# Renewable Energy in Latin America

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RECENT events, such as the 'war against terror' (war for oil?), the rise of fossil fuel prices, and the commitments of the *Second World Renewable Energy Forum* along with the *Renewables 2004 Conference* in Bonn this year have created a new thrust in the need for renewable energies. As an outcome, renewable energy technologies are no longer only seen as a solution to global warming, but also as a means to cleaning up the messy politics of fossil fuels and offering a global sustainable perspective. Renewable energy sources currently in use reveal considerable growth in infrastructure, power generation and their related industries – particularly in the electrical sector.

In Latin America, despite rich renewable energy resources, only a few countries are 'actively working to develop policies, institutional settings, financing schemes, industrial infrastructure, human resources and other necessary elements, to facilitate the introduction of renewable energy as part of their energy supply options' [1]. This article discusses the state of development of the renewable energy sector in Latin America, focusing on Brazil.

## I. The Brazilian Experiencee

Due to its vast size (47% of the area of South America), abundant natural resources, favorable climate, and efforts by the government to liberate itself from fuel imports, Brazil is the most advanced South American country with regard to the development of renewable energies. Currently, however, only hydro and biomass resources are making a significant contribution to the country's energy supply, with the potential of other renewables such as solar and wind energy remaining unrealized..

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### A. Non-electrical renewable resources

*1) Development of bio-ethanol:* The first use of sugar cane based fuels was recorded in 1931. Since then, ethanol from sugar cane has always been added to conventional Brazilian gasoline – especially in periods of sugar cane over-production and low prices on the world market. Currently, the ethanol content of Brazilian gasoline is 24% [2].

Initially, efforts to increase the use of renewable energies were provoked by the oil crises in the 1970s. Today, Brazil is almost independent from the need to import oil, but in the 1970s, the dependency rate was nearly 85%. The oil crises and the sharp increase in the cost of imported oil (coupled with a weak currency) were the fundamental reasons for the implementation of PRO-ÁLCOOL, the world's most ambitious bio-fuel program [3], [4].

The program was based on high subsidies to support the entire ethanol production process – from sugar cane production through to the distilleries. As a result, distillation capacity and sugar cane production increased considerably and the percentage of the admixture of ethanol to conventional gasoline rose to a level of nearly 20% by the end of the 1970s. With the start of mass production of ethanol cars in Brazil at the beginning of the 1980s, the PROÁLCOOL program entered a second phase: the government fixed the price of the new gasoline at 30% lower than that of conventional gasoline price. Such price-fixing and additional tax incentives for the purchase of ethanol cars led to the quick dominance of the ethanol car in the Brazilian market (between 1984 and 1986 sales of ethanol cars grew to 90% of the total car market) [5]. This rapid change did, however, result in some negative social and environmental impacts, with the diversion of government subsidies away from public transport to individual car ownership [6-8].

The price of oil fell in the early 1980s, but ethanol production capacity rose faster than demand with many sugar cane producers in Brazil investing in ethanol production facilities on the back of low world sugar cane prices. Consequently, subsidies for enlarging ethanol production facilities were abolished in the mid-1980s. But the price advantage of bio-ethanol led to continuing demand for the fuel and for ethanol cars [9], [10].

At the end of the 1980s, world sugar prices rose again, thus making sugar export more attractive to Brazilian producers. The reorientation of the country's sugar industry towards the production of sugar for the world market caused a severe shortage of bio-ethanol in Brazil. As a result, and reinforced by relatively low oil prices, Brazilians lost confidence in the fuel and ethanol car sales dropped to nearly zero in the 1990s (< 0.5% of total car sales). Nevertheless, ethanol production continued at a high level (between 11 and 14 million $m^3$/year) to service the existing ethanol fleet, and to supplement conventional gasoline with 24% ethanol [2]

