Technology Brief

Harnessing Biomass for Off-grid Rural Electrification

Biomass is a versatile source of energy; it can produce electricity, heat or fuel for transportation and is storable. It is the world's fourth largest energy source and contributes to at least 14 percent of the world's primary energy demand. In developing countries, the contribution of biomass to primary energy supply is at least 35 percent. In developed economies, such as the European Union, its contribution ranges from 2 to 14 percent.[1]

The Philippines has abundant agricultural residues that are suitable for power generation. The EC-ASEAN COGEN Programme estimated that the volume of residues from rice, coconut, palm oil, sugar and wood industries is 16 million tons per year. Bagasse, coconut husks and shell can account for at least 12 percent of total national energy supply. The World Bank-Energy Sector Management Assistance Program estimated that residues from sugar, rice and coconut could produce 90 MW, 40 MW, and 20 MW, respectively.[2] According to Agrilectric, U.S., burning one kilogram of rice husk can generate as much as one kilowatt of electricity. This is made possible by improving the burning efficiency in which rice husks are ground or pulverized and fired as powder fuel.[3]

The Philippine Energy Plan for 1999-2008 forecasts that the country's aggregate biomass fuel supply will grow from 247.9 MMBFOE in 1999 to 301.5 MMBFOE in 2008, an annual growth rate of 2.2 percent. Bagasse is projected to account for almost half of the contribution of renewables to energy supply to the commercial and industrial sectors. Municipal solid waste is expected to contributes 10 MW in 2005 and 50 MW in 2008.

Table 1
BIOMASS FUEL SUPPLY PROJECTIONS
In Million Barrels of Fuel-Oil-Equivalent, MMBFOE

	1998	1999	2004	2008
Rice Residues	7.5	7.7	8.7	9.6
Coco Residues	22.9	23.2	24.8	26.2
Bagasse	17.8	18.1	20.0	21.6
Woodwastes	83.2	84.7	92..1	97.7
Animal Wastes	12.1	12.2	12.8	13.4
Municipal Wastes	98.7	101.9	119.1	133.1
Total	**242.1**	**247.9**	**277.6**	**301.5**

