The Use of Wind Energy for Electricity Generation in Brazil

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Abstract

This thesis report investigates ways of incorporating the use of wind energy in the Brazilian Energy Matrix and the conditions required for the creation of a local wind power market. The report details the current situation with wind power worldwide, with focus in markets where wind power has a major contribution to electricity generation. Those examples and the conditions that created such development degree are analysed more carefully.

The position of the Brazilian Government regarding renewables is discussed and the current market mechanisms are explained. Also an analysis of the actual electricity market in Brazil and the restructuring process it has been undergoing in the last years is conducted to understand how wind power would fit in this new scenario.

Finally, some case studies are presented to analyse the technical and economic feasibility of wind power generation for Brazil, covering all the aspects of developing this industry in the country.

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Introduction

Several countries in the world are looking with increasing interest at wind energy, both for its use in an environmentally sustainable supply, and for its potential to create new economic activity.

Today, wind prospecting, research and development, turbine manufacturing, and installation employs more than 35,000 people worldwide, and the industry has become a 1.5 billion (USD) dollar world industry [1]. The growth rate of the Danish and German part of the industry within the past five years even exceed the growth rate of Nokia, Europe's largest mobile phone manufacturer, or the number of server on the Internet. [2]

Generating electricity from the wind makes economic as well as environmentally sense. Wind energy is already competitive with coal or nuclear power across most of Europe, especially when the cost of pollution is taken into account. What is more, the cost of wind energy is falling, whilst other energy technologies are becoming more expensive.

Brazil's wind potential is far better than Europe's, according to companies interested in the Brazilian market, such as Asea Brown Boveri (ABB). High stable offshore winds are close to population centres and the windly season is complementary to the rainy season, so wind power would work well in conjunction with the country's hydroelectric resources. Given this potential, this thesis aims to:

- Look at the conditions for the creation and establishment of a local wind market, covering the economical, social and environmental impacts;
- Discuss the energy policy and market mechanisms that will allow such development;
- Show the benefits of integrating wind power generation with Brazilian hydroelectric system

First, a closer look is given to countries where the wind industry is well established to understand the market conditions that allowed this position, like Denmark, German, and Spain. The UK market is also analysed understand the difficulties faced for the deployment of wind energy in a restructured market and to get the lessons learned from it.

An analysis is conducted to current Brazilian situation, willing to identify what effective mechanisms and energy policy instruments could be replicated and exposing the initiatives done so far.

To achieve an effective integration of wind generation in the local market, the structure of the Brazilian energy matrix is explained and an overview of the electricity market is shown. A special attention is given to the restructuring process of this sector, to analyse the sustainability of wind in an "open" market.

The need for investments in new generating capacity in Brazil was reinforced last year, with the outage period the country faced, and the need for diversification of the actual hydro-based energy matrix to create new options emerges as one more reasoning for the development of wind energy in the country.

At last, case studies for different regions are presented, assessing the technical and economic feasibility of wind power generation.

Chapter 1 - World Wind Market Overview

Some 6,500 megawatts (MW) of new wind energy generating capacity were installed worldwide in 2001, amounting to annual sales of about $ 7 billion. This is the largest increase ever in global wind energy installations, well above the capacity added in 2000 (3,800 MW) and 1999 (3,900 MW). The world's wind energy generating capacity at the close of 2001 stood at about 24,000 MW[1].

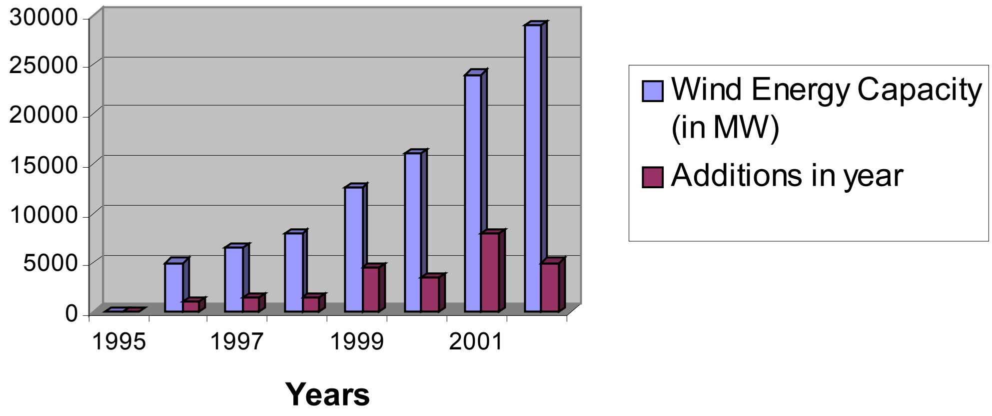


Figure 1 – World Wind Energy Capacity

Germany alone set a world and national record of more than 2,600 MW of new generating capacity installed during the year. Germany, Denmark, and Spain are demonstrating that wind can reliably provide 10% to 25% and more of a region or country's electricity supply.

In the United States, the wind energy industry left previous national records in the dust with a blowout year in 2001, installing nearly 1,700 megawatts (MW) or $ 1,7 billion worth of new generating equipment. The new installations account for close to a third of the world wind energy generating capacity added in 2001.

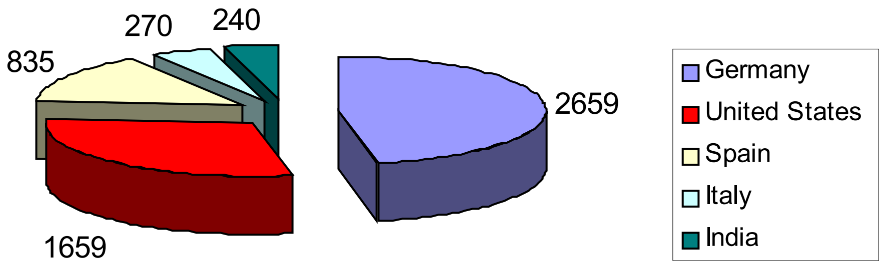


Figure 2 - Largest Addition to generating capacity in 2001 (in MW)

Europe currently accounts for over 70% of the world's wind power. European countries made up two-thirds of the 2001 addition.

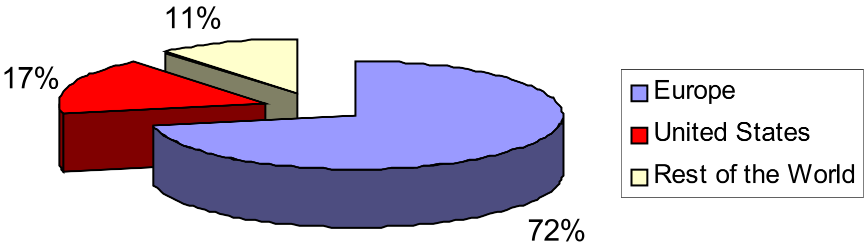
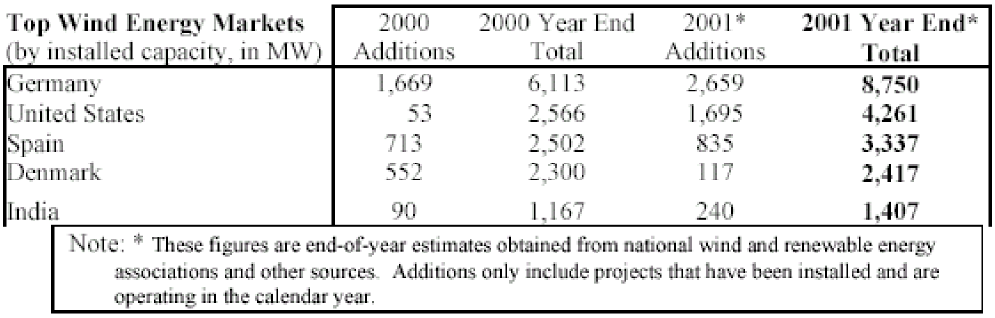


Figure 3 - Cumulative capacity at end of 2001, by region

The global wind energy market continues to be dominated by the “big five” countries with over 1,000 MW of generating capacity each: Germany, the U.S., Spain, Denmark and India. The number of countries with several hundred megawatts is growing larger, and it may be that in the next several years other potential countries - like Brazil and the UK – will see their own wind generating capacity achieve this level.



Top Wind Energy Markets (by installed capacity, in MW)	2000 Additions	2000 Year End Total	2001* Additions	**2001 Year End* Total**
Germany	1,669	6,113	2,659	**8,750**
United States	53	2,566	1,695	**4,261**
Spain	713	2,502	835	**3,337**
Denmark	552	2,300	117	**2,417**
India	90	1,167	240	**1,407**

Note: * These figures are end-of-year estimates obtained from national wind and renewable energy associations and other sources. Additions only include projects that have been installed and are operating in the calendar year.

Table 1- Wind Energy Marktes

1.1 – Wind in Europe

The installation of new wind power capacity has been growing at an average of over 40%, over the last 8 years. In Europe, this market development has been driven by government policies, which were intended to allow wind energy to compete with existing established technologies, recognizing the various benefits of wind power that are largely not accounted fro in the electricity prices paid by consumers.

European Union wind energy market: sustained growth

Over the past 10 years, cumulative installed wind power capacity has increased at a rate of over 32% per year, to give a total installed capacity of around 33,000 MW for Europe at the end of 2000. The rate at which new capacity is being installed has in fact been increasing at an average of well over 40% per year over the same period.

In 2000, the European Wind Energy Association (EWEA) increased its target for installed wind power capacity in the European Union (EU) from 40 GW to 60 GW by the year 2010. This increase reflects the trend towards continued strong growth in new capacity installed; to attain (but not exceed) 40 GW by 2010 would actually require a drop in the present rate of installation of new turbines in Europe. The 60 GW target implies a slight increase in rates of installation for a few years, followed by stabilization of this rate.

Historically, the wind power industry has shown progress ratios of 0.85 to 0.8. A progress ratio of 0.8 implies that a costs decrease by 20% every time the number of units produced doubles. And there is potential for further progress leading to cost design optimisation.

However, the patterns of market development vary greatly between European countries. To a very large extent, within the EU this development ahs taken place in three countries: Germany, Denmark and Spain. The developments that have taken place reflect the successful wind energy policies introduced by those governments.

