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# Potential and Demand for Energy from Biomass by Thermo-chemical Conversion in the Province of Antique, Philippines – Part 1, Biomass Availability Analysis

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**This study gives information about the potential for biomass to provide the province of Antique, Philippines, with electrical power by thermo-chemical conversion. The focus is on agricultural residues, like rice husk, bagasse or coconut shells, and on sustainable wood from reforestation areas. Information about the current power consumption and supply in Antique is collected. The main bioenergy potential can be achieved by using rice husk for energy generation, which could substitute about 30% of fossil generated electricity in the province. Reforestation wood is considered to allow further contributions to renewable energy supply, especially for remote areas.**

## INTRODUCTION

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), 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 (Liu et al., 1993).

Antique is one of the six provinces that compose the Western Visayas Region (Region 6), and it is the smallest of the four provinces on Panay island (see Fig. 1). There are 18 municipalities (see Fig. 2), mostly coastal, one being an island (Caluya) and three being inland municipalities (San Remigio or San Remegio, Sibalom and Valderrama) and a total of 590 barangays.

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According to the Provincial Planning and Development Office, the province has 534,560 inhabitants as of 2010 with an expectation of 573,151 inhabitants in 2016. It is situated on the western part of the island, a strip of land shaped like a seahorse facing the northern tip of Palawan Island. Its capital town, San Jose de Buenavista, is found on the southern part of the province and is approximately 96 kilometers or about two and a half hours drive away from Iloilo City, the commercial and educational center of Region 6.

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 enforce the power generation from renewable energy sources. A Feed-in

Tariff (FiT) system is established, guaranteeing access to the grid, long-term contracts and stable purchase prices. The rates are 6.63 PHP/kWh for biomass and 5.90 PHP/kWh for hydropower, both with a degression rate of 0.5 % after two years from the coming into effect of the FiT (Republic of the Philippines, Energy Regulatory Commission, 2012).

The total land area of the province is 252,200 hectares (2,522 km²), 82.81% of which is classified as upland with rugged terrains and steep slopes. The Baloy-Madyaas Mountain Range 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,

