Techology Brief

Harnessing Wind Energy for Off-grid Rural Electrification

Wind energy is a secondary form of solar energy. It is considered one of the safest and cleanest forms of renewables. Wind turbines do not generate greenhouse gases although there are concerns about their noise and harmful effects on bird life. Moreover, wind energy systems do not pose environment problems related to decommissioning of obsolete plants. Apart from low operating costs, wind energy system can be used for various applications in agriculture and industries. The system, however, is site-specific requiring areas with wind speed of at least 3-4 meters per second. It requires storage in terms of batteries or water reservoir due to considerable power supply variations. A back-up system is also recommended for areas where wind supply is low.

Wind farm technology has had more advanced applications in Europe and the US. The Middelgrunden wind farm in Denmark is currently the world's largest offshore wind farm with a capacity of 40 MW. It is the first step towards a batch of other Danish offshore wind farms, each planned to generate 150 MW. In the US, the state of Texas has become the hottest wind energy market, having recently developed a 250-MW wind energy facility. A 500-MW facility is scheduled for construction this year; another 300 MW is being considered. This development occasioned the restructuring of the power sector in Texas. An integral component of the reform is the "Renewable Portfolio Standard" (RPS), *i.e.,* a program to dedicate to renewables about 2,000MW of energy capacity, approximately 3 percent of the state's power supply, by 2009.[1]

In the Philippines, wind energy system is gradually gaining advocates following the completion of the wind resource map of the country. The potential sites for wind energy generation have already been identified; majority of them are in the western side of the archipelago. Among the promising areas are: Cuyo Island (5.58mps), Basco, Batanes (5.39mps), Catanduanes (4.15mps), and Tagaytay City (5.0mps). Under current negotiations is a project in Mindoro that will showcase wind energy system in the Philippines. The proponent plans to set up 25 units of 750-kW or a 18.75-MW of wind power facility. A similar system is being eyed for installation in the provinces of Catanduanes, Masbate and 12 other islands.

The Philippine Energy Plan for 1999-2008 forecasts that the contribution of wind energy systems to the country's power supply will reach 5 to 80 MW between year 2004 to 2008. If current plans materialize, off-grid stand-alone wind turbine generators may be able to contribute 36.87 MW to the grid by 2008.