Source: Philippine Energy Plan, 1999-2008

SATMP

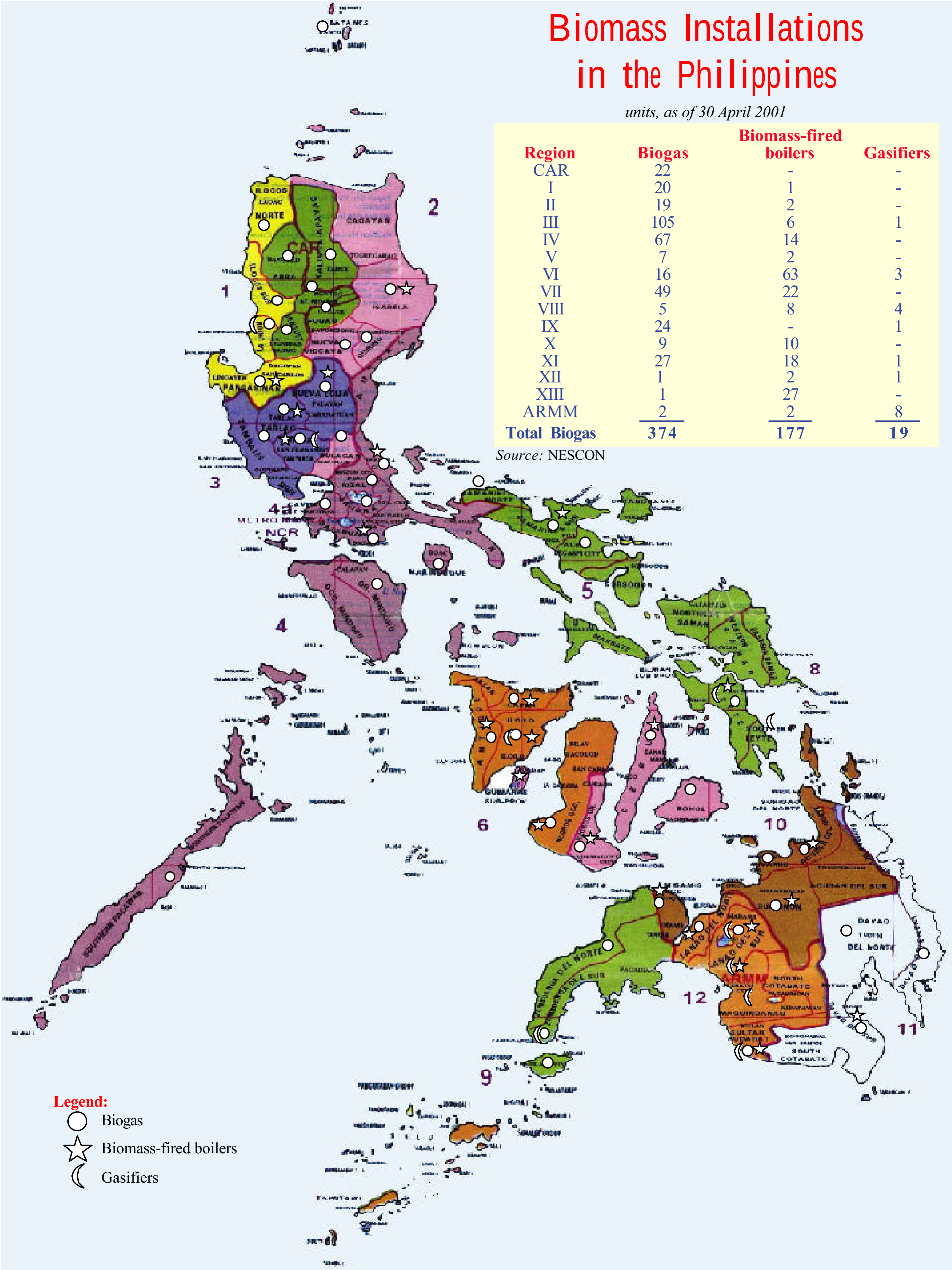
Prepared by the Society for the Advancement of Technology Management in the Philippines with the support of the Department of Energy and U.S. Agency for International Development as part of the *Technical Assistance to the DOE for Enhancing Private Sector Participation in Renewable Energy.*

Biomass Installations in the Philippines

units, as of 30 April 2001

Region	Biogas	Biomass-fired boilers	Gasifiers
CAR	22	-	-
I	20	1	-
II	19	2	-
III	105	6	1
IV	67	14	-
V	7	2	-
VI	16	63	3
VII	49	22	-
VIII	5	8	4
IX	24	-	1
X	9	10	-
XI	27	18	1
XII	1	2	1
XIII	1	27	-
ARMM	2	2	8
Total Biogas	**374**	**177**	**19**

Source: NESCON



Producing Electricity from Biomass

Biomass Basics

The term biomass applies to a wide range of materials, but the main resources are: (i) short rotation forest crops (*e.g.*, ipil-ipil) ; (ii) woodwastes (*e.g.*, saw dusts); (iii) sugar crops (*e.g.*, bagasse); (iv) starch crops; (v) herbaceous lignocellulosic crops; (vi) oil crops; (vii) agricultural wastes (*e.g.*, rice hull); (viii) municipal solid wastes and refuse; and (ix) industrial wastes.

These materials are converted into fuels which are used to run the engines that generate electricity. The conversion involves three main processes: thermochemical (combustion, gasification, pyrolysis, liquefaction), chemical (esterification) and biochemical (acid hydrolysis, enzyme hydrolysis, fermentation) processes.

Thermal Conversion

Thermal conversion processes can be applied to rice hull, considered one of the more abundant biomass resource in the Philippines. There are three major processes involved: (i) direct combustion; (ii) gasification; and (iii) pyrolysis. In the direct combustion process, rice hull is burned in a furnace to produce steam in a boiler. The steam is used to run a steam engine or a steam turbine, which, in turn, drives an electric generator. In gasification and pyrolysis, rice hull is converted into combustible gas to fuel internal combustion engines (diesel or gasoline types). The thermal conversion occurs inside a reactor containing the rice hull. In gasification, air is utilized as an oxidant medium of conversion in order to facilitate the production of combustible gas. Pyrolysis is done without an oxidant. It is a more energy intensive process, and the quality of gas produced is better. The latter process produces liquid and solid (charcoal) by-products. The liquid portion contains methanol, acetone and other organic acids.