EU Policy Context

Moves towards the liberalization of the electricity sector in the EU have had a strong influence on the design of renewable energy policies. The 1996 Directive on the creation of an internal market for electricity (96/92/EC) set a timetable for opening markets to a minimum of 30% liberalization by 2003. In practice, wind energy developments in the EU take place within markets at various stages of liberalization, from completely open markets in Finland, Germany, Sweden, and the UK, to markets with only 23-26% market opening, as in Greece, France and Portugal. The directive also includes provisions for transparency in energy markets, with flexibility as to how provisions can be applied; this leads to different approaches to third party access and regulation in the different European countries. In March 2001, European Commission (EC) published a proposal to speed up the opening of European power markets. This proposal, if it is accepted, will allow consumers to choose their electricity supplier by 2005.

While liberalization improves the opportunities fro wind energy developments, such as through ensuring third party access to the grid, it is well recognized that market failure occurs in liberalized markets. Energy prices do not reflect the true social costs of different forms of generation. European wind energy generators compete against large, polluting, fossil fuel and nuclear electricity generators, which do not pay the full cost of damage they may cause. On top of that, many of these conventional generators receive very substantial additional subsidies, estimated at Euros 15 billion (US$ 13 billion)[1] per year in direct subsidies alone[2]. So far, it has proved impossible to reach politically acceptable solutions that address many of these market distortions. Taxes on carbon dioxide (CO_2) emissions, for example, exist in a number of countries, although with exemptions for categories of large polluters to mitigate any possible impacts on the competitiveness of domestic industries. So far, all attempts to introduce a CO_2 and/or energy tax at EU level have failed. Similarly, despite calls from the organization for Economic Co-operation and Development (OECD), from non-governmental organizations, and from the clean industries, there are no signs of move to address subsidies paid to conventional generators.

Nevertheless, new promising renewable energy technologies are penalized by these market failures. Solutions must be found to allow the penetration of such technologies into the newly liberalized electricity markets, in which they are in competition with established generators and technologies, which were introduced and developed under monopoly market conditions.

The EU regulates public spending by member states under state-aid rule enacted to avoid subsidies that may give national companies an advantage over their European counterparts. The interpretation of these rules and the development of guidelines for environmental protection by the member states are important factors that influence the design and implementation of renewable energy policies by these states. The recently published EC guidelines on State Aid for Environmental Protection allow certain types and levels of support for renewables to be provided by EU member states, in conformity with the provisions of the draft directive on electricity from renewable sources. In March 2001, The European Court of Justice ruled that the German Feed-in Tariff does not constitute state aid, as no transfers from the public purse are involved. This decision provides clear assurance that obligations imposed alongside a minimum price guarantee can be in compliance with state aid rules.

In the past years, the focus of EU energy policy has shifted back to the issue of security of energy supply. A green paper on the issue, published on November 2000 has gained additional importance following the oil and gas price fluctuations that occurred in 2000. While the green paper recognizes the potential benefits of renewable energy, it is pessimistic in its estimation of renewable energy costs and the potential to contribute to energy supply, and limited in its strategic vision.

Finally, climate change in proving an important driver, as it focuses the attention of governments on the role of renewables to help address this problem. Recent Intergovernmental Panel on Climate Change reports re-emphasize the necessity fro action well beyond that required in the Kyoto Protocol. At the same time, the EC's consultation to set priorities for measures under the European Climate Change Programme was issued in July 2001. The EC is backing the development of

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[1] Sutdy by Vrije University, Amsterdam, for Greenpeace, quoted in European Parliament Report on Electricity from renewable sources and the internal electricity market.

[2] The indirect subsidies are also very large. A 1992 study for the German Ministry of Economics by the Swiss Prognos Institute estimated the indirect subsidies paid to the German nuclear industry in the form of Civil Liability Guarantees amounted to DM 3.60/kWh (US$ 1.60/kWh). In addition, the tax-free set-asides on provisions fro decommissioning and waste disposal are estimated at DM 70 bilion (US$ 30 bilion).

emissions trading at the EU level. This will result in some benefit for wind energy projects, and interactions with measures designed specifically to promote renewable energy.

National policy trends to renewables

Member states of the European Union have each developed a series of policy measures to promote renewable energy use, with the stated aim of meeting various multiple objectives. Those policy measures and the status of wind industry at the main countries are detailed below.

1.2 - The Wind Market in Denmark

Denmark, which in the early 1970s was extremely dependent on (imported) oil, pursed a very active policy of energy savings, increasing self-sufficiency, and diversification of energy sources until the mid 1980s. Since then, energy policy has increasingly promoted the use of renewable energy to ensure environmentally sustainable economic development. [3]

Long term planning is considered to be important, with a planning horizon presently set at the year 2030 in the Government policy document “Energy 21”. [4] The reason for this very long term planning is to ensure consistency in policy, and to send strong signals to market actors about the policy scenario in which they will operate. In the electricity sector, plant and equipment have long lifetimes (e.g. transformers, transmission systems and generating plant). One important aspect of present planning is to ensure that the future electricity system will be able to accommodate a very long share of intermittent renewables.

Since the mid 1980s, the country has had an official goal of meeting 10 per cent of Danish electricity consumption by wind in the year 2005, implying an installed base of 1,500 MW of installed wind capacity. [5] It now seems likely that the target will be reached by the year 2000, and new ambitious Government plans in the “Energy 21” policy document indicate that around 50 per cent of electricity consumption should be recovered by wind by 2030, most new installations being located offshore.

1.2.1 - The Energy Policy Role of Power Companies

The Danish Government has very wide-ranging powers to regulate utilities. Regulation takes many forms, including energy efficiency and demand-side management (DSM) measures. Integrated Resource Planning (IRP) is an integral part of the procedure through which power companies obtain permission to install new generating capacity. Other measures include price and accountancy controls[3].

The Government has ordered the utilities to install 400 MW of wind power on land to date. The first two orders of 100 MW each were issued in 1985 and 1990. The latest onshore order for 200 MW to be completed before 2000 was issued in 1996[4].

Competitive public tendering fills wind turbine orders from power companies. Formerly the tenders were based on power companies doing an extensive part of site prospecting, installation, and service work. Lately, turnkey contracts with manufacturers have become the rule, since they are expected to be significantly less expensive for the power companies.

The use of turnkey tendering makes the process more similar to the NFO or SRO system used in the UK that what is generally realised.

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[3] Permission to install new capacity are subject to strict environmental criteria. E.g. coal has been outlawed as a fuel for new generating facilities. Danish power companies (mostly co-operatives) are tax exempt, provided their annual account show no profits. Accountancy rules, however, provide generous depreciation allowances, which allow power companies to depreciate 75% of the cost of new 5 years prior to investment. [6] This effectively allows power companies to collect funds for investments from electricity consumers before investments are made. [7]

[4] This of course, in addition to the existing and future cooperatively- and privately-owned turbines, which account for the amrjority of wind generation in Denmark. In 1998, a new order was issued for 750 MW of offshore wind power.

1.2.2 - Power Companies' Ownership of Wind Power

Danish utilities are mostly non-profit co-operatives owned by the electricity consumers in each area, although some municipalities in the larger cities are the owners of distribution companies. Ownership of distribution companies cannot be traded, but is implicitly held by the property owners who consume electricity. Governing boards are elected locally. The distribution companies jointly own transmission and generating companies.

The many local power companies operate an internal sharing arrangement for their wind energy deployment, which means that they effectively pool their wind energy investments to ensure that wind energy is deployed primarily in good, windy areas.

1.2.3 - Attitudes to Wind Energy in Power Companies

Danish development of wind power could probably have been carried through with private (non-power company) investment only, like in Germany. The primary advantage of power company participation from a political point of view has been to ensure that expertise and renewable energy commitment within power companies has been much larger than what would otherwise have been the case. Until recently, however, there was a dividing line between an overall positive attitude at the technical level, dealing with practical wind power implementation, and a more reserved attitude at the political level of utility boards, basically resenting cost and tariff increases due to (costlier) renewables.

The improving economics of wind energy has changed this: Power companies today realise that wind is the cheapest option for meeting the (legal) environmental requirements for power companies, the objectives of which are likely to remain on the political agenda for the foreseeable future[5]. In this situation, the power companies have urged that the Government leave wind development to power companies only, since with the present energy tax refund system, it is far cheaper for power companies to produce their own wind power than to buy it from independent generators. The average cost for power companies' own wind generation is around 0.28-0.34 DKK/KWh (0.04 USD/KWh). But since they get a CO_2 tax refund of 0.10 DKK/KWh, their generating cost is really 0.18 – 0.24 DKK/KWh, versus 0.30 to 0.37 DKK/KWh (0.05USD/KWh)[6] for energy purchased from independents. [8]

It should be realised however, that these power company's costs are quoted on the basis of a 5 to 6 per cent real rate of interest, and a 20-year project lifetime, and that the costs do not include grid reinforcement. It should be noted, that Danish infrastructure is characterised by a strong electrical grid, and widespread local expertise in installation and planning. The extensive 20-year experience with wind energy is indeed reflected in lower installation costs than elsewhere in Europe. [9]

The strengthened commitment of Danish power companies to wind energy can be seen in their eagerness to develop the first 750 MW of offshore wind power, where applications for planning permission were launched even before the actual Government order was issued.

1.2.4 - Public Service Obligation

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[5] Cf. Numerous press statements from the President of the ELSAM Utility Group, Egon Sogaard.

[6] All figures are 1998 based

The European Union directive on the liberalisation of electricity markets allow members countries to impose a “public service obligation”(PSO) on electricity suppliers, which are allowed to shift the cost burden onto customers. The obligation may, for example, be related to ensuring universal service to all consumers in a region at the same tariff, meeting obligations in relation to environmental policy, or funding research.

In regard to renewables, the Danish legislation ensures that all electricity consumers effectively have to share the excess cost, if any, of using renewables in the electricity system, in order to avoid distortion of competition between suppliers. In practice, this means that electricity generated using renewables, or all forms of combined heat and power production (CHP) has a priority access to the grid[7]

1.2.5 - Municipal Planning

The policy of installing 1,500 MW onshore in Denmark has been considered a challenge for municipal and regional planning, given the country’s high population density[8]. For the past few years’ Danish municipalities have been required by a planning directive from the national Government to make plans for wind turbine siting. [10]

Although no specific quotas were set by the national Government, most regions (countries) have required municipalities with good wind resources to provide suitable sites for turbines. After the recent round of planning with extensive hearing procedures for local residents, sites for more than 2,600 MW have been made available. [11]

The Danish system has inspired a similar system, which is being implemented in Northern Germany. [12]

1.2.6 - Advanced Wind Resource Mapping

To assist municipalities carrying out planning for wind turbines, a national wind map based on rough manually prepared estimates was made available in 1991. [13]

A new and much more advanced method is being employed in 1997-98: Using the European Wind Atlas Method (Wasp) developed by Riso National Laboratory, software from the leading commercial wind software vendor Energy & Environment Data, and detailed digital maps, a very detailed, automated analysis of the entire country (divided into cells of 100 by 100 metres, with automatic assessments of terrain roughness out to 20 km distance) is being prepared.