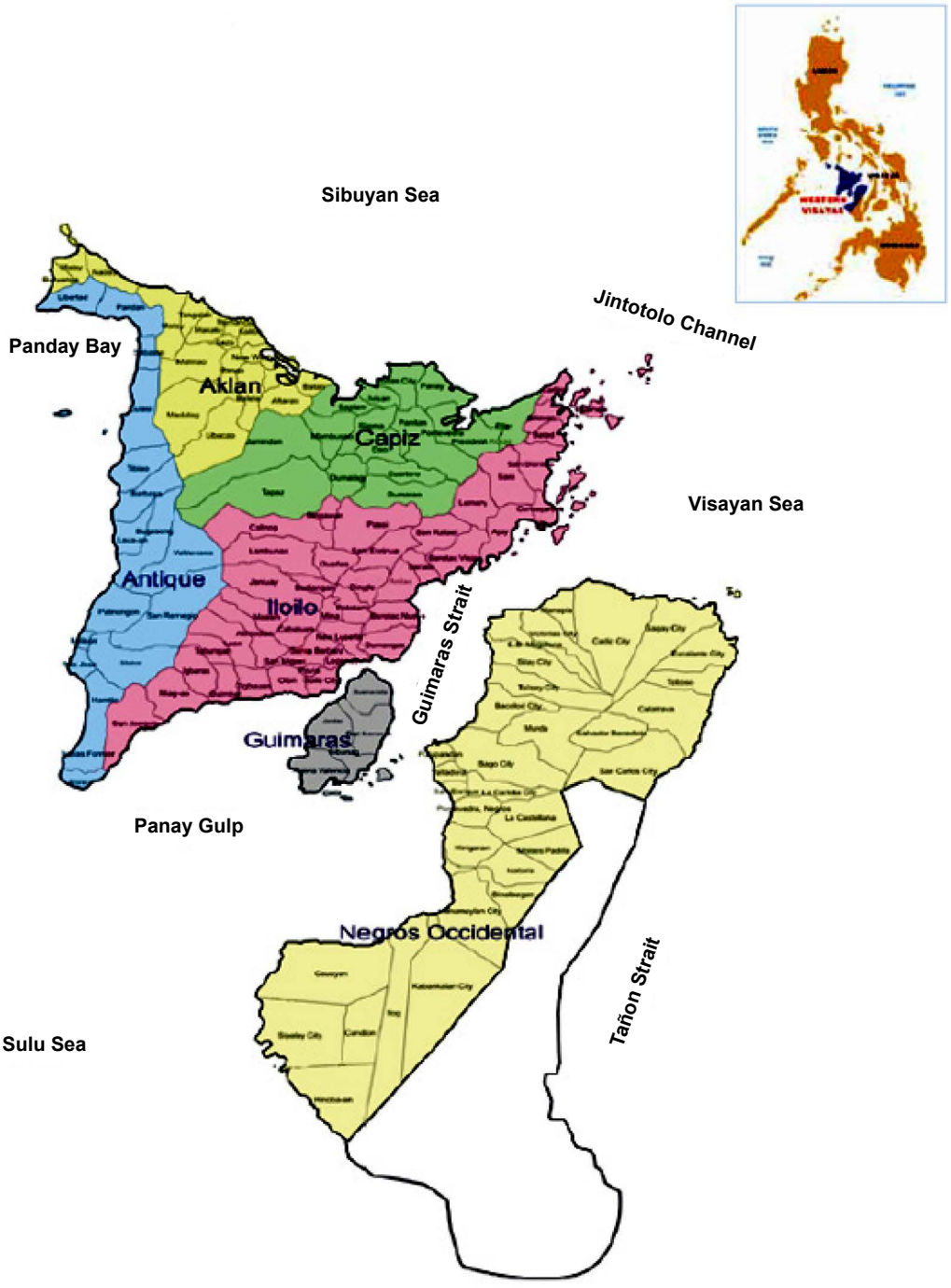


**Figure 1**. Map of Western Visayas Region [RDC]

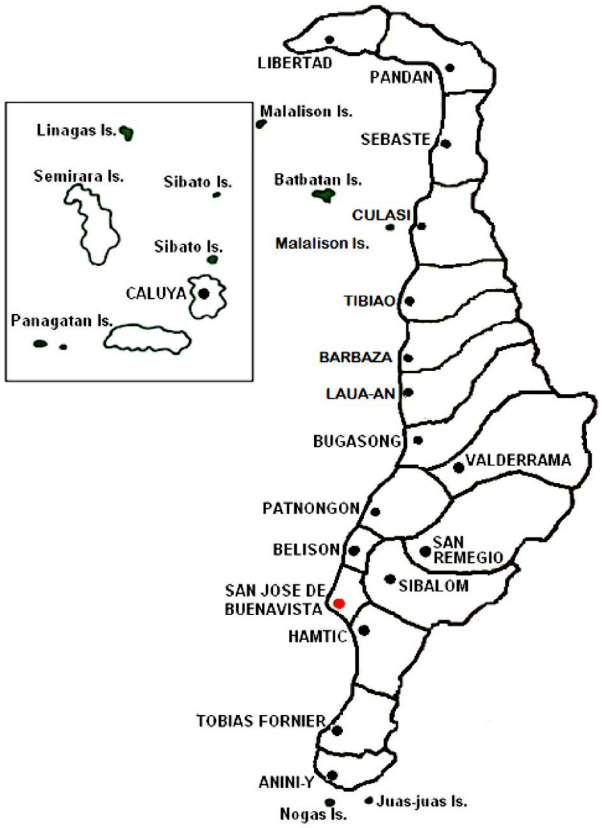


**Figure 2**. Map of Antique Province showing the Municipalities (source: Antique Provincial Profile).

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.

In the following section, the biomass potential for thermos-chemical conversion in Antique will be analyzed on municipality level. By giving information on the power consumption and supply in Antique within the next section, the importance of additional renewable energy sources for the province is emphasized.

## Biomass Potential in Antique

In general, the potential for energy from thermo-chemical conversion of biomass in Antique can be found in agricultural residues and reforestation wood. Manure from livestock breeding (mainly hog, cattle and chicken) is not considered in this study, because it will usually be converted to biogas by biochemical processes (Elauria et al., 2005). Municipal solid waste will also not be considered here, but should be a subject to further studies.