Chemical Conversion

Esterification is the chemical modification of vegetable oils into oil esters that can be used as biofuels in engines. Oils are extracted from oil crops, *e.g.*, rapeseed, coconut, sunflower, and made to undergo esterification to adapt the vegetable oil to the requirements of diesel engine. The introduction of alcohol and a catalyst (sodium hydroxide or potassium hydroxide) eliminates glycerides. Methyl esters are formed when methanol is used while ethyl esters are formed if ethanol is used. It is estimated that 1 ton of methyl ester can be produced from 3 tons of rape seed.

Biochemical Conversion

Biological processes include anaerobic digestion, acid and enzyme hydrolysis and fermentation. Methane is produced during the anaerobic digestion of wastes. It can be used for direct burning or for internal combustion engines. A kilo of dry wastes can produce 0.2 to 0.3 cu m of methane.

The main product from acid and enzyme hydrolysis, fermentation and distillation is ethanol. Ethanol can be used as fuel for engines, either in its pure form or in mixture with gasoline. The technologies for acid hydrolysis, fermentation and distillation, especially for sugar and starch substrates, are in the commercial stage, especially for sugar and starch substrates. In contrast, the process of acid and enzymatic hydrolosis of cellulosic substances still needs strong R&D support.

Table 2
Philippine Biomass Resources, 1999
In metric ton

Region	Rice hull	Bagasse	Coco shell	Coco husk	Coco coir
CAR	44.3			0.4	0.3
I	216.4		14.9	33.0	23.1
II	341.8	55,591.4	86.2	16.0	134.0
III	368.5	392,732.9	546.7	1.1	850.0
IV	241.5	521,779.1	65.0	740.3	101.1
V	144.0	74,836.3	7.2	252.9	11.2
VI	306.3	3,441,250.8	0.5	97.4	0.8
VII	41.7	687,724.0	333.1	136.9	518.2
VIII	101.3	183,257.9	114.2	509.6	177.7
IX	65.2		43.8	539.0	68.2
X	66.4	426,274.4	61.6	191.5	95.8
XI	136.2	135,649.9	229.3	1,214.9	356.7
XII	159.8	66,742.9	242.6	144.5	377.0
XIII	56.0		43.0	95.5	66.8
Philippines	**2,357.3**	**5,985,840.5**	**1,948.9**	**4,330.8**	**3,031.6**

Source: Biomass Atlas of the Philippines, 2000.

Investing in Biomass Power

Biomass represents the largest NRE installations in the Philippines. In 1999, out of the 42,872 operating NRE installations, 40,735 (or 95 percent) are biomass systems. They account for more than 70 percent of energy contributed by the NRE sector. It is forecasted that the energy share of biomass in the NRE sector will reach 89 percent by year 2008.[1] Yet while the contribution of biomass to energy generation has been substantial, its utilization for generating electricity remains scant. Less than 2 percent of the total installations is designed to generate electricity. These are biogas (374 units), biomass-fired boilers (177 units) and gasifiers (19 units).

In what follows, the economics of using biomass systems to supply electricity is explored. The levelized energy costs of the installations are calculated under the following assumptions: (i) 20-year life of the system; (ii) 12 percent capital recovery factor; and (iii) 12 percent cost of loan with repayment amortized over the life of the system.

Biogas Digester

The most successful application of biogas system to date was installed in Maya Farms, owned by Liberty Flour Mills, in Antipolo, Rizal. The system is known for its large-scale continuous split-type system using floating gas holder. However, apart from Maya Farms, there has been no report of large-scale utilization of biogas for power generation. A number of small-scale systems have been installed but they produce intermittent power and are not designed to supply village power.

Table 3 presents the comparative investment costs for two popular local designs: metal elevated tank and rectangular concrete commercial type. The first involves a digester of 100-head capacity, while the second is designed for 300 heads. The corresponding costs are P300,000 and P865,000, respectively. The first type would require 4 operators, while the second, about 10 persons, excluding those involved in the actual piggery operation. The annual operating cost is about 20 percent of the initial investment cost; maintenance and repair expenses are approximately 10 percent of the capital costs.