USAID SATMP

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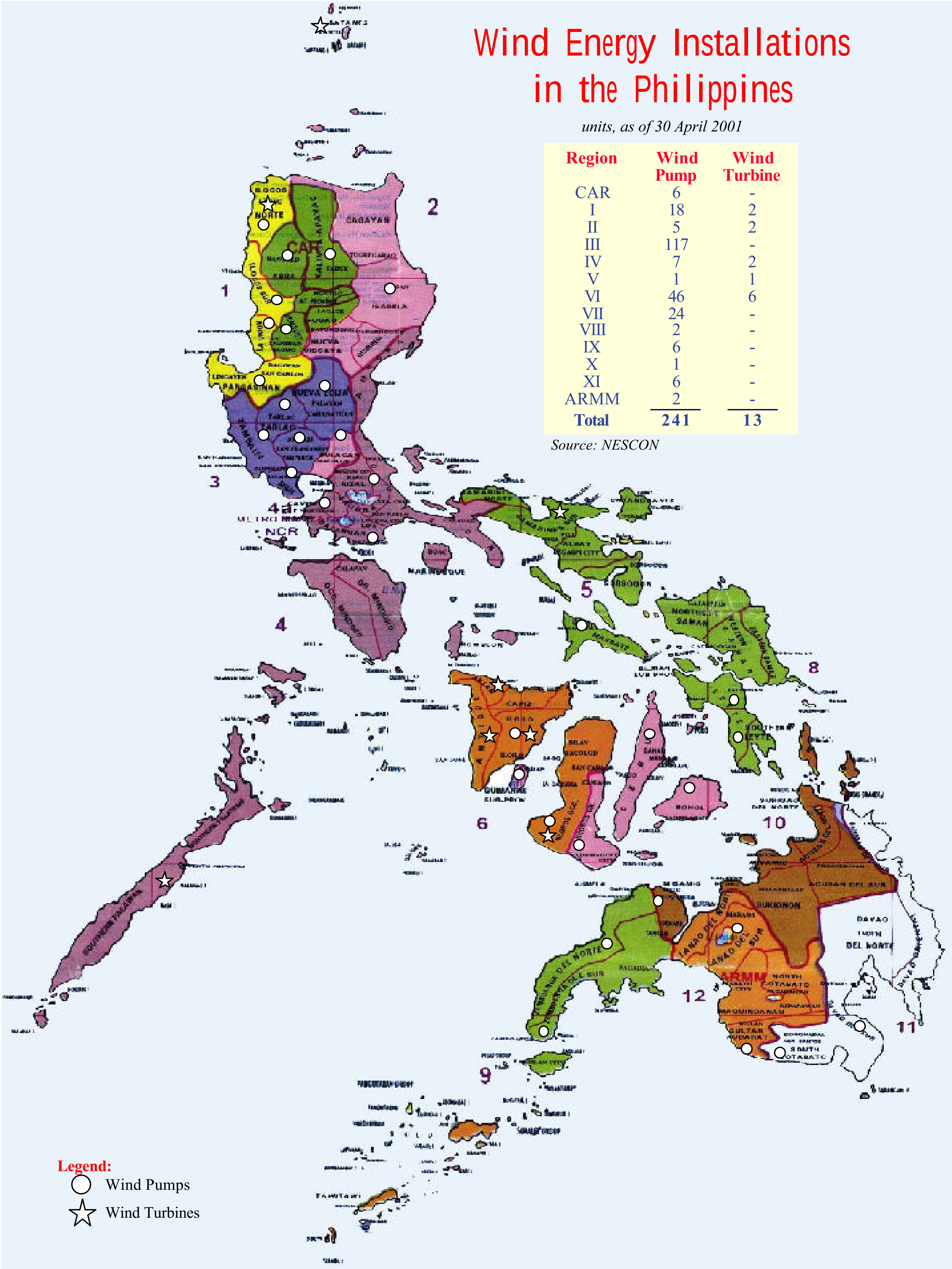
Wind Energy Installations in the Philippines

units, as of 30 April 2001

Region	Wind Pump	Wind Turbine
CAR	6	-
I	18	2
II	5	2
III	117	-
IV	7	2
V	1	1
VI	46	6
VII	24	-
VIII	2	-
IX	6	-
X	1	-
XI	6	-
ARMM	2	-
Total	**241**	**13**

Source: NESCON



Wind Energy Systems in the Philippines

What is wind energy?

Wind energy is derived from kinetic energy of moving air that is converted into power through a mechanism called *rotor*. The kinetic energy produced by the wind in unit time increases with the wind velocity (exponentially, at a power of three). Thus, doubling the wind speed increases the power eight times, while doubling the rotor diameter increases the available power four times. For example, at 3 meters per second wind speed, the wind power per square meter is about 17 watts; while at 6 mps, the power that can be generated per square meter is 136 watts.

In general, wind machines can only extract about 59 percent of the wind kinetic energy. Actual performance efficiency of wind machines varies from 10 to 50 percent depending on the aerodynamic quality of the rotor. They are useful at a mean wind velocity of about 2 mps and are safe to operate up to a wind velocity of 25 mps.[2]

Wind energy conversion technologies are classified depending on size and applications. The first is *medium- to large-size grid-connected Wind Turbine Generators (WTG)* that have evolved from 50-kW in the 1980s to about 800-kW in the 1990s. The present generation of commercial wind turbines has gone past the 1000-kW mark. There are different design concepts: three-bladed, stall- or pitch-regulated, horizontal-axis machines operating at near-fixed rotational speed. There are other concepts such as gearless designs and variable rotor speed designs. Modern installation techniques allow commissioning in less than 6 months.

Another group belongs to *intermediate-size wind turbines in hybrid energy systems*. The system is usually combined with other energy sources such as photovoltaics, hydro, and diesel, and used in small remote grids or for special applications such as water pumping and battery charging. These systems may have a capacity of 10 to 500 kW.

The third group is *small stand-alone turbines* for battery charging, water pumping, heating, and the like. These systems have capacity less than 10 kW. In small battery-charging wind turbines, the size can range from 25 to 150 watts. By far, the most common use of wind energy system in the Philippines is the mechanical wind pump.