Wood from reforestation is an interesting option, if regulated properly, since it can form an economic perspective for sustainable forestry. For Antique, most reforested trees are Gmelina (*Gmelina arborea*), Mahogany (*Swetenia macrophylla*) and *Acacias*. Further reforestation plants are Ipil Ipil (*Leucaena leucocephala*) and Madre de Cacao (*Glyricidia sepium*).

As in many Asian countries, rice production residues are an easily available source of bioenergy. For the purpose of this study, the focus will be on rice husks, disregarding rice straw, since rice straw has been observed to be used as fertilizer for the rice fields. Additionally, rice husk is already collected at the rice mills, thus being logistically advantageous.

Residues from coconut plantations (especially shells) and sugar production (bagasse) are of further interest, since these are the main agricultural products besides rice for the province Antique as well as for the whole Philippines (Elauria et al., 2005). The main features of these residues and (as an example for reforestation wood) *Leucaena leucocephala* are given in Table 1. It should be noted, that the characteristics of a specific biomass might differ from

**Table 1**. Main characteristics of biomasses considered in this study

| Biomass | C | H | N | S | O | Cl | Ash | HHV (MJ/kg, dry basis) | RPR (-) |
|---|---|---|---|---|---|---|---|---|---|
| | (wt.%, dry basis) | | | | | | | | |
| Rice Husk (Abe et al., 2007, Kapur et al., 1996, Channiwala et al., 2002) | 37.89 | 5.04 | 0.29 | 0.00 | 39.52 | 0.14 | 17.13 | 15.38 | 0.14-0.23 |
| Coconut Shells (Abe et al., 2007, Kapur et al, 1996, Ounas et al., 2011) | 46.67 | 5.43 | 0.55 | 0.00 | 44.03 | 0.73 | 2.58 | 18.56 – 20.5 | 0.15 |
| Bagasse (Abe et al., 2007, Ounas et al., 2011, Rodriguez et al., 1987, Kaltschmitt et al., 2009) | 47.43 | 5.21 | 0.48 | n.d. | 44.68 | n.d. | 2.7 | 16.5 – 17.33 | 0.33 |
| *Leucaena leucocephala* (Kaput et al., 1996) | 46.99 | 6.23 | 0.75 | 0.00 | 45.10 | 0.07 | 0.86 | 19.53 | n.a. |

HHV – Higher heating value
RPR – Residue-Product-Ratio
n.d. – not determined
n.a. – not applicable

these values, according to factors such as soil conditions, plant age etc. The amount of the main elements carbon, hydrogen, nitrogen, sulfur and oxygen is important for the design of thermo-chemical conversion plants. Chlorine as a trace element is important in terms of corrosion. Ash content is important for the selection and design of the thermo-chemical process, e.g. for the construction of the grate firing. For agricultural residues, typical residue-to-product ratios are given, thus making it possible to estimate residue amounts on the basis of agricultural production.

**Wood from Reforestation**

In Antique, there are a number of reforestation areas with the potential for bioenergy from wood. In Table 2, the known reforestation areas as of December 2011 are listed. A promising area can be identified for the three municipalities of Pandan, Sebaste and Culasi.

**Table 2**. Reforestation area (already planted) for different municipalities in Antique (Source: DENR Region 6)

| Municipality | Reforestation area already planted [ha] |
|---|---|
| Libertad | 122 |
| Pandan | 264 |
| Sebaste | 794 |
| Culasi | 258 |
| Tibiao | 285 |
| Barbaza | 246 |
| Laua-an | 280 |
| Bugasong | 282 |
| Valderrama | 751 |
| Patnongon | 89 |
| San Remegio | 276 |
| Total | 3,647 |

The municipalities from Libertad down to Patnongon and San Remegio have an overall known reforestation area of 3,647 ha. In the three potential pilot municipalities Pandan, Sebaste and Culasi 1,316 ha are reforested. While their land area represents only 15.6% of the province land area (39,428 ha out of 252,200 ha), about 36% of the reforestation area is situated there.