The system already includes an exact mapping of all 4,800 wind turbines in the country, and the results will be calibrated by production data from more than 1,500 wind turbines reporting to the monthly statistics system run by the software vendor for the Danish Wind Turbine Owners’ Association.

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[7] It is up to utilities to implement a tariff structure which implements this. In the eastern part of the country, the transmission company ELTRA has implemented this using a tariff which reflects the energy mix during each period. In winter, when there is a lot of CHP-generated electricity and much wind, tariffs tend to be slightly higher than in summer. Large customers who have their right to purchase electricity from any generator in Europe effectively have to buy a mixture of locally made prioritised electricity and imported electricity (plus transmission fees). [10]

[8] It is in fact a testament to wind power’s general acceptability that it has developed so powerfully in density populated countries like Denmark, Germany and the Netherlands (the second most densly populated country in the world , after Bangladesh).

1.2.7 - Market Development Schemes

In the beginning of the 1980s the Danish Government instituted a number of successive market developing schemes, originally funding 30 per cent of investments in new wind turbines, but gradually lowering this support until it was abandoned in 1989 (it was 10 per cent by then). [14]

1.2.8 - Pricing of Wind Energy from Independent Power Producers

Power companies are by law required to pay for electricity from privately owned wind turbines at the rate of 85 per cent of local the local, average retail price for a household with an (high) annual consumption of 20,000 kWh (effectively allowing a gross 17.6% mark-up on sales of electricity from this source). [15] (The reason for the 20,000 KWh rules is that electricity prices in most areas include rental fees for meters, but the tariff structure varies with the local distribution company).

The electricity price paid by power companies for wind energy from privately owned wind turbines vary between 0.25 and 0.35 DKK/kWh (0.036 to 0.05 USD/kWh), reflecting the varying prices of electricity from different local distribution companies.

The price is not substantially different from what would have been obtained under the time tariff system applied to other independent power producers. Under that system the generators is paid different rates, depending on whether deliveries are made during peak, medium load or low load hours. Since wind energy production in Northern Europe tends to be highly correlated with demand (more wind at day than at night, much more wind in winter than summer), wind is actually some 40 per cent more valuable in the grid, than if production were purely random. [16]

Originally the pricing arrangement was negotiated between the Danish Wind Turbine Owner's Association and the Association of Danish Power Companies. In 1992 the power companies terminated the agreement, and subsequent negotiations with the turbine owners failed to reach a compromise. After this, the Government and Parliament intervened and made a general law on renewable energy, including a purchasing obligation with the tariff mentioned above[9].

1.2.9 - Partial Refund of CO_2 and Energy Tax

Households in Denmark pay vary high electricity prices, even though Denmark has some of Europe's lowest generating cost for thermal plant. The reason is an extremely high indirect taxation of electricity, as shown in the graph below. [17]
This political reasoning behind the high taxation is to reduce pollution emissions and encourage energy savings. (The fiscal motive plays a role as well, of course: voters less resent "Green" taxes than other taxes).

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[9] The events are described in detail in an article by the Danish Wind Turbine Owners'Association, Flemming Tranas, posted at the internet address http://www.windpower.dk/articles

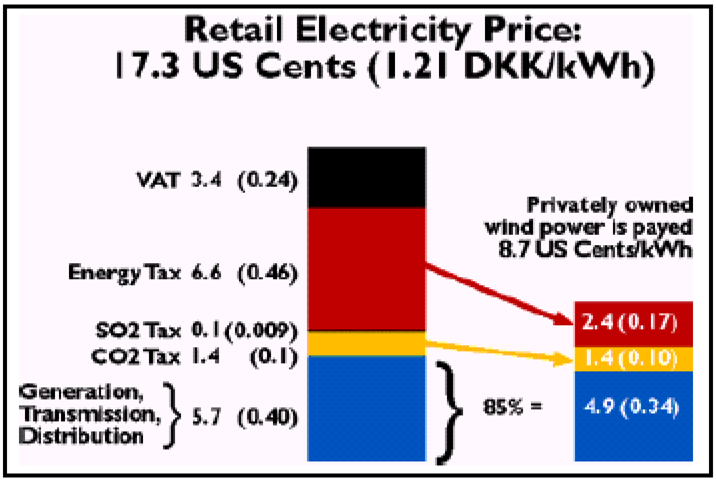

Figure 4 – Electrcity Price Structure at Denmark

The electricity tax is collected on all electricity sold to households, service business, etc. Only manufacturing industry is to a certain extent exempt from this taxation[10].

Electricity from renewable sources gets a refund of the 0.10DKK/kWh (0.014USD/KWh) CO_2 tax [18]. This refund is paid regardless of whether the generating equipment is owned by power companies, firms or households. This particular tax is called the CO_2 tax. (The labelling of different electricity taxes is historically somewhat random, depending on whether the originally declared political aim was environmental or fiscal).

1.2.10 - Special Rules for Private (Individual or Co-operative) Owners

Wind turbines owned by non-power companies, i.e. other firms, individually or co-operatives, in addition to get a refund of 0.17 DKK/kWh (0.024 DKK/kWh) of electricity tax. [19] The size of the refund has been set to ensure a reasonable profit for wind turbine owners, given existing tax regulations. On the other hand, there is currently some political concern that the profitability of wind energy is “too high” on the very best sites. [20] Some future adjustment, primarily concerning these sites cannot be excluded.

Total remuneration for private (non-power companies) wind turbine owners varies between some 0.5 and 0.62 DKK/kWh (0.071 to 0.089 USD/kWh).

The basic reason for treating power companies and other turbine owners differently is that power companies in Denmark are tax free, provided that they do not make a profit. (Generous accounting rules allow power companies advance depreciation, which effectively ensures, that they are tax free, “non profit” institutions. They are allowed to collect investment financing in their tariffs, before investments are actually made, thus obviating the need for shareholders or other external sources of finance).

1.2.11 - Grid Connection, Grid Reinforcement

According to the Executive Order on Grid Connection of Wind Turbines of 1996 [20], local power companies are obliged to provide grid connection facilities at any site

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[10] Under very complex rules which graduate the tax according to the use of energy. Heating is taxed like household use, while process use is taxed very highly. Companies which embark on particular energy savings programmes may be partially exempted from the tax.

which in municipal planning has been seen set aside for the development of at least 1.5 MW of wind power (rated generator power).

In other cases, power companies are obliged to allow grid access to the local 11-20 kV grids, but the turbine owner is responsible for paying for the extension of the grid to the site in question. The power company has to pay for the entire grid extension, however, if the cabling can be used for other purposes in the normal extension of its grid facilities.

The power company pays for the necessary reinforcement of the grid, unless the power company can prove that the reinforcement in the area is particularly uneconomic. The Danish Energy Agency (part of the Ministry of Energy and the Environment) is the authority to which prospective turbine owners may appeal power company decisions of these matters.

Wind turbines owners have to pay for the transformer to connect to the 11 Kv grid. In addition, a fee for the rental of electricity meters applies. (Reactive power consumption is not charged, but turbine generally has to observe a certain phase angle [21]).

1.2.12 - Tax Treatment Of Wind Turbine Investments

Wind turbines are treated like machinery in industry, i.e. a declining balance 30% annual depreciation is allowed.

Wind turbine owners may alternatively (once and forever) opt for a simplified tax system, being taxed on 60% of gross revenues from electricity sales exceeding 3,000 DKK/year (450 USD/year) without any depreciation allowance or any deduction of other costs. This means that people who only own a few shares in a wind turbine co-operative are not taxed on their wind turbine income.

1.2.13 - Limitation on Private Ownership

The private (non-power companies) ownership of wind turbines in Denmark is limited by regulation in the executive order on national grid connection rules, meaning that members of wind co-operatives be resident in the municipality where the wind turbine is located, or in a neighbouring municipality. [22] Municipalities make exceptions for individual wind turbine projects, but exceptions are fairly rare.

The regulation also limits the number of shares residents may own in a wind turbine co-operative to an annual production of 30,000 kWh per (adult) person, corresponding to a total investment of some 120,000 DKK (17,000 USD).

These restrictions were allegedly made to “prevent the misuse of Government support schemes for wind energy” (quote from the Minister for Energy and the Environment in Parliament), But the basic political aim are to probably to preserve local ownership of the exploitation of a natural resource, much like is practised in Danish agricultural legislation which requires that farm owners be resident on their farms.
Individual may own one wind turbine located on the same property on which they are resident (no size limit). The ownership of a complete wind turbine and co-operative shares are mutually exclusive.

The quantitative restrictions on independent power production were likely imposed as a result of visibly strong pressure from power companies[11].

1.2.14 - Turbine and Component Suppliers

All of Denmark's 4,800 wind turbines (end 1997) have been manufactured domestically. Denmark hosts five of the world's largest wind turbine suppliers: NEG-Micon, Vestas Wind System, Bonus Energy, Nordex and Win World. The first three companies account for more than 50 per cent of world production of wind turbines measured in MW. Most of three companies have a background in agricultural machinery manufacturing, with the exception of Wind World, which was founded on gearbox and marine technology manufacturing.

Competition in the Danish market is definitively the toughest in the world, making the market rather uninteresting to foreign turbine suppliers. Another problem facing some foreign suppliers may be the very stringent safety regulations which e.g. require two independent failsafe systems on turbines, one of which must be aerodynamic, or providing equivalent safety.

The Danish component industry includes I.M Glasfiber, which is the world's largest motor blade manufacturer, with an employment of more than 1,000 Danish manufacturers of electronic turbine controllers likewise have a very large market share world wide. Other component manufacturers include suppliers of braking systems, hydraulics, etc.

1.2.15 - Employment

Denmark is home to 60 per cent of world's wind turbine manufacturing capacity. Presently 2/3 of production is exported. The Danish wind turbine manufacturers presently employ some 2,200 persons in Denmark, while domestic component and service suppliers employ another 10,000 people (1991).[12]

In addition, another 4,000 – 5,000 jobs are created abroad through deliveries of components, and installation of Danish turbines. These figures do not include assembly work, etc done in foreign subsidiaries or license of Danish firms.

1.2.16 - The Home Market's Role in Industry Development

The Danish home market is what created the modern Danish wind industry originally, and gave it the testing ground to sort out both wind technology and manufacturing technology, including important issues of quality control.