Major wind turbine installations

● 11.5kW Atulayan Hybrid Remote Area Power System (HRAPS)

Inaugurated in October 2000, the Atulayan facility is a hybrid of wind turbine as primary energy generator, and solar panels as secondary energy source. The wind turbine generates power even at low wind speed of 4.5 meters per second. The turbine's patented tilting axis allows power generation even at high wind speeds; and in cases of typhoon, the turbine tower can be lowered for safety. The solar power component has twelve 75Wp panels. In periods where solar and wind resources are not available, a diesel generator serves as a back up system. An existing 75kVA genset was retrofitted for the purpose.

The system provides 36.5kWh/day of electric power to the village's 72 households, a school, street lights, playground and seaweed dryer. It is equipped with 3x5.5kVA sine wave interactive inverter and storage battery bank that allows 24-hour AC power, 220V single phase and 380V three-phase. The system has safety features that are ideal for remote area installations including automatic controls for easy operation. The investment cost of the Atulayan project amounted to P2.3 million including installation cost. Consumers pay P4.35/ kwh plus a fuel cost adjustment charge.

● 10-kW Wind Turbine, Pagudpod, Ilocos Norte

In March 1996, NPC commissioned a pilot wind turbine in Ayoyo, Pagudpud, Ilocos Norte with support from the Philippine Council for Industry Energy Research and Development (PCIERD). The project which costs P2.1 million demonstrates the technical and economic viability of harnessing wind energy for power generation based on local conditions. The average wind speed at the site was monitored at 7.3 m/sec. The easterly wind blows about 36% of the year, and the equivalent annual wind power density is estimated at 532W/m^2.

Plant operation is limited to nighttime for 4 to 6 hours during the lean wind months of May to September, but is available for 24 hours daily during peak wind period from October to April. In its first year of operations, the plant had an energy surplus since the turbine was generating more electricity than what was needed by the village. Revenues generated from the 23 households served by the system amounted to P21,600 during the year. This corresponds to a daily load demand of 16 kwh. Due to the limited capacity of the battery banks, surplus energy has to be dumped. The project has been in operation until recently when the battery system was damaged.

● ANEC-Iloilo KW-Level WTG

A locally-designed and fabricated kilowatt-level wind turbine generator designed by the ANEC-Iloilo is installed in Isla Maahas, Calatagan, Batangas. The rotor has three 10-foot long fiberglass blades with NACA 4412 profile. It is coupled to a 15kVA generator via a two-step belt and pulley transmission that multiplies the rotational speed (rpm) of the rotor to match the rpm of the generator. The protected head assembly is mounted atop a 60-foot tower made up of galvanized pipes.

The power produced by the generator is used to charge a battery bank which stores the energy for a more sustained power availability even in the absence of wind conditions. An inverter is used to convert the DC electricity from the battery bank to 220VAC.

The generator is an induction motor that was slightly modified to work as a generator. The modification was introduced so the generator could operate at variable rotational speeds thus enabling the system to produce electricity by operating as an asynchronous generator.

● Aerovolt: NewFendered Bucket Windmill

Aerovolt is a vertical axis windmill apparatus where a movable wind shield covers the backturning buckets. This set up limits the entry of usable wind to prevent over-revolution of the windmill during strong winds. The aerovolt, which is installed in Isla Maahas, Calatagan, Batangas, comprises of six sets of half-rounded buckets that are made of light metals. The wind pushes the buckets to rotate the centrally located vertical shaft connected to the gears and pulleys that drive the synchronous generator assembly. As the intercepted wind is released, the buckets backturn traveling against the flow of the wind. The slamming between the bucket and the wind is prevented by the movable windshield that moves forward to the position of wind scooping buckets.

The estimated investment for a 20 KW typhoon-proof aerovolt windmill is about P716,800. The only imported component is the generator costing P49,000. This represents not more than 10 percent of the total cost. The prototype has produced 50 to 100VAC electric power from a 5kw generator at windspeeds of 4 to 10 meters/second. The overall efficiency of the model was estimated at 30% to 40% and could go up to 70% with improvements. The estimated cost of power generation was P0.22/kwh.