For the availability of reforestation wood from these areas, some assumptions have been made. It is estimated, that only 50% of the reforestation area is accessible for wood harvesting. The annual growth is assumed to be in the range of 10 $m^3$/ha with a density of 700 kg/$m^3$ and a moisture content of 50% (Kaltschmitt et al. 2009). It is also assumed, that around 50 % of harvested plantation wood is converted into sawn timber, and the remaining 50 % can potentially be used as energy wood. Thus, on accessible reforestation sites a potential of 5.0 $m^3$/ha equivalent to 1.75 t/ha (dry matter) can be assumed for energy generation purposes. Thus, the sustainable production potential of energy wood is 3,191 t/year (dry matter) in the municipalities down to Patnongon and San Remigio, and 1,152 t/year (dry matter) in the three municipalities Pandan, Sebaste and Culasi. Since natural forest shall be excluded from wood harvesting, only plantation wood has been considered for this study.

If the usage of wood for energy generation purposes is not regulated, increasing prices have to be expected as well as an increase in illegal harvesting. Thus, the wood for such use should not be purchased from the free market, but from strictly regulated and certified harvesting within the reforestation area. During the study, the price for logged wood was found to be in the range of 150 – 250 PHP per woodpile (ster), usually around 500 kg, which means about 400 PHP/t for logged wood. The additional efforts for certification and regulation should be remunerated by higher prices for that wood.

**Rice husk**

In 2010, an amount of 211,466.26 t of rice has been produced in the province of Antique, according to the Provincial Profile of the province. Since the production has been significantly higher in 2008 and 2009 (244,354 t and 250,913 t, respectively), it can safely be assumed that an amount of at least 210,000 t of rice per year is produced in Antique.

In Fig. 3, the rice production for each municipality of Antique is shown. It can be seen, that the six regions of Patnongon, Belison, San Jose de Buenavista, San Remegio, Sibalom and Hamtic (which are situated close to each other) together produce 93,402 t of rice, which is about 44% of Antique's overall rice production, while these municipalities represent only 33.8% of the province land area (85,281 ha out of 252,200 ha).

The ratio of rice husk to rice may differ. According to the National Food Authority of the Philippines, the ratio is 23%. Some rice millers estimated an amount of 15 to 17% during interviews. Values in literature vary from 14 to 27% (Kapur et al., 1996). Thus, an average ration of husk to rice of 20 % seems to be reasonable; which is in good agreement with literature (Natarajan et al., 1998; Armesto et al. 2002).

Altogether, a rice husk production of 42,000 t per year for all Antique can be assumed, of which an amount of 18,680 t per year of rice husk is produced in the six marked municipalities. Assuming an availability of 75% of this rice husk (which is conservative, since most rice millers were willing to give away the rice husk for free),


**Figure 3**. 2010 rice production in metric tons in the municipalities of Antique (modified from source: Antique Provincial Profile).

an annual amount of 31,000 t of rice husk is expected to be available in Antique, of which 14,000 t of rice husk are from the marked area. The distances of all municipalities in the marked area and the rice mills in Sibalom or San Jose de Buenavista are less than 35 km (road distance). Thus, these two municipalities are advantageous in terms of logistics.

Prices for rice husk are estimated to be nearly zero since it is considered waste today. Anyway, if a larger amount

of the rice husk is used for energy generation purposes as in other parts of the Philippines (Elauria et al. 2005), it should be expected to gain some value depending on the market. Thus, for economic considerations, a price of at least 100 PHP/t should be considered, including transportation and handling.

**Residues from Cane Sugar Production**

Sugar cane production in Antique for crop year 2010 as reported in the Bureau of Agricultural Statistics On-line Database amounted to 53,942 t (Bas, 2011). This sugar cane is mainly milled to produce brown sugar called muscovado, the production of which is a major industry in the province. In sugar production, there is always a residue called bagasse, which can be considered a potential source for energy from biomass. The residue-to-product ratio of bagasse is roughly 0.33 (Elauria et al. 2005).