When the Great California Wind Rush started in the early 1980s, the Danish companies were practically the only ones in the world with a substantial track record. The result was that investors tended to prefer Danish machines, which in the end made up around half of the capacity installed in California. The importance of the learning process within the major Danish manufacturing companies from manufacturing for the California market cannot be overestimated.

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[11] It is somewhat doubtful whether these regulations are in accordance with EU rules on the free movement of capital, since they effectively prevent cross-border ownership.

[12] These figures are a cautious estimate updating an extensive input-output analysis study conducted in 1995 by the Danish Wind Turbine Manufactures Association. [23]

1.2.17 - The Danish Concept

The track record of the early Danish machines in California has in general been better than those of the competitors, leading to yet another track record advantage. The result is, that the so called "Danish Concept" in its newer and more refined versions today dominates the international wind turbine market more than ever, despite occasional revolutionary technology predictions in the press.

The last company manufacturing vertical axis machines (Flowind) went bankrupt in 1998, and manufacturers who used to stick firmly to a two-blade concept (WEG, Nedwind and Lagerwey) have all launched new three bladed designs.

The "Danish Concept", consisting of a three bladed upwind designs with fixed speed operation and direct grid connection rules about 75 to 80% of the market. [24] This design dominance resembles the status of the 4-stoke petrol engine, which has actually been around since 1856.

Whether other designs (full variable speed operation, indirect grid connection) will penetrate the market is largely a matter of component costs, in particular the costs of power electronics. There is, of course, a bit of circularity in this argument: Cost will decline with large scale manufacturing, so nothing is given about future technology in this area. It seems likely, that the present basic design will dominate the market well into the next century.

1.2.18 - Can the Danish Industrial Success be replicated?

The Danish success in wind energy is not easy to replicate elsewhere, and certainly not with the same means. Technology development is different today, markets and competition are different, and in some sense the Danes were fortunate enough to be in the right place with the right concept.

Starting from scratch is much more difficult today, when the largest market segments have tougher competition, with a more mature and reliable technology. The same market segment requires large machines with larger capital requirement and higher development risks.[13] Furthermore, there currently are no fundamentally turbine technology in sight, i.e. demonstrably economically superior technologies, although there are many for further development and cost cutting within the major variants of present technology [25].

Manufacturers in several countries have chosen to link up with Danish manufacturers in a variety of joint ventures. This coupling has included significant technology transfer to local companies, and developed local manufacturing. Most of the licences have a machinery and equipment manufacturing background. The primary advantages of a technology link to an existing manufacturer is to acquire proven technology, and the possibility of being able to offer a more complete and continuously optimised model range.

1.2.19 - Origin and Mainstay of the Market: Private Citizens

Denmark is somewhat unique among wind turbine markets, since the market really grew out of a popular interest in alternative generating technologies, partly in

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[13] The technological innovation process and different design strategies in the wind turbine industry are thoroughly analysed in [24]. A summary of the major design options can be found on the web site of the Danish Wind Turbine Manufacturers Association, http//www.windpower.dk/tour/design

opposition to the use of nuclear power, partly as a result of the energy supply crisis in the late 1970s, when oil prices skyrocketed due to OPEC action and political and military unrest in the Middle East.

Private individuals, either as members of wind energy co-operatives, or as whole owners of a wind turbine (farmers) account for about 80 per cent of installed wind power capacity in Denmark. (Almost about 900 out of 1100 MW of installed wind power capacity at the end of 1997). 100,000 families in Denmark own shares in a local wind turbine, and almost 2,000 wind turbines are owned by individuals.

Wind co-operatives are organised as unlimited partnerships, but since the turbine and its installation is usually completely paid up, partnerships have no loans (joint) risk in this respect.

1.2.20 - The Benefits of Through Statistical Coverage

Wind turbines are highly organised in the Danish Wind Turbine Owner’s Association, which publishes a monthly magazine production figures and notes on technical failures for more than 1,500 turbines. This excellent statistical data base, plus user groups, and technical consultancy services for members has been a very important instrument to ensure a transparent market with tough competition between manufacturers.

Turbines are usually sold with 5 years guaranteed production (insured with insurance companies). This makes all manufacturers keen on not overstating expected production, as this would bounce back in the form of a higher risk premium for that particular brand from insurance companies.

1.2.21 - The Role of Publicly Financed R&D

In stark contrast to Germany, Sweden, the USA, Canada and the UK, publicly financed R&D projects played a relatively minor role in initiating the early development of the Danish wind turbine industry [26]. The early stimulus came in the form of investment grants, supporting market development to small scale privately owned turbines, (5 to 11 Kw) which typically covered their owner’s annual electricity consumption, by a factor of 2 to 4.

Later, the Danish Government and the European Union have financed a significant number of basic research projects, and given some support to development projects. It is estimated that a staff of about 60-80 people in Denmark (including both researchers and administrative staff) work on (partly) publicly financed R&D. Danish wind turbine manufacturers have a staff of about 100 people working on technology development. Total public support for this work is below 2 million USD/year.

1.2.22 - Type Approval Requirements

In the late 1970s Riso National Laboratory (whose original task was nuclear research) was charged with type approval of wind turbines, which could be installed with public investments grants. The type approval process was extremely useful for weeding out low quality potentially dangerous products, and put a pressure on manufacturers to upgrade their design and manufacturing skills [27].

Riso’s very safety requirements, its demands for physical testing of rotor blades, and conservative norms for load calculations, indirectly saved the core Danish manufacturers from the fate of many foreign competitors whose turbines collapsed in these early days. The result was sturdy and stable, but rather heavy machines. (The potential for weight saving has in fact been so large, that Danish wind turbines have shed half their weight per Kw power installed during the past 5-10 years, despite a 50 per cent growth in their physical size).

1.2.23 - The Role of Riso National Laboratory and Others

Riso has been since the early eighties evolved to become probably the foremost international research institute on basic research in wind turbine technology and wind resource assessment.

A much smaller, complementary Institute of Fluid Dynamics developed at the Danish Technical University. Its parallel development of turbine design software has served As a commercial tool in many companies, and as an important tool to ensure mutual verification of its own and Riso's methods aero elastic analysis.

1.2.24 - The Role of Power Companies in R&D

Danish power companies played a pioneering role in the early technology development of wind energy. When the Danish Government instituted a publicly financed wind energy research programme in the mid 1970s, the power companies once again became involved in wind power research, concentrating on relatively large machines for their time (630 kw), and building two experimental wind turbines near the town of Nibe around 1979 (one pitch, one stall controlled). In the early 1980s another group of five 750 Kw machines were built, and during the 1990s another two experimental machines of 1 and 2 MW were built.

The primary aim of these ventures appeared to be training and development of in-house wind energy expertise in the power companies, rather than aiming at commercially relevant equipment.

1.2.25 - Is The Danish Market System an Economic Success?

The Danish market system for wind energy has been a popular success in regards to public's possibility of direct involvement in energy policy.

The power company share of the market (determined by Government orders to power companies) has worked reasonably well, except for the fact that power companies have been three years behind schedule in fulfilling their obligations (with no consequences for them)[14].

The refund of 0.10 DKK/kWh (0.014 USD/kWh) for power companies has apparently been based on mostly on political considerations of the name "CO_2 levy" which was a convenient amount of refund. Since the SO_2 taxes have been implemented without any talk of a similar refund to wind. Today the 0.10DKK/kWh roughly compensates for the difference in average generating costs between wind and fossil fuel plant.

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[14] The first two orders to power companies were not legally executive orders, but the power companies "volunteered" to put up two times 100 MW and entered into an agreement with the Ministry of Energy without a penalty clause, thus avoiding a legally enforceable executive order. The power companies say that difficulties in obtaining planning permission was the reason for their late compliance. The present 200 MW order and the 750 MW offshore order are in fact executive orders, but are referred to as agreements in power company publications. The reason for using executive others (other than enforcement aspect) is the EU directive on the free electricity market, where it is important that the utilities have the legal right to consider excess costs of renewables as a "Public Service Obligations", whose cost may be included in electricity tariffs.

1.2.26 - Rationing Gives Questionable Market Efficiency

The Danish wind energy support system has lately come under political attack for being too generous to private wind turbine owners, and conversely unnecessary expensive in terms of energy tax refunds.

The timing of the attack is directly related to the discovery of the regulatory loophole described above, which created a record boom in turbine investments in Denmark. (The boom was reinforced by the fact that the authorities by accident warned about a change in regulations beforehand, thus creating a virtual “buying panic before closing time”).

This has been a clear demonstration of the fact that the “segregation policy” which had effectively excluded anyone but farmers from owning their own wind turbine, has the effect of keeping less risk averse (and more bankable) investors out of the market, and of keeping yield requirements (on the windiest sites) higher than necessary.

Like wise, the apparently acceptable price differential between negotiable shares in wind co-operatives and non-negotiable shares gives an indication of the liquidity premium paid for the “localness” of wind turbine ownership.

1.3 – The Wind Market in Germany

1.3.1 – Wind Resources

Germany generally has modest average wind speeds around 4m/s at 10m heights, but a few areas with good wind speeds in the coastal regions of Northern Germany in Schlewig-Holstein, and part of Niedersachsen. Inland, however, it is possible to find good locations for wind turbines in areas with hilly terrain, where one can rely on speed-up effects. An important offshore resource may be found along the short North Coast, and along the Baltic coast. [3]

1.3.2 – The Role of Government: Market Development Schemes

Both the federal Government and the individual states (Länder) have operated support schemes for the investment in wind turbines. The most important stimulus on the federal level came from the 250 MW programme. This was a national support programme introduced in 1990, originally with a 100 MW target. In March 1991, after the first year of existence of the programme, the original target was exceeded, and therefore the programme was extended to 250 MW. [28]

The highly successful feature of this Government wind energy programme was an additional 0.06 DEM/kWh (0.034 USD/kWh) on top of the payments from power companies, according to the Electricity Feed Law (Stromeinspeinsungsgesetz). This helped to kick-start the market until it expired at the end of 1995.

Some additional 60 wind energy projects had been supported by a follow-up investment grant programme from the Federal Ministry of Economic Affairs between 1994 and 1997. Apart from the Federal support programmes for wind energy, several German Länder (states) introduced, during the 1990s, their own support schemes. Most of these support schemes have been phased out in later years, and the remaining systems are almost symbolic.