Utilizing biogas digester to generate power requires investments of about P50,000 per kW. On a per kW basis, the cost difference between the two systems is not material. The economies of scale however shows up in levelized energy costs. Used engines can be utilized for both systems.

Table 3
Economics of Biogas Digester
In pesos

	Commercial	Elevated Tank
Capacity (kW)	18	6
Investment cost	865,000	300,000
Investment Cost per kW	**48,056**	**50,000**
Annual costs:		
Operation	173,000	60,000
Maintenance	78,500	26,500
Life-cycle cost	2,562,826	904,122
Levelized Cost per kWh	**5.22**	**5.53**

Ethanol Plant

The continuous escalation in the prices of petroleum-based fuels inspires a fresh review on the potential of producing ethanol from sugarcane molasses, coconut and nipa sap, among others. In other countries, the production cost of ethanol (based in sugarcane) has been reduced to US$1 per gallon, or equivalently P13.21 per liter. Ethanol obtained from corn costs a little more than US$1.2 per gallon (P15.85 per liter). Even as technological development of ethanol use for power generation in other countries has advanced, the interest in locally developing the fuel remains lukewarm on account of the lower cost of petroleum fuel in the past. The following discussion therefore pertains to a theoretical ethanol power plant.

As the cost of ethanol falls below that of gasoline, the remaining issue to its commercial viability as fuel for power generation is the cost of engine and generator that will run on ethanol. The highest available engine-generator rating in the local market is only 12-kVA. This consists of a brand new Honda 4-cylinder engine with a rating of 100-hp or 75-kW, costing P336,000, and a brand new 12-kVA generator, costing P136,000. If a second-hand generator set were used instead, the investment cost would be reduced by about two-thirds.

Two ethanol plants, one using a rehabilitated, another a brand-new, generator set, are compared in Table 4. The life-cycle and the levelized energy costs for a rehabilitated genset are materially less than using a brand new genset. In a rural setting, however, maintenance cost differentials and the difficulty of sourcing replacement parts would favor installing brand new generator set.

Table 4
Economics of Ethanol Rehab vs. Brand New Ethanol Power Plant
In pesos

	Rehabilitated power genset	Brand new power genset
Capacity (kW)	12	12
Investment cost	215,000	612,000
Investment Cost per kW	**17,917**	**51,000**
Annual costs:		
Operation	43,000	43,000
Maintenance	16,500	8,250
Life-cycle cost	624,660	827,093
Levelized Cost per kWh	**1.91**	**2.53**

Biomass Thermal Power Plants

Several models have been designed locally to utilize biomass for power generation. Most notable are those involving rice hull and bagasse, two of the most abundant agricultural resources in rural areas. However, there is yet no operating biomass power plant in the Philippines for which actual data can be used as basis. Previous biomass power projects such as the 1,920-kW Southern Philippines Grains Complex Power Plant, the 2.1-MW NFA Rice Hull Fired Steam Power Plant in Iloilo, and PNOC's 22-kW Pilot Power Plant, have not been successful.

The data used in the simulation are based on the Biomass Atlas of the Philippines which provides estimates on available biomass resource, costs of transporting biomass fuel, and prices of technologies. The estimates have been carefully validated using ground data of operating rice or sugar mills within a certain economical radius of potential sites. In addition, the use of Differential Geo Positioning System increases the reliability of the estimates, especially on transport costs that were based on actual road network in rural areas. Nonetheless, the estimates remain theoretical as the feasibility of setting up renewable power plants of this magnitude in rural areas remains to be proven.