Considerable progress in the distillation process of ethanol combined with low sugar prices enabled the price of ethanol to drop to almost 50% of that of gasoline during the last years – very competitive even without subsidies. Although the fuel consumption of an ethanol car is 10%–15% higher than that of traditional fossil-fuelled vehicles, the cost advantage for the consumer is still substantial. The recent large-scale introduction of 'flex-fuel' cars on the Brazilian market has once again led to an increased demand for ethanol fuel. Such cars can be refueled by any mixture of ethanol and conventional gasoline without the need for any adjustments. Car owners can spontaneously decide at the petrol station which type of gasoline they want to buy. The flex-fuel cars, which are generally sold at the same price as conventional cars, are a success in Brazil. Between January and June this year, almost 120,000 flex-fuel cars and an additional 20,000 pure ethanol cars were sold. Together, these represent 20.4% of all private cars sold in the first semester of 2004 (compared to 6.9% in 2003 and 4.3% in 2002). Volkswagen Brazil and General Motors estimate that within two or three years, their complete fleet will be composed of flex fuel cars. The future of bio-ethanol in Brazil looks very promising [11], [12].

*2) Solar thermal:* The main, and most cost-efficient, application of solar thermal systems in Brazil is in the substitution of widespread electrical showerheads. Typically, these showerheads heat the flow of water via a very simple 4 kW electrical heating device and are readily available for US$5. Most showers are used when people return home from work, with utility companies recording an absolute peak load between 7.00–9.00 pm (see ***Figure 1***). The utilities have calculated that each $5 electrical showerhead causes investment necessities of at least $ 1,800 for peak load power plants. As the cost of a typical thermosiphon-based solar thermal system starts at $ 700, the utilities could save about $ 1,100 per household just by providing a free solar thermal system.

Due to Brazil's favorable conditions – high solar irradiances and limited seasonal flux – nearly 100% solar coverage could be achieved using relatively simple, locally produced equipment. There are about 30 manufacturers in Brazil, typically producing a 2–4 m_ flat-plate collector and a warm water storage tank (horizontal cylinder type) of 200–400 liters, often equipped with a spare electrical heating device (rarely utilized). The cost of such a system, for a four-person household, is between $700–$900 plus $150–$300 for installation. Assuming that each person took a daily 15-minute shower and the price of electricity was 10 US cents/kWh, the most cost-efficient solar thermal system would pay for itself from savings in electricity bills within three years – without subsidies. The Brazilian National Surveillance and Certification Institute (INMETRO) has repeatedly tested the conversion efficiency of solar thermal collectors and is in the process of rating and labeling them. Unfortunately, most households are not equipped with a hot-water tube system and thus installation is not convenient. Nevertheless, 2,037,000 m_ of solar thermal collectors have been installed since 1983 in Brazil by about 100 local companies [13].

### *A. Electricity generation by renewable energy*

Renewable energy power plants are either connected to the national electricity grids or work autonomously off-grid.

*1) Grid-connected power generation:* The electricity sector is dominated by big hydro power plants that utilize the huge freshwater reservoirs of Brazil. These hydro power plants currently generate about 86% of the country's electricity [14]. According to the "Agência Nacional de Energia Elétrica" (ANEEL), 67,630 MW of hydro power represents a little more than a quarter of Brazil's potential 260,000 MW [15]. But the erection of big hydro power plants has had adverse social and environmental repercussions, with the flooding of vast areas. This has implications for the remaining hydro potential, which is typically characterized by vast amounts of water whose power-generating potential is offset by low altitude differentials and low flow speeds which would create the need to even flood larger areas [16].

A change of attitude by the Brazilian Government, towards more diversified electricity generation, was prompted by the 2001 energy crises. A long period of low investment in generation capacity, which began with the partial privatization of the electricity sector, was followed by a focus on maximizing the use of existing capacities and a relatively dry period which left the hydro power plants much below their nominal generation capacity. A substantial gap between increasing energy demand and stagnating electricity generation forced energy rationing, with severe economic consequences [17].