Investing in Wind Power

Despite the abundance of wind resource in the Philippines and the fact that wind energy technology has matured, local utilization of wind energy system has not been as widespread as may be expected. Several reasons account for this. Foremost is the site specificity of the resource. In most areas with abundant wind resource, the communities have low incomes to be able to afford the relatively huge investment costs required by the system. In the case of mechanical water pump system, for instance, the upfront costs can be steep for a single household to bear. Another obstacle is the absence of product standards for locally fabricated systems. There have been plans to establish product standards, testing and accreditation procedures to ensure the quality production of wind energy systems, but none have yet materialized.

Nonetheless, communal wind pump systems are becoming popular because more consumers can pitch in for the upfront investment costs and there are cost savings in larger systems due to economies of scale. The scale economies apply as well to wind turbine generator systems; thus, bigger wind turbines involve larger investments and but the cost of generated electric power is lower.

The following sections show the life-cycle and levelized electricity costs of wind power installations under the following assumptions: (a) 10 years useful life for wind pump; 15 years for wind turbine generator; (b) 12 percent capital recovery factor; (c) 12 percent loan rate; (d) labor cost at P150/day.

Wind Pumps

Wind pumps are mechanical devices that transform the kinetic energy of wind to cause the vertical action of a piston to suck water upwards. In simple terms, the windmill replaces human power in a hand-operated water pump set up.

Table 1 presents the financial profile of wind pump systems, classified according to rotor size and capacity. The estimates are based on installations in Western Visayas. The cost of the system varies considerably depending on the design, materials, labor costs of manufacturing and installation, and the cost of transporting the system to the site. Prices may range from P30,000 for a small system to P145,000 for a larger model. Scale economies translate to lower investment cost per cubic meter of pumped water as capacities become larger. The levelized cost per cubic meter falls to P2.00 for large systems that can pump 120 cubic meters of water daily.

Investment-wise, a windpump installation in Central Luzon does not materially differ from those in Western Visayas. A 500-gallon model manufactured by Reymill Steel Products in Sta. Rosa, Nueva Ecija, is priced at P75,000. This model is comparable to the WP 3.5 model quoted at P68,000 in Iloilo. The price differential could be attributed to differences in labor costs, transportation charges and costs of raw materials.

The current policy of local government units is to treat wind pump system like other agricultural machinery or equipment. Thus, no tax is imposed on the installation and operation of the system.

Table 1
Economics of Wind Pump-Western Visayas
In pesos

	WP 1.5	WP 3.5	WP 4.5	WP 6.0
Rotor Diameter	1.5 m	3.5 m	4.5 m	6.0 m
No. of blades	8	18 – 24	18 - 24	24 – 32
Tower height	6 – 10 m	6 – 10 m	6 – 10 m	6 – 10 m
Pumping head	6 m	6 – 10 m	10 – 40 m	10 – 40 m
Typical output*	1 – 5 m^3/day	15 – 30 m^3/day	30 – 70 m^3/day	45 – 120 m^3/day
Investment cost	30,000	68,000	100,000	145,000
Investment Cost per cu m	10,000	3,022	2,000	1,758
Annual costs:				
Operation	4,500	4,500	9,000	9,000
Maintenance	2,500	6,000	9,000	13,000
Life-cycle cost	84,288	160,730	403,381	493,087
Levelized Cost per cu m	**13.62**	**3.46**	**2.43**	**2.00**

*at 3 m/s wind speed.

Wind Turbine Generator

Wind turbine generators (WTG) harness the power of the wind through a system of gears and pinions that drives a generator to produce electric current. The action of the wind rotates the blades, that in turn, drives the shaft to power the generator. Instead of a combustion engine or electric motor, the wind serves as the prime mover that drives the generator.

Table 2 presents three types of WTGs with 1 to 2 meters of rotor diameter. A 50-watt system utilizing local components costs P45,000. Annual operating and maintenance expenses amount to P8,500. Based on an estimated useful life of 15 years and capital recovery factor of 12 percent, the levelized electricity cost is P103.40/kwh. A larger system of 500-W would need an investment of P80,000, or almost double the smaller system but the levelized cost would decrease to P18.63/kwh. Increasing the capacity 10 times would lower the levelized cost per kwh by 5.5 times.