Interviews with muscovado millers at traditional mills as well as at a modern mill conducted by the authors of this study showed that currently all of the bagasse produced is used for the production of sugar. Actually, bamboo is usually bought as a supplementary fuel for sugar cooking. According to this information, there is no potential for the use of bagasse for energy generation purposes other than sugar cane juice cooking. It should be noted, that the technology currently used for sugar production is often outdated and not very efficient. By introducing new technologies to sugar mills, higher biomass availability might be achieved.

**Residues from Coconut Processing**

In Antique, coconut production is of economic relevance, too. According to the Bureau of Agricultural Statistics, in 2010 the total coconut production reached 67,492 t. The residue-to-product ratios of coconut shells and husks are 0.15 and 0.33, respectively (Elauria et al. 2005).

According to interviews with different actors in Antique, including the Philippine Coconut Authority, all residues of coconut production are used either for cooking and charcoal production (shells) or for the production of ropes and nets (husk) which are used for the prevention of erosion. Thus, it can be assumed that the actual availability of coconut processing residues for energy purposes is very low. Anyway, the largest amount of coconut (27.4 Mio. pieces out of 62.4 Mio. pieces, or 43.9%) is available in the municipality of Caluya consisting of islands away from Panay, which was not part of this study.

## Power Consumption and Supply

### Electricity Supply

For the province of Antique, there are two power suppliers. Aklan Electric Cooperative (AKELCO) supplies the two municipalities in the north, Pandan and Libertad besides their core area in Aklan. The 16 southern municipalities are supplied by Antique Electric Cooperative (ANTECO).

ANTECO gets its power from two sources: 7 MW from a coal-fired power plant from Panay Energy Development Corporation (PEDC) in Iloilo City and another 7 MW from the National Power Corporation's Diesel Power Plant in Dingle, Iloilo. AKELCO gets its power from three sources: 10 MW from Green Core Geothermal Inc. in Palinpinon, Negros Occidental, 12 MW from PEDC's coal fired power plant in Iloilo City and 14 MW from Global Business Power Corporation's Diesel Plant in Nabas and their Embedded Diesel Plant in New Washington, both in Aklan.

Antique province is at the tail end of the Visayas power grid. Grid electricity is supplied to the province through two 69 kV NGCP (National Grid Corporation of the Philippines) sub-transmission lines that go into the province in the north via Pandan from Nabas, Aklan, and in the south via Hamtic from Miag-ao, Iloilo. Currently, there is no existing sub-transmission line from Culasi to San Jose, so ANTECO is using its 13.5 kV primary distribution line to supply electricity in this area.

However, NGCP has already programmed the installation of 88 kilometer of a 69 kV sub-transmission line from Culasi to San Jose to complete the loop of the Panay grid by December 2012. Another 15.8 km of the 69 kV sub-transmission line from Hamtic to the municipality of Tobias Fornier is included in the 5-year capital expense plan of ANTECO.

Total electrical energy demand for the year 2010 of the 16 municipalities served by ANTECO was 72,468,458.70 kWh, see Table 3. The demand peaked during April and May. It should be noted, that the power

**Table 3**. Electrictal Power [kWh] sold by ANTECO, 2008 – 2010.

| | 2008 | 2009 | 2010 |
|---|---|---|---|
| **January** | 4,879,978 | 4,846,517 | 5,806,396 |
| **February** | 4,685,514 | 5,146,980 | 5,738,499 |
| **March** | 4,537,873 | 4,919,679 | 5,591,010 |
| **April** | 5,286,992 | 5,561,345 | 6,587,996 |
| **May** | 4,572,933 | 5,406,823 | 6,767,290 |
| **June** | 4,220,493 | 5,497,446 | 6,390,075 |
| **July** | 3,837,993 | 4,924,981 | 5,675,051 |
| **August** | 4,642,395 | 5,355,868 | 5,751,236 |
| **September** | 4,683,382 | 5,385,177 | 6,146,432 |
| **October** | 4,650,231 | 5,190,834 | 5,665,122 |
| **November** | 5,048,811 | 5,666,004 | 6,215,554 |
| **December** | 4,871,810 | 5,481,509 | 6,133,797 |
| **Total** | **55,918,405** | **63,383,163** | **72,468,458** |