1.3.3 – Good Statistical Reporting Increases Transparency

An interesting and useful feature of the German market development support schemes has been the requirement under the 100/250 MW Programme to report production, technical reliability, etc. closely for the supported turbines. This has lead to an interesting set of annual statistics published by ISET.[15] The reports are concerned with machine reliability, causes and effects of failures, plus verification of wind climates assessments and power curves. Another statistical database reporting on the production of wind turbines, comprising more than half of all operating turbines is managed by the independent engineer's office IWET. In many ways this database resembles the system operated by the Danish Wind Turbine Owner's Association, and it has been a good way of increasing market transparency. [29]

Like Denmark, Germany has a very strong free trade tradition, and its carefully planned support system did not (and does not) discriminate in favour of domestic suppliers. Its market development programme, however, has been well coordinates with its R&D support programme, and its subsequent Eldorado export promotion programme to support developing countries, and has created a viable industry, as explained later. Under the Eldorado programme some 22 million USD had been spent for wind energy between 1991 and 1997. [29]

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[15] Institut Für Energiversorgungstcchnik, Verein and der Universität Gesamthochschule Kassa c.V.

1.3.4 – Energy Policy for Wind

Contrary to the Danish long-term policy approach, there has been no coherent official German policy for renewable energies. The main reasoning for a pro-active approach on renewable is Germany's strong commitment to cut carbon dioxide emissions by 25 per cent between 1990 and 2005. Speaking on the importance of the Electricity Feed Law, the German Ministry of Economic Affairs writes: "An official bonus may be granted to environmentally friendly energy sources. This is possible…. By introducing a legal obligation whereby electricity generated from renewable energy must be purchased by the utilities at a fixed price, which is higher than the costs incurred by the purchasing utilities".[16]

1.3.5 – Pricing of Wind Energy: The Electricity Feed Law

The Electricity Feed Law from1991 requires Germany to pay 90 per cent of the average retail electricity price for final consumers (household, commercial, industrial) (ex.tax) for wind (or solar) generated electricity supplied to the grid[17]. [30]

Since electricity prices in Germany are very high[18], electricity tariffs for wind energy are quite high. These tariffs are sufficient to ensure profitability of wind energy on a good site in the coastal regions, and increasingly even with the moderate speeds prevailing in the inland areas. However, most turbines in the inland areas need some additional financial support due to the low wind speeds.

1.3.6 – Grid Connection, Grid Reinforcement

Contrary to Danish regulations, turbine owners in Germany have to pay for any costs incurred by grid reinforcement or extension caused by wind power. These costs can be quite substantial, especially in the rural areas of Northern Germany with a comparably better wind regime than inland. Due to the lack of legislation for grid reinforcement and grid extension costs, as in Denmark, and due to low transparency of the German utilities in regard to transmission and distribution costs, many projected wind farms in the Northern Germany have problems getting started.

1.3.7 – Tax Treatment of Wind Turbine Investments

Wind turbines are treated like any other investment in Germany, including higher depreciation allowances in the initial years. General (non-wind specific) incentives for investments in Eastern Germany applied until the end of 1998.

1.3.8 – Favourable Financing Schemes

Agricultural financing institutes, which offer low interest loans for agricultural investments, may frequently be able to finance 90% of a farmers' wind turbine.

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[16] The German Ministry of Economic Affairs is known as the first and foremost bastion of free market in Europe. This quote is politically remarked in the sense that it justifies tinkering with the market mechanism. Germany, like Denmark, has in principle favoured a universal European Union wide energy/CO_2 tax.

[17] The remuneration rate is lower between 60 and 80 per cent, for other renewable technologies, including small hydro, landfill gas and various biomass sources and technologies.

[18] This is mainly due to monopolistic structure of the electricity industry for more than half a century, although also an historical preference for domestically mined coal for power generation. [29]

German investors offered several favourable loan facilities to attract capital for wind power and other renewable energy projects.

The Deutsche Ausgleichsbank (DtA) Is a Federal institution under public law with the majority of its share owned by the European Recovery Programme (originally the "Marshall") Fund (EPR). The DtA/EPR Fund has granted low-interest loans to small and medium-sized companies since 1990s for installations using renewable energy. The average lowering of the interest rate on these loans is between one and two percentage points. Furthermore, interest rates are fixed for the entire duration of the loan, which may be up to 20 years (but usually does not exceed 12 years). A maximum grace period of five years cab be agreed in order to protect liquidity of the investor, particularly during the early phase of the development. This instrument has proven especially effective to ease investments in wind power. The loan approvals, for all renewable energy, mounted to more than 2.2 billion USD between 1990 and mid-1997. Within five years (1990-1995), more than 1500 wind energy projects had been granted ERP loans totalling more than 500 million USD in conjunction with complimentary Data loans totalling some additional 300 Million USD. [29]

About 80 per cent of all existing wind turbines have been supported by DtA's environmental protection loan.

1.3.9 – German Power Companies' Attitude to Wind Energy

German power companies resent the obligation to give what they consider in an excessive price for electricity from renewables. The large, super-regional electricity company Preussen Elektra, in particular, has been complaining about uneven burden sharing, and alleging that environmental policy is not part of the obligations for German power companies in their monopoly charters, which were granted by the Third Reich. However, the reformed German electricity law puts and end to the closed monopoly charters and clearly expresses in its preamble that environmental protection is one of the three pillars of German electricity suppliers.

The German Electricity Feed Law does provide a "hardship clause" which allows local distribution companies faced with large cost increases to shift the excess cost of their power-purchasing obligation to the regional power company.

However, the local or regional companies have never used this option. An amendment of the law, coming into force probably in spring 1998, puts this hardship clause into more concrete terms, at the same time indirectly introducing a cap to the further expansion of renewable energy in the electricity sector. The obligation for utilities to pay the tariff set out in the Electricity Feed Law has been limited to only 5% of their total electricity supply mix. This effective cap on wind energy is designed to protect regional utilities in windy areas against excessive financial burden. Once the volume of excess renewables exceeds 5% of such utility's sales, it can pass the exceeding amounts to the supra-regional utility, e.g. Preussen Elektra.[19] Once the supra-regional utility has reached the 5% limit, additional renewable energy power would no longer receive payments. This super-regional power company has no way of shifting its obligation to other regional competitors.

In sum, utility companies in Germany are obliged by law to pay for renewable energy up to a maximum of 5% of total German energy consumption.

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[19] Preussen Elektra controls the utility supply company Schleswag in Schleswig Holstein in Northern Germany, where 10 per cent of electricity consumption is covered by wind.

Since 1994 German power companies under the leadership of Preussen Elektra have mounted a joint attack on their power-purchasing obligation through both the German Constitutional Court, and through a complaint to the European Commission about unfair competition. Both initiatives failed, and a subsequent political initiative in Boon demonstrated an unusually strong bipartisan support for the present environmentally friendly policy in the German Bundestag (Parliament).

More than 90 per cent of all wind turbines erected in Germany are owned and operated by private citizens and investors, farmers, or co-operatives. In contrast to their Danish counterparts, German electricity companies have never seen any government obligation requiring them to build wind farms.

1.3.10 – The Energy Policy Role of Utilities

The political polarisation of power companies against renewables advocates is probably politically unsustainable in the longer term. Right now an armistice prevails, since the German Parliament has decided not to touch the present legislation for another two years. For strategic reasons it is likely that the present power company attitude (displayed in public) will continue for some time, and a complicating factor is definitely the liberalisation of electricity markets in Europe[20].

If a reform of the present system comes about, it seems likely that there will be an attempt to include some form of national sharing of excess costs of wind power, although the federal structure and the constitutional complications surrounding the regional chartered electricity monopolies makes this a difficult task. The idea of a nation wide sharing system for utilities has been demanded in 1997 by the second chamber of the German Parliament representing the Länder, the Bundesrat. It has also been advocated by the German Wind Energy Association.

1.3.11 – Market Size

At the end of 1997 close to 2,100 MW of wind power was online on Germany, making Germany the largest wind power country in the world. During 1997 a record high 550 MW (849 turbines) were added to the installed base. This is a market growth of another 18 per cent, once again making Germany the largest market for wind power in the world for the fifth successive year. Germany has increased its installed wind power capacity by ten times in just five years.
Compared with an installed base of 56 MW in 1990, before the Electricity Feed Law came into force, this is a 37-fold increase.

In the early phase of development most of the wind power was place in the windy states (Länder) of Schleswig Holstein and Niedersachsen in Northern Germany, but increasingly development has been moving South into in and areas. More than half of the newly installed capacity during 1997 was erected in the non-coastal regions. This is partly due to a delay and administrative barriers (from a planning perspective) along the German coastline, but also due to a keen environmental interest in the population throughout Germany. At the end of 1997, the Northern region of Schleswig-Holstein has just passed half of its won official target of 1200 MW.

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[20] It is noteworthy, however, that Preussen Elektra has recently entered into an agreement with the largest German wind turbine manufacturer, Enercon, regarding the marketing of its products abroad.

1.3.12 – Origins and Mainstay of the Market: Private Citizens

Wind energy in Germany has been developed by private people (non-power companies) to an even larger extent than Denmark. Both wind co-operatives and individual farmers play an important role in this respect. More than 90 per cent of all turbines are owned and operated by private citizens. Power companies have only invested in a few large experimental turbines, including the 3 MW Aeolus machine in Wilhelmshafen in the North.

Like in many other countries, the first 10 years from about 1980 was a long and tough haul by private idealists, who occasionally hardly had assurance that they could receive payments for the electricity delivered to the grid. Even so, some 250 MW were installed by 1989, before turbine installation took off after the Federal started its market development programme.

1.3.13 – The Role of Publicly Financed R&D

Germany has a strong tradition for support of large-scale projects in wind energy development, mostly managed by the private sector, and culminating in the 3 MW GROWIAN machine in the early 1980s (100m rotor diameter). That particular project failed when the machine, which had cost 300 million DEM (170 million USD) encountered a blade failure after only 280 hours of operation.

Large German companies like MBB and MAN were active on the scene during that period, but like other counterparts elsewhere, they left as public research money ran out.

Like elsewhere in the world, where the course was taken towards large machines only, it was difficult to get follow up funding for subsequent projects. In retrospect, the political accent on large, visible technology demonstration projects did not recognise the fundamental differences between wind turbine and aerospace technology, both in terms of the large unknown of turbine aerodynamics and structural dynamics.

Interestingly enough, Enercon, a small engineering firm that started in 1984 without funding from the large research programme, has succeeded to become the largest German manufacturer of wind turbines, using its own gearless direct drive concept.

When the interest in renewable energy rekindled in the late 1980s, several market support schemes wear in place by 1990, as mentioned before, R&D support to private industry became an important instrument to promote German wind turbine manufacturing. The unification of Germany added another of supplementary finance trough regional development incentives. Industry co-operation with several large number of companies, often as subsidiaries of traditional mechanical engineering firms, such as Tacke, a gearbox manufacturer, or Husumer Schisffswerft, HSW, a shipyard.