Table 5 shows the economic viability of two rice hull-fuelled thermal power plants to be located in the province of Isabela. The rice hull will be sourced from 71 mills operating within a radius of 10 and 15 kms from Santiago and Cabatuan, respectively. Bulk density of rice hull is set at 125kg/cu.meter; one truckload can carry 25 cu.m or 3.2MT per trip, while transporting the rice hull will cost P63.75/km. Given the seasonality of rice farming, the mills are assumed to operate at 8 hours/day for 210 days or 7-month operation. The power plants are assumed to operate 24 hours per day for 365 days/ year. The heating value of rice hull is equal to 16.80MJ/kg. The capacities of the plants were based on maximizing available resource to sustain year-long operating cycle. Thus, the Santiago plant will be fed out of the 12,489 MT generated by mills around the plant which will involve almost 4000 trips at a cost of P1.8 million. The Cabatuan plant will utilize 23,093MT of rice hull involving more than 7000 trips that will cost P6.6 million in freight charges.

The 3-MW Santiago plant will cost P311 million or about P103,667/kW of installed capacity. It will generate revenues of P43.7 million/year against an annual operating cost of P38 million or about P5.7 million profit per year. Materials cost is estimated at P1.87 million, while operating and maintenance expense is estimated at 0.5% of plant cost or P1.4 million. Financial charges would amount to P32.9 million based on interest rate of 10% for 20 years amortization. Its life-cycle cost is estimated at P584.2 million and levelized cost at P2.98/kwh.

The 6-MW Cabatuan plant will cost P436.5 million or P82,750/kW of installed capacity. Annual net profit is estimated at P16.2 million from revenues of P80.8 million and operating cost of P64.6 million. Materials will cost P3.4 million while operating and maintenance expense will be about P2.2 million. Interests charges would amount to P52.5 million at 10% for 20 years amortization. The life cycle cost is estimated at P961.89 million and the levelized cost is P2.45/ kwh.

TABLE 5
ECONOMICS OF RICE HULL BIOMASS
In pesos

	Rice Hull-1	Rice Hull-2
Capacity (MW)	3	6
Fuel	rice hull	rice hull
Location	Santiago City, Isabela	Cabatuan, Isabela
Investment Cost	311,000,000	436,500,000
Investment Cost per kW	**103,667**	**82,750**
Annual costs:		
Transport	1,833,932	6,385,500
Materials	1,873,368	3,441,312
Operation & Maintenance	1,400,000	2,235,000
Life-cycle cost	584,229.6	961,893
Levelized Cost per kWh	**2.98**	**2.45**

Table 6 presents the economic viability of bagasse power plants. Two sites were considered: plant 1 with a theoretical size of 220 MW to be located in Victorias, Northern Negros, and a 97-MW second plant in Southern Negros. Bagasse will come from 18 mills with a total rated capacity of 98,729 ton cane per day (TCD). The Victorias plant will be served by 1,114,432 DM bagasse tonnage from 14 mills; the second plant will utilize 488,016 DM bagasse tonnage from four mills. The bagasse will be loaded on trucks at 30 tons per truckload-trip. Transport costs are estimated at P63.75 per km.

The 220-MW Victorias plant will involve 3 generating units (2 x 85 MWe and 1 x 60 MWe). The 85MW system costs US$82.93 million while the 60MWe costs $63.64 million. In terms of $/kW, the latter is more expensive at $1,060/kW versus the bigger unit at $975/kW. The 94-MW southern plant will also involve three generating units (85 MW, 6 MW, 3 MW). The huge investment was meant to maximize the available resource in the area.

The proposed thermal plants would be operating 365 days per year at 50% efficiency. Bagasse has a heating value of 12.5MJ/kg. The electricity generated will be priced at P1.50/kwh. The first plant will cost P11.47 billion (or P52,159/kW). Life cycle cost would amount to P26.25 billion while levelized cost will be lower at P1.82/kwh.

For the second plant, the project total cost amounts to P4.95 billion (P52,702/kW or not much different from the first plant). Life cycle cost would about half of the first plant at P12.67 billion, levelized cost would amount to P1.95/kwh.

Facilities that use rice hull as fuel for combustion could have smaller investment cost but higher levelized cost of power compared to facilities that utilize bagasse. In terms of investment per kilowatt, however, the use of bagasse is more economical, although the investment required is huge in order to realize scale economies. The levelized costs between the two bagasse plants exhibit not much of a difference and are more economical than those of rice hull thermal power plants.