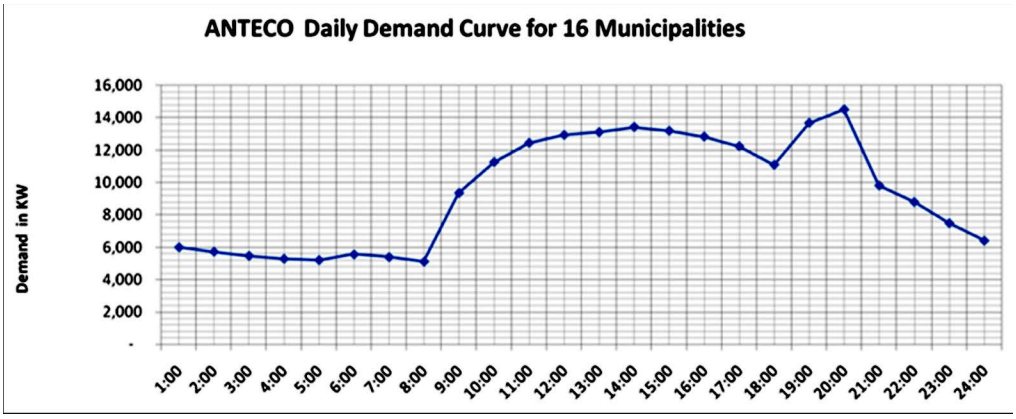


**Figure 4**. Daily Demand Curve for ANTECO municipalities (served by ANTECO).

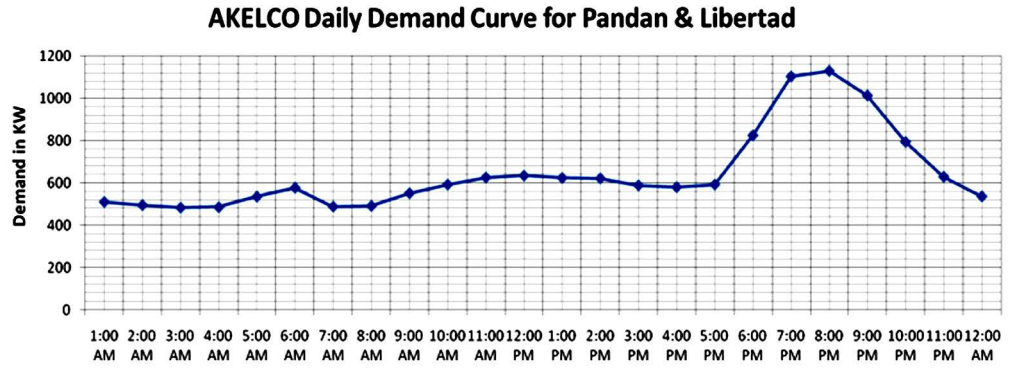


**Figure 5**. Daily Demand Curve for Pandan and Libertad (served by AKELCO).

demand increased more than 13 % from 2008 to 2009 and more than 14 % from 2009 to 2010. Further increase should be expected. Daily demand curves are given in Fig. 4 and 5.

For the municipalities of Pandan and Libertad (served by AKELCO) the total electricity purchased from November 2010 to October 2011 was 3,446,553 kWh, see Table 4.

According to AKELCO, the daily peak demand for the municipalities of Pandan and Libertad is 1.129 MW with a base load of ca. 600 kW, while for the other 16 municipalities it is 14.511 MW with a base load of ca. 6 MW, according to ANTECO. Especially in the municipalities served by ANTECO, there is also a significant difference between day and night consumption, which can be explained e.g. by the larger amount of mechanical driven (thus, electricity consuming) chillers in the cities, especially in San Jose de Buenavista.

The prices for electricity in Antique range from 10.6 PHP/kWh to 12.81 PHP/kWh. They depend on the provider and the type of consumer (residential, commercial or industrial) (Lim, 2011). According to ANTECO, their generation charge is 5.76 PHP/kWh as of August 2011 (Lim, 2011).

