should be reduced, where necessary.

Discussions with the DA Executive Director Region 6 confirmed the interest to continue the Regional Convergence Initiative with DENR and GIZ and to include joint efforts to promote rice husk fired flatbed dryers. The details shall be agreed in an MoU between DA, DENR and GIZ.

6.5 Conclusions

The supply of energy from solid biomass has the potential to reduce greenhouse gas emissions on the island of Panay. Additionally, added value (e.g. from selling power to the grid or charcoal to consumers) can help to improve economy on several levels.

For rice husk, the economically most feasible possibility to produce power and heat is to use the combination of combustion and a steam cycle. A variation with less maintenance efforts and staff requirements, but higher investment, is the usage of Organic Rankine Cycle. Both technologies have been commercially implemented with rice husk as a fuel.

Still, implementing rice husk fueled rice dryers is an interesting option for the Philippines, especially taking into account the possible reduction of rice grain losses during drying compared to traditional sun drying.

In a recent National Renewable Energy Board (NREB) meeting, the biomass industry association was asked by the board why the biomass projects under FIT are moving slowly. The representative cited the problem with the feedstock. He mentioned several problems encountered related to feedstock which include collection/buying, moisture content, sorting, weighing, transport, storage, shredding and drying. As a measure to solve it, the association is studying the feasibility of putting up plantations for super napier or bana grass as buffer feedstock.

A more efficient approach than adding grass as feedstock is the use of energy wood, as widely practiced in many countries. Under the right regulatory framework, using sustainable reforestation wood can provide a significant contribution to energy generation. With an annual amount of at least 18,000 t of dry wood from reforestations in Panay, even under conservative assumptions (minimum of 1.425 t of dry wood per ha), and an annual consumption of 270 t dry wood per small scale gasification plant, around 66 gasifiers could be implemented especially in isolated areas to provide power. The substitution of traditional charcoal making kilns with more modern retorts (e.g. the so-called Adam retort) could help to reduce not only wood consumption for charcoal making but also emissions. The condition to introduce improved charcoal technologies, however, is that the sustainably produced charcoal from plantation wood does not have to compete with illegal products using wood for free.

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