Table 6
Economics of Bagasse Biomass
In pesos

	Bagasse-1	Bagasse-2
Capacity (MW)	220	94
Fuel	sugarcane bagasse	sugarcane bagasse
Location	Negros	Negros
Investment Cost	11,475,000,000	4,954,000,000
Investment Cost per kW	**52,159**	**52,702**
Annual costs:		
Transport	421,031,149	270,638,893
Materials	344,883,364	150,956,399
Operation & Maintenance	51,640,000	24,770,000
Life-cycle cost	26,255,603,872	12,014,324,022
Levelized Cost per kWh	**1.82**	**1.95**

Gasifier

Gasifiers generate electrical power in much the same way as direct combustion system. Table 7 compares the economics of an imported gasifier with a locally fabricated system. The imported system has a capacity of 250 kW. The import price of the equipment is quoted at US$214,500; an additional P14.3 million would be needed for civil, electrical works, systems design, installation, training and commissioning. The annual operating cost is benchmarked at 10 percent of initial investment, while maintenance expenses, at 10 percent of capital cost.

As an off-grid source of electricity, the gasifier is competitive to other biomass facilities. The investment cost per kW for an imported gasifier is less than for a rice hull thermal power plant and about the same for a bagasse plant. For smaller systems, the savings are even bigger because used engines can be utilized. The levelized cost of electricity can be reduced to P3.43/kwh for a 10-kW locally fabricated system.

Table 7
Economics of Imported vs. Locallly Fabricated Gasifier
In pesos

	Imported Gasifier	Locally Fabricated Gasifier
Capacity (kW)	250	10
Investment cost	13,611,804	214,700
Investment Cost per kW	**54,447**	**21,470**
Annual costs:		
Operation	1,361,180	42,940
Maintenance	1,218,180	19,000
Life-cycle cost	41,047,543	851,645
Levelized Cost per kWh	**6.60**	**3.43**

However, a locally fabricated gasifier would be more expensive on a per kW basis compared to an ethanol power that uses a rehabilitated genset. The ethanol plant, demonstrated in Table 3, is almost of the same size as the local gasifier, but the former produces cheaper power: P1.91 versus P3.43 per kWh.

End Notes

[1] EUREC Agency, *The Future for Renewable Energy, Prospects and Directions.*
[2] Trade Guide on Renewable Energy in the Philippines, p.7.
[3] Society for the Advancement of Technology Management in the Philippines, *Can the Philippines Become an Energy Exporter by the Year 2020?*. Roundtable discussion on Energy, Monograph Series No. 97-01, p. 32.
[4] Quejas, Reuben E.T. *Philippine Renewable Energy Policies and Opportunities for Development.* International Workshop on Energy Efficiency, Cebu City, 21-22 June 2000.

Laws and Regulations Relevant to Renewable Energy Projects

Omnibus Investment Code of 1987 (amended by RA 7918)

The Code provides investment incentives to enterprises registered with the Board of Investments (BOI) NRE projects can be registered with BOI for its "pioneer" status to avail of the following incentives:

- (i) Income tax holiday for 6 years
- (ii) Exemption from value-added tax
- (iii) Simplified customs procedure
- (iv) Unrestricted use of consigned equipment
- (v) Employment of foreign nationals
- (vi) Deduction on taxable income of expenditures on necessary infrastructure related to project development
- (vii) Additional deduction on taxable income of 50% of wages corresponding to the increment in direct labor hired within the first five years of registration
- (viii) Deduction on taxable income of expansion expenses if additional deduction for labor expense were not claimed.

Mini-Hydro Power Incentives Act (RA 7156)

Mini-hydro proponents can avail of the following incentives:

- (i) Special privilege tax rates of 2% of gross receipts from sale of electric power and from transactions incident to the generation, transmission and sale of electric power
- (ii) Tax and duty-free importation of capital equipment, materials and parts
- (iii) Tax credit on domestic capital equipment
- (iv) Realty tax cap not exceeding 2.5% based on original costs of equipment and machinery
- (v) VAT exemption on gross receipts from electricity sales
- (vi) Income tax holiday for 7 years

Law on OSW (EO 462, amended by EO 232)

For generation projects exceeding 1 MW, the private sector is allowed to participate in the exploitation, development, utilization and commercialization of ocean, solar and wind (OSW) energy resources, through a production sharing contract with the national or local government. The Department of Energy can extend assistance to OSW developers in obtaining all applicable fiscal and non-fiscal incentives, including registration as pioneer industry with the Board of Investments. In addition, OSW developers can charge the cost of assessment, field verification and feasibilty studies on other sites to their current commercial projects. They can also secure access to lands and/or offshore areas where OSW energy resources can be harnessed.