Table 2
Economics of Wind Turbine
In pesos

	WT 1.0	WT 1.5	WT 2.0
Rotor diameter	1.0 m	1.5 m	2.0 m
No. of blades	2	2	2 or 3
Drive	direct	direct	direct
Power output*	50 W	200 W	500 W
Voltage	12 or 24	12 or 24	12 or 24
Battery	automotive	automotive	automotive
Investment cost	45,000	67,500	80,000
Investment Cost per kW	**900,000**	**337,500**	**180,000**
Annual costs:			
Operation	4,500	4,500	4,500
Maintenance	4,000	6,000	8,000
Life-cycle cost	154,229.87	216,020	277,811
Levelized Cost per kWh	**103.40**	**36.21**	**18.63**

*at 4 m/sec wind speed.

Wind Hybrid Systems

Wind energy systems can be used in combination with other NRE systems. A WTG can work in tandem with a PV system to store power in batteries. A common and practical set up is an internal combustion engine such as diesel as a back up for windmills. Alternatively, an engine can be powered by biomass fuel in a windmill-biomass set up.

Table 3 illustrates the economics of wind hybrid system coupled to biomass, PV and internal combustion engine. Levelized cost would be lower for wind-biomass hybrid using rice hull gasifier, although the difference would only be about 3 percent compared to an Internal Combustion Engine system. Utilizing a solar module would drive the cost to P166.12 per kwh on account of the higher cost of solar panels. Investment cost would be higher for wind-biomass hybrid on account of additional investment for fabrication of gasifier, imported generator and purchase of used engine.

Table 3
ECONOMICS OF WIND HYBRID SYSTEMS*
In pesos

	Wind-Biomass	Wind-PV	Wind-ICE
Technical specification	WT 2.0 (500 W) Generator 3 kW, 220V (China); used engine (4K Toyota); 40 cu.m.rice hull gasifier	WT 1.0 (50 W) Solar module 75 W Controller 6 A Inverter 200 W 2 units car battery 12V	WT 2.0 (500 W) Robin engine genset 1400 W, 220/110V (brand new)
Capacity (W)	3,500	125	1,900
Investment cost	167,000	99,400	127,000
Investment Cost per kW	**47,714**	**795,200**	**66,842**
Annual costs:			
Operation	11,435	4,500	32,240
Maintenance	14,700	6,170	11,200
Life-cycle cost	529,901	247,778	549,247
Levelized Cost per kWh	**35.53**	**166.12**	**36.82**

*at 4 m/sec wind speed.

Projects in the Pipeline

Two major wind energy installations are currently in the pipeline: the 1,100-kW Batan Island Wind Plant Project and the Mindoro Wind Farm.

The Batan project was originally conceptualized as a stand-alone PV-Wind-Diesel hybrid system by the provincial government of Batanes. Due to the high cost of solar panels, the photovoltaic component was eliminated. The plant is envisioned to have an initial capacity of 200KW and will be expanded to 1100 KW over a ten-year period as the demand increases and funds are made available.

The project team would be led by the First Philippine Energy Corporation with the support of the Advanced Energy Systems Ltd. of Australia. The facility will supply power to four towns: Ivan, Uyugan, Mahatao and the capital town of Basco.

The project cost, including the provision for automated diesel control and radio communication hardware, is estimated at P160.4 million. The generation cost of the existing diesel generation system in Batan Island is P12.80/kwh; the wind project is expected to generate power at P4.77/kwh.

Another major boost to the wind energy sector is a proposal by BreezElectric-Philippines to establish wind farms in 14 islands in the archipelago. In Mindoro, the project involves developing 18.75-MW of wind power with an annual output projected to reach 59 to 68 GWh. The details and terms of the proposal are still being worked out with concerned agencies. Similar facilities are contemplated in Catanduanes, Masbate and other areas.

End Notes

[1] Renewable Energy World Jan-Feb 2001
[2] The Basics of Wind Energy Systems, Alexis T. Belonio, Wind Energy Association of the Philippines.

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.