German incentives, in fact, have been so strong and successful that hey attracted the Danish manufacturer Nordex to move its turbines development to Germany (Nordex-Hackle Dürr is now majority owned by German interests, and has manufacturing facilities in both Denmark and Germany).

1.3.14 – Type Approval Requirements

Germanisher Lloyd is one of the official type approval institutes for wind turbines in Germany. (Its role has to some extent historically been similar to that of Riso in

Denmark in the early years, being the anchor point for much of the infant wind turbine industry). The type approval requirements have also worked well to protect investors.

1.3.15 – Turbine and Component Suppliers

In 1997 Germany accounted for about 18 per cent of world market production of wind turbines measured in MW. About half of the installed base of wind power in Germany has been supplied by domestic companies, although distinguishing between domestic and foreign turbines is not straightforward, since all the major Danish manufacturers have assembly facilities or license manufacturing in Germany, and since Nordex-Balcke Dür is now 51% German owned.

Germany is actually has a net surplus on its “wind turbine balance of payments”, since the companies Flender (gearboxes), Siemens (generation), and AEG (electrical components) have very large market shares (close to 50 per cent) for their products in the wind turbine industry world-wide, including Denmark. Other components manufactures in Germany include ball bearing and roller bearings (FAG), yaw motors and gears, and yaw wheels.

The bankruptcy of Germany’s second largest company, Tacke Windtechnick, in 1997 (partly due to a series of technical failures) increased the foreign market share on the German market in 1997. Tacke has since been taken over by the American developer and turbine manufacturing firm Enron Wind Corp., a subsidiary of the energy conglomerate Enron[21].

The German wind turbine industry today consists of Enercon, Tacke, and a dozen smaller firms, which are repeatedly going trough a takeover and merger period. The two large firms account for about 85 per cent of German turbine manufacturing.

1.3.16 - Employment

The German Wind Energy Association estimates that employment in the German wind industry is around 12,000 persons, or roughly equal to Danish employment in the area. German wind technology manufacturing is more directed towards the employment intensive component area than in Denmark.

1.3.17 – German Technology Concepts

Most manufacturers in Germany have stuck to wind turbine designs resembling the classical “Danish Concept”. The largest German manufacturer, Enercon, however, has its own multi pole synchronous generator design with direct grid connection (using power electronics), which has managed to capture about 30 per cent of the German market, but which has failed to take major market shares abroad.

1.3.18 – Profile of a Success

After a misguided start in the early eighties, the German wind energy programme has largely been a success for the past 7 years. In the view of the German Wind Energy Association, the success is largely attributable to:

- The Electricity Feed Law of 1990;

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[21] Enron Wind Corp also took control of Zond, a major wind energy player in 1997. With the recent conglomerate bankruptcy, all wind activities were assumed by GE Power systems.

- Federal support programmes (100/250 MW programme) between the early and mid-1990s;
- Various support programmes by the German Länder until recently;
- Preferential loan and financing schemes (investment allowances and preferential depreciation schemes), and
- Privileged status for wind power in the building codes.

1.4 - The Wind Market in Spain

1.4.1 - Wind Resources

Spain has excellent wind resources, particularly in Andalucia facing the Southern Mediterranean, and in Galicia, Aragon and Navarra in the North, facing the Bay of Biscay. [3] These regions tend to be quite hilly or mountainous, thus adding an important component of speed up effects to local wind speeds.[22]

1.4.2 - Wind Generation Structure

Wind generation in Spain is located in (usually very large) wind parks in the windiest areas of the country, where the density of parks is quite high, particularly around Tarifa in Andalucia (at the Strait of Gibraltar). The development of wind energy in Spain started in 1991, but picked up speed around 1994. About 500 MW were installed at the end of 1997. Approximately 250 MW were added to capacity in 1997, and another 250 MW are expected for 1998 [25].

1.4.3 - Energy Policy for Wind

The National Government has not set a declared target for wind, but several provinces in strongly federalised Spain have set very ambitious targets, as mentioned in the next section. The Spanish system for support to renewables is in many ways similar to the German system, i.e. an open-ended system with guaranteed prices from utilities, and guaranteed power purchasing by the utilities in the national grid. Wind and solar in 1997 received 12 ESP/kWh (0.065 USD/kWh)[26].

Unlike the German system, the excess costs of the premium payment system is spread on all electricity users nationally. The system is very similar to the German system, but the whole Spanish national electric system has always had a compensation and equalisation system under which distribution companies are required to balance revenues and losses. Spain has a common national grid, which Germany does not. It is planned that the system will be changed to a system, which gives each technology a premium over the electricity pool price, rather than a fixed amount per kWh. (The pool price is currently around 9 ESP/kWh (0.05 USD/kWh)).

The premium should reflect the relative environmental benefits of each technology, much like the present Danish system. In addition, a competitive bidding system is envisioned for large wind parks above 50 MW. No details on the future policy are presently available.

1.4.4. The Role of Regional Governments

Regional governments are in many ways taking the lead in promoting wind energy in Spain. [30]

Regional governments are responsible for planning, and the municipalities issue actual planning permits.

In the North, Navarra wants to cover 100% of its electricity consumption from renewables in 20 years' time. By the year 2000 wind should cover 25% of local

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[22] Typical wind speeds of 5.5 to 6.5 m/s at 10 m height are therefore not a good guide to actual wind speeds at wind turbine sites, which may be substantially higher on ridges.

electricity consumption (roughly 220 MW), the total being tripled to more than 600 MW by 2010.

Galicia wants 2,800 MW to be installed by 2010, a figure which according to many observers may be too optimistic, given that the present grid capacity is around 600 MW. A strengthening of the grid is, however, being planned.

As a member of the European Union, Spain is of course obliged not to discriminate on the basis of nationality, and there is a free circulation of goods in the Union. Spanish provincial governments, however, attach considerable weight to local employment, and with their strong hand on planning permissions, have managed to entice many foreign companies to establish joint ventures with local industry. According to one leading observer: "Regional support in terms of cutting red tape in exchange for new jobs in their region, seems to be the solution in most parts of Spain".

1.4 5 - Wind Resource Mapping

Spain has a national wind map, but its level of detail and quality is apparently insufficient for actual planning work.

1.4.6 - The Role of Developers

Large, international wind turbine developers are increasingly dominating the picture in Spain. The major market actors are Seawest (USA), Tomen (Japan), Endesa-MADE (Spain), and Iberdrola (Spain). The Spanish market is generally dominated by professional developer firms, much like the UK.

1.4.7 - Turbine and Component Suppliers

Spain accounts for about 14 per cent of the world production of wind turbines (1997), and three Spanish firms are now on the list of top ten manufacturers worldwide, i.e. Gamesa, Endesa-Made and Desarrollos with world market shares around 6, 5, and 3 per cent respectively. The three firms accounted for around 85 per cent of wind turbine installations in Spain in 1997. [25]

Spain's largest manufacturer with a 36% share of the local market is Gamesa Eòlica founded in 1994, which uses technology from Vestas Wind Systems, and is a joint venture with 40% Vestas ownership, while the other two shareholders are a regional development corporation, and a company group manufacturing car and aircraft components. Endesa-Made and Desarrolos have market shares of 29 and 21 per cent. Endesa is a utility, which owns the turbine manufacturer Made. The design looks remarkably like a classical (1985) Danish design. Desarrolos was originally a joint venture between the Spanish manufacturer Abengoa and U.S. Windpower (U.S. Windpower later became Kenetech, which went bankrupt in 1996). These two companies and the fourth Spanish manufacturer, Ecotèchnia, have their own technology, which are basically variations on the Danish concept.

Large, international wind turbine developers are increasingly dominating the picture in Spain. The major market actors are Seawest (USA), Tomen (Japan), Endesa-MADE (Spain), and Iberdrola (Spain). Professional developer firms generally dominate the Spanish market, much like the UK.

Other companies have been or are being established in Spain, and some 80 companies are estimated to take part in supplying components or services to this industry. Danish NEG Micon, which has already been engaged in Spain through the joint venture Taim-Nordtank is currently establishing a factory in Galicia in Northern Spain, while Danish Bonus Energy has entered into a joint venture with a government-owned company, Bazàn which is known for its manufacture of ships for the Spanish navy, diesel engines, steam turbines, and weapons systems. In 1997, after only two years of operation, this company had captured 15% of the Spanish market.

Component manufacturing is growing rapidly in Spain. The world's largest supplier of rotor blades, LM Glasfiber is now operating three plants in Spain, and one of ABB's two European wind turbine generator factories is located in Spain.

1.4.8 - Employment

No estimate has yet been made of the employment impacts of wind energy is Spain. However, it is noteworthy that most outside wind manufacturers have established manufacturing facilities and in some cases entered into joint partnerships, as this inevitable maximizes job creation in the host country.

1.4.9 - The Home Market's Role in Industry Development

The Spanish home market presently takes all of the production from Spanish manufacturers. Given the strong domestic market growth of 90% per year over three years, and the fact that most firms were established recently this is hardly surprising. In the longer term, Spain sees itself as a natural stepping-stone to South American markets for wind power development.

1.4.10 - Assessment of the Spanish System

Spanish wind power development has been a dramatic success in terms of creating much local employment. In time, Spanish wind turbine companies may be able to benefit on other markets from the experience acquired during these boom years. Despite a financing system roughly similar to the German regulations, the Spanish system creates less of a problem for power companies, since costs are shared nationally.

1.4.11 – An example of a new model applied in Spain

Early in 2000, the largest wind turbine order ever made, for 1800 machines, was placed by Spanish developer EHN (Energía Hidroeletrica de Navarra). It was equal to 15% of the installed wind capacity in Europe at the time. In June 2001, an EHN project received the largest loan ever granted in the field of renewables. The group has now installed nearly 900 MW of wind power in Spain, and is planning to double that amount in Spain in the next two years, as well as transfer its experience to other countries.

From the beginning EHN has aimed to show that it is both technically and economically possible to shift towards a new, more sustainable energy model. From the very start, the company took a firm decision to commit itself to clean forms of energy generation. They began their operations 10 years ago in Navarre, a region in Spain unknown in the energy world at the time. Nowadays, Navarre has become a benchmark for the exploitation of renewable resource, showing how, if they are developed within a framework of social consensus and Institutional support, they can add value and create employment. Meanwhile, EHN has transferred its expertise to another region of Spain, Castilla-La Mancha, where it has been developing 1173 MW of wind power capacity in this region between 2000 and 2002.