Apart from the establishment of gas power plant, the Government undertook the most ambitious program in Latin America for connecting renewable energy sources to the electrical grid – PROINFA (see Table 1) [18],[19]. Implemented in 2002, PROINFA supports electrical generation via biomass, wind and small hydro power plants up to a maximum of 3,300 MW (1,100 MW each sector) during the first phase of the program, which ends in 2006. The PROINFA program should especially benefit the wind sector which has been stagnant in last years at only 22 MW total capacity. With an installed power of 1,155 MW and 2,734 MW respectively, biomass and small hydro power plants contribute 4% of Brazil's electricity generation capacity [15]. The invitation to tender, which closed in May 2004, attracted projects totaling 6600 MW, with potential wind projects of around 3,600 MW. Only biomass projections did not reach the 1,100 MW limit set by PROINFA. At the end of May 2004 the selected projects had been published [20]. In the competed wind sector some selected projects had to be replaced afterwards, because of some irregularities in the habilitation process of these wind projects. The methodology applied in the replacement process by Eletrobrás, the responsible entity, has been qualified as illegal by a competing wind company that opened a lawsuit. [21]. PROINFA works in a similar way to the typical feed-in tariff system found in some European countries, such as Germany and Spain. Investors are guaranteed that the electricity generated by their renewable energy power plants will be purchased for a 20-year period. The feed-in tariff paid for electricity fed into the grid is above market price. PROINFA doesn't determine fixed feed-in-tariffs for 20 years, but rather a similar compensation that is tied to a price index (for actual feed-in-tariffs, see Table 1).

The Brazilian Development Bank provides significant financial support by loans totaling R$5.5 billion (US$1.77 billion) at a relatively low rate of interest, covering up to 70% of the total investment costs. Reimbursement is achieved within ten years, postponing the first payment rate for up to six months after the system goes into operation. The remaining 30% will be contributed by an investment fund for energy projects supported principally by Brazilian pension funds [22], [23].

Grid-connected PV play only a minor role in Brazil (only seven grid-connected systems have been reported, mainly installed on research centers, with a total generation capacity of less than 0.1 MW). A grid-feed tariff system for PV does not exist. Speaking at *Renewables 2004* in Bonn, Germany, on 3 June 2004, the Minister for Mines and Energy, Dilma Rousseff, said that such a system '…will not be introduced in the near future … due to unsatisfying previous experience'. However, the Minister could be persuaded to strengthen support for training planners and installers through an International University for Renewable Energy (see below) and for better monitoring and evaluation, as seen in Germany's 1,000-Roofs-PV Program (later a 100,000 Roofs Program was established) where 10% of the systems were intensively monitored, ultimately leading to a significant improvement in the reliability and performance of grid-connected PV.

*2) Off-grid power generation:* The aim of the "Programa de Desenvolvimento Energético dos Estados e Municípios" (PRODEEM), established in 1994, presently at its "revitalization"-phase, was introduced to supply electricity generated by photovoltaics to remote, impoverished areas in order to increase living standards and so reduce migration to the big cities. In total, 9,000 PV systems with a typical size of about 500 $W_p$, amounting to around 5 $MW_p$ in total, were installed at a total cost of $70 million: 67% of this off-grid electrification will be for health centers and schools, 30% for PV pumping systems and 3% for PV-powered street illumination [24].

Unfortunately, scant attention was paid to the proper installation, operation or maintenance of the systems. Projects were incorrectly identified, with a main installer from the state of Ceará noting: 'Some of the health posts and schools which should be electrified did not even exist, while others had already been electrified by electrical grid extension.' These factors, combined with a lack of experienced installers, incomprehensible manuals from the manufacturers, inadequate wiring, overuse and insufficient resources to purchase spare batteries, caused at least 50% of the systems to fail. As a result, the Minister of Mines and Energy, Dilma Rousseff, was reported in Bonn as saying: 'PV is a poor quality power source'. Nevertheless, Rousseff has agreed to actively take part in the *RIO 5* Congress and to discuss the issue of PV with the scientific community and with the industry. In addition, she is in favor of an International University for Renewable Energies to be set up in the north-east of Brazil. The university, which would act as an international forum for the exchange of information on renewable energy technologies, would feature a demonstration and application centre, R&D units and training suites.