Agriculture and Fisheries Modernization Act of 1997 (RA 8435)

Apart from providing trade and fiscal incentives on the agricultural and fisheries sectors, the Act provides for duty-free importation of machinery and equipment, including renewable energy systems such as solar panels, provided that such equipment shall be for the exclusive use of the importing enterprise.

Clean Air Act (RA 8749)

The Act sets emission standards on stationary and mobile sources for greenhouse gases, including power plants. NRE projects are favored to the extent that some of its technologies, such as photovoltaics, have zero emissions. But the Act imposes outright ban on incineration facilities which may have adverse impact on biomass combustion facilities. Combustion should be set at very high temperature levels for it to be complete and free of emissions.

National Integrated Protected Areas System (NIPAS) Act of 1992 (RA 7586)

Some areas in the Philippines have been declared protected, thus construction of NRE projects in these sites would require special permit. The Department of Environment and Natural Resources (DENR) issues the Environment Compliance Certificate to projects complying with the environmental standards . For NRE projects that are located in areas considered ancestral domain, the proponent must secure permits from the concerned indigenous communities and the National Commission on Indigenous Peoples.

RA 6957 BOT Law as Amended by RA 7718

Power plants may be constructed under a build-operate-transfer (BOT) scheme whereby the private sector project proponent can recoup its investments through the charging of toll fees and rentals during the contract periods. Section 10 of RA 7718 provides that BOT projects in excess of P1 billion shall be entitled to incentives as provided by the Omnibus Investment Code.

DOE Circular No. 2000-03-004

This Circular amends the law that seeks to elicit private sector participation in power generation. Relevant to NRE development are the following proviso:

- (1) Companies do not have to show a five-year track record to receive accreditation for NRE generation facilities, provided that the technology being proposed has already achieved commercial status and can be demonstrated to be adaptable to local conditions; or if the project is for self-generation purpose, or the proponent is technically and financially capable.
- (2) The provision for spinning reserve imposed on Private Sector Generation Facility shall not apply to RRPPF/NREF projects if (a) the project is not connected to either the national backbone grid, or regional or island mini-grids; or (b) the project is connected to a regional or island mini-grid powered by conventional generation reasonably capable of load following, e.g., peaking or intermediate diesel generation plants. If the RRPF/NREF project is proposed for connection to the national backbone grid, the provision on spinning reserve shall be subject to negotiation with the transmission system operator or from any future regulatory body overseeing the operations of the transmission grid system.
- (i) Thermal efficiency requirement for cogeneration facilities using NRE, including hybrid systems has been removed.
- (ii) Renewable resource power production facilities are exempt from submitting 10-year power supply agreement and are only required to demonstrate potential net foreign exchange savings by virtue of utilizing renewable energy sources.
- (iii) For projects that supply electricity to a designated utility or user, or for internal use, the power development plan review and approval requirements of the Department of Energy shall not be required.

DOE Circular No. 2000-10-011

This Circular mandates the acceleration of Rural Electrification Program by instituting summary procedures in the approval and subsequent release of the electrification fund to the franchised distribution utility or project implementor. Section 2f of the Circular provides that the electrification of target areas should be accomplished in the least-cost possible manner which means either adopting the conventional line design or utilizing indigenous and renewable energy sources.

DOE Circular No. 2000-03-003

This Circular amends the 1994 DOE regulation that prescribes the provision of direct benefits to local government units (LGU) hosting energy resource development projects and/or energy-generating facilities. The amendments streamlined provisions concerning allocation of fund and generation of livelihood projects. Section 7 provides that in cases where the grid type is deemed unavailable for energizing a particular LGU, the electrification fund may be redirected by the DOE in favor of utilizing NRE system to speed up the electrification of the concerned area.