To carry out plans in theses two regions EHN has so far invested 940 million euros (US$ 844 million), mainly since 1994 when it started developing its first wind farm in Navarre. The company expects to invest a further 574 million euros over the next two years, and thus to bring its project in the two regions to fruition. This level of investment has helped considerably to improve the industrial fabric of both communities, giving rise to a new high-tech industry sector that employs more than 3300 people in the two regions (3600 if the jobs with other wind power developers are included).

Navarre's development of renewables, led by EHN, has enabled the region to produce 50% of its electricity needs from clean energy sources, a figure expected to concentrate on 100% by 2010. The region's strategic choice to concentrate on renewables, in which both public and private interests have come together, has created a new industrial sector, closely linked to wind power development. This sector has generated some 2000 new jobs and over 500 million euros investments in just five years. 80% of this sum has been invested by the EHN group.

EHN has put particular efforts into public information and participation, in the form of seminars, meeting with a wide range of people in public roles, through educational programmes and other initiatives. As a result, wind power development has generally had wide-range public support. At the present 85% of the people in Navarreare in favour of the implementation of wind farms, and only 1% against.

Behind the plan there is a clear wish to drive forward technological development in order to improve the competitiveness of renewables. As a result, Navarre will soon be home to the Spanish Technology Centre for Renewables, and a Chair in Renewables promoted by EHN has been inaugurated in the Universidad Publica de Navarre. Strong R&D teams have been set up around this project.

The installed renewables capacity of the EHN group in Navarre is 630 MW (540 of this is wind power). The group also operates 25 small hydro stations with total installed capacity of 64 \MW. It is building a 25 MW biomass plant based on straw combustion and is also developing the largest photovoltaic power sun tracking technology.

The company's activities in Navarre have led to the emergence of projects by other promoters. If the capacity installed by these promoters is added to the existing figures, the region now has 870 MW from renewables, enabling to cover 50% of its internal electricity demand.

The Wind Power Implementation Plan approved by the Government of Navarre will be completed in the near future, bringing capacity installed by the EHN GROUP TO 612 mw and the regional total 912 MW. This will mean that by 2004 Navarre, with a population of 556,000, will have 1100 MW of renewable in service, equivalent to the capacity of a nuclear power plant.

Renewable energy infrastructure in Navarre

Technology	Capacity installed by the EHN group (MW)	Capacity installed by other developers group (MW)	Total Installed capacity (MW)
Wind *	540	149	689
Small Hydro	64	91	155
Biomass**	25	-	25

Photovoltaic ***	1	-	1
Total	**630**	**240**	**870**

Table2 – Energy Matrix of Navarre

* Including the 93.2 MW wind farms at Las Llanas de Codes (1st phase), currently under construction
** The 25 MW correspond to the new straw combustion plant that EHN is building at Sanguesa, which will enter service in the first half of 2002
*** The 1.2 MWp photovoltaic solar powers at Tudela is due to enter service in the first half of 2002

Evolution of self-sufficiency in electricity in Navarre from renewables

	1990	2000	2001*	2005*
Total electricity demand (GWh/year)	2441	3775	3543	4060
Electricity production from renewables (GWh/year)	332	1456	1810	3256
Coverage ratio (%)	13.6	43	51	80

Table 3 – Electricity production in Navarre

* Estimated figures on the basis of increases of electricity consumption in Navarre of around 4% per annum between 2001 and 2005

The importance of the Public Support

All wind power implementation programmes have been carried out on a basis of an open, transparent approach. The community has been kept informed about the projects and this has led to greater public awareness of the need to promote this type pf energy. Hundreds of visits have been made to wind farms, and the other range of social players and associations, such as environmentalists' groups, trade unions, professional and business associations, university lecturers/students and citizens' groups. This has created a favourable climate around the development of renewables in the areas concerned.

Opinion surveys are carried out regularly for the company by an independent company. The most recent (October 2001) found that 85%of the people of Navarre consider that the development of wind power in the region to have been beneficial, with only 1% against. For 75% of the population wind power is the best way to produce electricity, and its main advantage is that it is a clean energy source (93%). The survey also reveals that around 23,500 (54% of the population of Navarre) people have visited a wind farm.

Similar results have been obtained in the first opinion survey carried out in Albacete, Castilla La Mancha (October 2001), approximately two years after the wind power implementation plan for the province was started. Here, 79% of the people considered that plan to be beneficial, with 1% against. 69% think that wind power is the best way to produce electricity because it is a clean source of power (88%) and creates jobs and wealth (48%). Around 81% of the people of Albacete would be in favour of the installation of a wind farm in their area.

1.6 – Support mechanisms – Main Conclusions

Under the current liberalized market conditions, renewable energy technologies face significant barriers before they can be widely implemented, including:

- High capital cost
- Lack of network infrastructure
- Lack of confidence in new technologies
- Technical problems associated with the geographical distribution of available potential, and the stochastic nature of the primary energy (wind)
- Legislative barriers to obtaining construction and operating licences
- Electricity trading mechanisms that inequitably penalize unpredictability.

Support mechanisms are clearly needed to accelerate development of renewable energy in the world.

The most critical policy issue for achieving the EU white paper targets concerns the support mechanisms to be established for renewable energy. A wide range of support mechanisms is in place across Europe, such as:

- *Fixed feed-in tariffs* - these are not market-based, but are highly effective for promoting local industry (e.g. Germany)
- *Quota system (with or without penalties)* - competition-based mechanisms which ensure that the quotas are obtained with the cheapest technologies (e.g. Belgium)
- *Public tender approach* - e.g. the former Non-Fossil Fuel Obligation in the UK
- *Green certificates* - a market-based approach, where the wind farm generates both energy and 'green' certificates, which are handled separately and are traded. This requires, however, a large enough trading area (for example, across Europe) to be effective and stable. It also presupposes harmonization of rules at the European level (such as those of Denmark and the Netherlands).

The ongoing liberalization of the energy sector has introduced significant uncertainties with regard to subsidies, as whole schemes have been revised in order to comply with EU common market requirements. In some countries, the procedure of exchanging old support mechanisms for new ones has been delayed, putting developers in a difficult situation; uncertain about which set of rules has been applied.

In general, the liberalization procedure seems to result in subsidy schemes being harmonized towards the green certificate model, awarding wind power an extra bonus determined by a certificate market. In the Netherlands, such a scheme is already in operation. For other countries, the schemes are not yet fully in place, which introduces significant uncertainty on future prices.

In March 2001, the European Court of Justice made an important decision concerning the future of price support for the development of renewables, as it decided that the German Feed-in Law - the Stromeinspeisungsgesetz - was not state aid. The court also stated that the German laws were in compliance with internal market rules, as they were intended to help achieve environmental objectives, which are a priority for the European Community. This decision makes it possible for member states to implement similar schemes without challenging European state aid rules, as such rules are not considered to act as barriers for countries that set an obligation to purchase electricity from renewable sources.

Since the time of this decision, however, the future of the green certificate market is becoming increasingly uncertain, as the feed-in tariffs in Spain and Germany can now continue. Furthermore, a law on renewables that resembles the German Feed-in Law has boosted the very promising market in France.

Regarding national incentives, it should be noted that feed-in tariffs have been used onshore in Denmark, Germany and Spain - Europe's top three onshore markets. After it was announced that the feed-in tariff in Denmark would be replaced by a green certificate market, the development of new onshore projects virtually stopped. Most Danish activity is currently in repowering (replacing small, older turbines with larger new models).

Based on this example, is not necessarily the case that feed-in tariffs alone can secure the future development of wind energy (including offshore), but it can be concluded that countries within the EU need to create long-term market support mechanisms that are sufficient and secure enough to attract investors and developers. The EC Court of Justice decision regarding the feed-in tariff system in Germany indicates that such tariffs are not in conflict with internal market rules, thereby securing the future of this market support mechanism within the EU.

Chapter 2 – Electricity market in Brazil and the Potential Use of Wind Power Generation

2.1 – Brazilian Energy Balance

In this section will be presented the structure of Brazil's Energy Matrix and its Energy Balance, in order to assess ways of integrating the use of wind power generation to achieve part of the capacity's expansion needs of the country. Some general data will be given, showing the difficulties of implementing new technologies in a country with continental dimensions, and the growth in the electricity consumption per capita and the actual electricity market structure will be explored, reassuring the need for creating new generating options.

2.1.1 - General Data of Brazil

Brazil's Area (km²) - 8,511,965
Demographic Density (hab/km²) – 19.5
Urban Population 2000 (%) – 81.2
Foreign Exchange Rate (average 2000) – R$/US$ 1,8302

UNITY SPECIFIC 1999 - 2000 %

Estimated Population (inhabitants) – 174,820,936
Gross Domestic Product (GDP- 10^9 US$(00)) - 569,9
Per capita US (00) - 3496 3586 2,6
Internal Energy Offer (10^6 tep) - 253 258 2,0
Per Capita (tep) - 1,55
per GDP (tep/mil - US$) - 0,44
Final Energy Consumption (10^6 tep) - 231,1
Electricity Offer (TWh) - 390
Oil Production (+LGN) (10^3 bep/day) - 1132
Electricity Generation (TWh) - 332
Total Energy Import (10^3 bep/day) - 1194
Total Energy Export (10^3 bep/day) - 136

Total Consumption

Oil and Natural Gas (10^3 bep/dia) - 1693
Gas Oil (10^3 bep/dia) - 311
Ethanol (10^3 bep/dia) - 245
Fuel Oil (10^3 bep/dia) - 223
Aviation Fuel (10^3 bep/dia) - 61
Total Electricity (TWh) - 315
Industrial Electricity (TWh) - 138
Residential Electricity (TWh) - 81
Commercial Electricity (TWh) - 44
Natural Gas (10^6 m³/dia) - 21,2
Total Oil Resources + Natural Gas + LNG (10^9 bep) - 17,1

Average Prices - US$ (2000)

Oil (CIF/b) - 16,8
Gas (Oil/bep) - 133

Diesel/bep - 52,6
Fuel Oil/bep - 25,1
Alcohol/bep - 117
Natural Gas industry/bep - 15,2
Wood/bep - 14,2
Coal /bep - 13,4
Residential Electricity /bep - 194,8
Industrial Electricity/bep - 83,7

Production

Iron -GUSA and Steel (10^6 t) - 25,0
Iron - LIGAS (10^6 t) - 0,8
Aluminium (10^6 t) - 1,2
Cement (10^6 t) - 40,3
Paper and Pulp (10^6 t) - 14,1
Residences serviced with electricity (*) % 94,9
Residences serviced with LPG and natural gas (*) % 96,5
Note: bep: equivalent barrel of oil
(*) Includes the rural area of North Region of Brazil

2.1.2 - Energy Balance – Main Issues (base year 2000)

The total primary energy production in 2000 was around 213.149 x 10^3 tep, i.e., 5,13% higher than the previous year. This value takes into account the sum of all primary renewable energy – 134.240 x 10^3 tep (63% of total, 0,25% growth related to 1999), plus all primary non-renewable energy – 78.908 x 10^3 tep (37% remaining, 14,64% growth related to 1999).