## II. Experience in other Latin American countries

*1) Grid-connected projects:* Most renewable energy grid-connected projects implemented in Latin America are hydro power projects. The widespread utilization of hydro power plants is due to the relatively low monetary cost of their electricity generation. Hydro power's high initial investment costs, often maintained through long-term loans granted during periods of military rule, are offset by low operational costs. Without special support schemes, hydro power is the only renewable energy source capable of competing in the common energy market. In Chile, for example, the Government has neither set up barriers to implementation nor offered incentives for renewable energy technologies. Under these conditions, 59.2% of the electric power in Chile is generated by fossil-fired thermo-electric power plants, 40.1% by hydro power plants and 0.7% (70 MW) by biomass power plants. Chile's utilization of wind energy is virtually non-existent at 2 MW [25].

In other Latin American countries, the situation for wind power generation – the fastest growing form of renewable energy worldwide – is similar. With the exception of Costa Rica (71 MW installed), there is no other country in Latin America with more than 30 MW of wind power installed [26].

In Costa Rica, where the Government has encouraged investment in one of the country's biggest projects – the 24 MW Tierra Morena wind farm – funding has been forthcoming from both private and public sources, with grants from several banks and other institutions, including the Danish International Development Agency. The 15-year power-purchase-agreement with the state-owned electrical utility, Instituto Costarricense de Electricidad, has provided security to investors [27]. Clearly, adequate planning is essential for the successful implementation of renewable energy technologies in Latin America, as well as other regions.

2) Off-grid programs: A key objective for off-grid programs is rural electrification, especially for remote areas, where grid connection is prohibitively expensive and where poverty is high. Such projects and programs have been established in many Latin American countries. Two examples, from Mexico and Chile, are highlighted here.

The “Programa Nacional de Solidaridad” (PRONASOL) provides the framework for one of the largest, rural, renewable energy based electrification programs in existence. It is characterized by the active involvement of the national electrical utility to maintain quality control standards during the project’s installation. Since the beginning of the 1990s, about 60,000 solar home systems (SHS) and 2,500 communities, 3,500 schools, health and community centers, as well as 13,000 rural telephones and 12 mini-grids powered by renewables have been installed. The standard SHS used in the program consists of three to five fluorescent lamps (with an accumulated load less than 60 W), a 50 $W_p$ PV panel, a 12 V 100 Ah lead–acid battery, and a charge controller. Other important projects include seven PV–wind hybrid systems and six micro-hydro systems. The communities benefiting contribute 10%–15% to the PRONASOL fund ($10 million a year), depending on Government subsidies [28].

The “Proyecto de Electrificación Rural” (PER) started in 1994 to overcome poverty, improve quality of life and integrate rural areas into the economic and social development of Chile. Under the umbrella of PER, a new project was created in 2001 – “Remoción de Barreras para la Electrificación Rural Con Energies Renovables” (Removal of Barriers for Rural Electrification with Renewable Energies). The main goals of PER are to: create a market for renewable energies (including rural electrification); standardize and certify renewable energy equipment; build capacity; implement financing mechanisms to reduce investment risks; introduce market evaluation; collect data on renewable energy resources; and develop rural electrification investment projects. These varied objectives have led to many different projects. One such is an extensive PV demonstration project with more than 3000 PV systems sited in isolated parts of the country. This project is supported by the UN Development Program, the “Comisión Nacional de Energia” and the Chilean Ministry of Foreign Affairs, with funding from the Global Environment Fund to the tune of more than US$6 million. The national contribution amounts to $26.3 million, mainly through investment in rural electrification, state subsidies, contributions from the private sector and financial support from the communities benefiting from the program [29].

## III. Conclusion

While the use of hydropower and biomass in Latin America has progressed considerably over the previous decades, wind, solar and geothermal potentials are still vastly underutilized. Currently there is no general grid feed law, but rather many diverse projects instead. Despite the vast potential, a substantial Latin American renewable energy industry does not yet exist (aside from the production of solar thermal systems, biomass converters, hydro power turbines and small scale wind turbines). The formation of an environmental movement within Latin America would be very beneficial towards greater renewable energy source policies.

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