**Table 4**. Electrical Power [kWh] sold by AKELCO, Nov. 2010 – Oct. 2011.

| | Pandan | Libertad | Total |
|---|---|---|---|
| **November 2010** | 206,777 | 75,790 | 287,213 |
| **December 2010** | 210,886 | 74,255 | 285,141 |
| **January 2011** | 204,964 | 73,167 | 278,131 |
| **February 2011** | 189,689 | 71,619 | 261,308 |
| **March 2011** | 179,505 | 68,928 | 248,433 |
| **April 2011** | 206,199 | 77,023 | 283,222 |
| **May 2011** | 246,503 | 83,155 | 329,658 |
| **June 2011** | 240,358 | 84,516 | 324,874 |
| **July 2011** | 207,442 | 74,992 | 282,434 |
| **August 2011** | 207,130 | 74,384 | 281,514 |
| **September 2011** | 229,313 | 76,217 | 305,530 |
| **October 2011** | 207,901 | 75,840 | 283,741 |
| **Total** | **2,536,667** | **909,886** | **3,446,553** |

It should be noted, that Global Green Power PLC

Corporation (GGPC) has started projects on biomass based power plants also for Panay island. It is known, that a plant in Mina, Iloilo, is in preparation. As far as it is known, the plant is still under planning.

**Energy Demand in the Households**

In the absence of data on household energy consumption for the province of Antique, national figures from the results of the Household Energy Consumption Survey (HECS) conducted by the Department of Energy (DOE) and the National Statistics Office (NSO) in 2004 were used.

The said survey revealed that 87.6 % of the sampled households nationwide used electricity for their homes. Lighting was the main use of electricity in the household, with household recreation such as use of televisions and players 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[1]. At the same time, 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 communities in the province of Antique.

**Non-residential energy demand**

Based on data obtained from different sources, crop drying, milling, and industrial processes such as food, wood and handicraft processing are the major energy consuming activities in the province of Antique. Post-harvest processing of crops such as drying and milling are on top of the list.

Crops and other products that undergo drying include rice, copra, corn, lumber and fish. Most of the drying activities however, use the sun as the direct source of heat energy simply by laying the crops in an open space to dry under the direct sunlight (streets are often observed to be used). A couple of rice mills use mechanical dryers that use kerosene or diesel as the source of heat while one uses rice husk as source of heat for its mechanical dryer. Copra drying is also accomplished either by direct sun drying or by using inefficient traditional fire hearth locally called "tapahan" fueled by coconut husks, shells and other coconut residues.

Significant milling activities are done on rice and sugar cane. Milling of sugar cane is a major process in the production of muscovado (brown sugar), which is an important industry in the province.

Other food processing activities mostly involve cooking and cold storing. Wood, metalcraft and handicraft processes usually involve the use of power tools for welding, cutting, machining, grinding and drilling. Lumber and other wood and bamboo materials that need to be dried are usually sun dried.

## CONCLUSION

In the province of Antique in the Western Visayas, Philippines, there is a significant potential for the production of energy from biomass. For sustainable energy wood from plantations, an amount of 3,191 t/year (dry matter) in the municipalities down to Patnongon and San Remigio, and 1,152 t/year (dry matter) in the three municipalities Pandan, Sebaste and Culasi can be expected. For rice husk, an amount of 31,000 t/year for all Antique is available. For comparison, in Isabela province two rice husk based steam cycle power plants have been reported from the companies Family Choice Grains Processing Center Inc. and Golden Season Grains Center Inc. Both plants supply 2 MW of electrical power, consuming 27,725 t of rice husk per year each (Ramos, 2008). Thus, the available rice husk in Antique has the potential to feed such a plant, providing roughly 30% of the overall base load for the province. Further research will be done on a feasibility study on such technology, including a technical, economical and ecologic evaluation.

It should be noted, that the devastating influence of typhoon Haiyan (or Yolanda, as it was called in the Philippines) in November 2013 has strongly affected the island of Panay, especially in the North. This gives even more importance to the establishment of a sustainable, decentralized energy supply from indigenous resources including employment.

**Outlook**

In following parts, possible technologies for the usage of rice husk and sustainable reforestation wood will be evaluated and discussed. This analysis will focus on combustion and gasification technology and provide an economic, ecological and technical analysis of different options for biomass usage in Antique.

[1]The occasional occurrence of more than one fuel type per household leads to a sum of more than 100 %.

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