Among the renewable energy sources, hydropower was the one that contributed with the highest share, having about 41,9%, followed by wood with 10,1%, sugar cane with 9,2% and other sources with 1,9%. From those sources, the only one that had a reduction in production related to 1999 was the sugar cane with 18,50%.

Regarding the non-renewable sources, oil has been the main fuel, having an increase of related to the previous year. The other fuels had the following increase related to the previous year: metallurgic coal with 66,67%, steam coal, with and natural gas, with 11,64%. The overall final energy consumption in 2000 was of 235.264 x 10^3 tep, and had an increase of 1,8% related to 1999.
Among the sectors that had major contributions to such an increase, the main one was industrial sector with 89.724 x 10^3 tep (38,1% of overall consumption or 3,9% increase related to the previous year). The residential sector maintained its consumption equal to 1999, having participated with 37.728 x 10^3 tep or 16,0% of total. The commercial sector, with 14.605 x 10^3 tep (6,2% of total), had an increase of 8,8% related to the previous year. Nevertheless, the transport sector had a reduction of 9,6% compared to 1999, participant with 46.430 x 10^3 tep or 19,7% of total consumption.

In terms of energy source, electricity had the largest share in the energy consumption, accounting for 40.9%. This happened mainly due to the way electricity is accounted in the energy balance, followed by oil by-products which had a participation of (Diesel 12,3%, gas oil 5,9%, fuel oil 4,3% and others 12,9%) and renewable resources, with wood having 5,8% and sugar bagasse 5,7%. Among the segments that have consumed more energy in 2000, the main relevant points are: At the industrial sector, natural gas with 4.237 x 10^3 tep, was the fuel that had the largest increase regarding the previous year, with 40,6% increase. Electricity, with 42.288 x 10^3 tep, corresponding to 47,1% of total, had an increase of 5,3% related to 1999. Nevertheless, sugar bagasse 7.951 x 10^3 tep (8,9%) and fuel oil with 7.476 x 10^3 tep (8,3%), had a reduction of 18,5% and 1,9%, respectively.

At residential sector, the natural gas represented an exception with an increase of 300% regarding the previous year. This increase was mainly due to the replacement at water heating and coccion, increasing from 68 x 10^3 tep to 287 x10^3 tep. All the other fuels kept the same consumption rates regarding the previous year. Electricity, with 24.213 x 10^3 tep, increased from 2,7% compared to 1999. Maintaining the standards, wood (with 6.553 x 10^3 tep) and LPG (with 6.206 x 10^3 tep) have increased 2,5% and 0,4%, respectively.

The commercial sector had its consumption mainly based at electricity, with 13.757 x 10^3 tep (94,2% from total), increasing 8,8% compared to 1999. Natural gas and LPG had an increase of 37,5% and 16,2%, respectively. Wood, with 81 x 10^3 tep, diesel, with 58 x 10^3 tep and fuel oil, with 308 x 10^3 had a reduction of 2,6%, 17,1% e 6,1%, respectively.

2.2 - Energy Matrix

As detailed before, the Brazilian energy matrix is mainly based on renewable systems, with the hydropower generation corresponding to 82% of the actual installed capacity. This structure was created due to an electric system expansion plan that was developed around 30s, aiming at maximising the generating capacity while using the available resources that the country offered.

Generation Source	Installed Capacity		Estimative	
	2001 (MW)		2004 (MW)	
Hydro Power	61555	82%	69448	67%
Thermal	6944	9%	17024	17%
Nuclear	1966	3%	1966	2%
Alternative Sources	2345	3%	5645	5%
(Wind, Biomass, Small Hydro)				
SUBTOTAL	**72810**	**92%**	**94083**	**91%**
Imports from Itaipu	5500	7%	6200	6%
Other Imports	1150	1%	3438	3%
TOTAL	**79460**	**100%**	**103721**	**100%**

Table 4 – Brazilian Energy Matrix

From this hydro basis, it is noticed that the environmental pressure for the replacement of the generation source and the reduction of greenhouse gases, which has been motivating investments in wind power generation in some countries as shown in Chapter 1, is not a characteristic of the Brazilian market.

Nevertheless, due to the hydro dominance in the Brazilian Energy Matrix, the seasonal stabilization of the energy offer has been a big challenge to the operational planning of the interconnected electrical system, because the hydrological regimes have seasonal fluctuations of great amplitude.
The outage demand risks at the dry periods have been increasing over the last years, since investments at expanding generating capacity have been delayed during

the restructuring process of the electricity system. At the same time, during the last decade, the use of wind energy reached the gigawatts scale, showing its effective contribution to electricity networks around the world.

To fully understand the context that has led to the development of this hydro based electrical system, a brief historical review covering the main facts of the Brazilian Electricity industry at the last years will be presented, showing the potential for the use of wind energy in conjunction with hydro-energy.

2.3 - Electricity System in Brazil

Historical Background

The Electricity system in Brazil dates back from the beginning of the 20th century, with the first legal text regulating the use of electricity being approved by the National Congress in 1903.

In 1934 it was established by the President (Getulio Vargas) The Code of Waters, which ensured to the Public Power the possibility to control the electricity concessionaires. Some years later, in 1939, it was created the National Council for Water and Energy (CNAE) to solve the supply, regulation and tariff issues related to the electricity industry in the country.

Having a very strong hydro basis, the whole history of the energy industry in Brazil has always been connected to the water system development. In 1941, it was regulated the “historical cost” for the electricity tariff calculus, establishing the rate of return of investors in 10%. In 1945, it was created the first Federal electricity company, Companhia Hidroeletrica do Sao Francisco – CHESF.
In 1952, the National Economic Development Bank (BNDE) was created, being responsible for the energy and transport areas. Two years later, in 1954, it was constructed the first hydroelectric plant, Paulo Afonso I hydro plant, installed at Sao Francisco River, belonging to CHESF, and the first thermoelectric power plant, running on diesel started its operation.
In 1957 it was created the Eletrical Central of Furnas (Furnas S.A.), aiming tat exploring the hydro potential of Grande River (Rio Grande) to solve the energy crisis of the Southeast Region. This region concentrated the industrial and economical centre of the country, and by this decade, energy expansion capacity was considered a bottleneck for the increasing industrial development.

In 1960, as part of the development policy implemented by the President Juscelino Kubitscek, known as the Target Plan, the Ministry of Mining and Energy – MME – was created. The following year, it was established Eletrobras, implemented in 1962 to regulate the electricity sector in Brazil. Its main objectives includes the promotion of studies and projects for the construction and operation of generation plants, transmission lines and substations, to supply electricity to the country.

Currently, Eletrobras is a company that has private and government investors, acting as a “holding” of the generation and transmission concessionaires companies, owned by the federal government, acting in the whole country, through its subsidiaries, CHESF, CGTEE, ELETRONORTE, ELETRONUCLEAR, ELETROSUL and FURNAS. Additionally, it has 50% of the capital of Itaipu Binacional, which is the generation company developed by a joint cooperation agreement with the government of Paraguay, besides promoting research and development through its

Electric Research Centre – CEPEL and coordinate federal government programmes such as PROCEL, RELUZ and Light in the countryside (Luz no Campo).

The Eletrobras system acts as an agent from the Federal Government, coordinating and integrating the electricity sector. It is responsible for almost 60% of the country's generation capacity and 64% of the transmission lines. It is also responsible for the energy conservation programme – PROCEL.
Being the main financial credit provider of the electricity industry, it accumulates the a portfolio that accounts for 60% of the total assets of the sector.
Throughout the years, many Electricity Centrals were created in the regions of the country.

In 1973, as a consequence of the international agreement signed between Brazil and Paraguay, regulating the construction and operation of a hydro power plan in River Parana (which crosses the two countries), it was created Itaipu Binational - ITAIPU. Also, in this year, it was created Nuclebras, for the development of nuclear power programme, and the Electric Research Centre – CEPEL, to promote research and development of electricity systems.

In 1975, it was created the Committee for the Distribution of the Region South-Southeast – CODI and the Committee for the Operation of North/Northeast system – CCON.

In 1982, the Ministry of Mining and Energy – MME created the Group to Coordinate the Electricity System Planning – GCPS. In 1984, it was finished the first part of the transmission system North-Northeast, allowing the transfer of energy form the Amazon basin to the Northeast Region. The Hydroelectric Itaipu started its operation, being the biggest hydro power plant at the time, with 12,600,000 MW of installed capacity.

In 1990, it was approved Law n°8031 creating the National Destatization Programme – PND, which started the privatisation of the electricity assets. It was also created the Electricity National Transmission System – SINTREL, to promote competition at generation, distribution and commercialisation of energy.

In 1995, the companies controlled by Eletrobras were included in the Privatisation Programme – PND, allowing the privatisation of the generation and distribution companies. It was, then, realized the first electricity distribution company privatisation, starting a new phase at the electricity sector.

In 1997, the new regulatory body of the electricity sector was established, with the given name of ANEEL. In 1998, the Wholesale Electricity Market – MAE was regulated, consolidating the differences between the activities of generation, transmission, distribution and commercialisation of electricity. The rules for the set up of the National Operator System –ONS were established, to replace the Coordination Group for the Interconnected System – GCOI. In this years, the reforms of the electricity system, with the implementation of a new model for the sector started, which will be detailed in the next section.

In 2000, President Fernando Henrique launched the Priority Programme of Thermoelectricity, to implement many gas fired thermal power plants in the country, in order to meet the increasing electricity demand.

Currently, The Interconnect Electricity System, is composed of three main subsystems:

- South/Southase/CentralWest
- North/Northeast
- North Isolated

The North Region is a complete isolated system, having no connection with the other regions, whereas the North/Northeast and South/Southeast/CentralWest Regions are connected through transmission lines, with some constraints.

Many investments are undergoing for the expansion of the transmission lines, and the connection of the North Region to the rest of the country. The main aim is avoiding situations, like in the rational period, when there was a superavit of electricity production in the North, which couldn't be exported to other regions due to the lack of transmission lines.

Each sub market has its own characteristics, with different prices and generation profiles, being all of the controlled by Eletrobras and regulated by ANEEL.

Latest Years

From the 90s onwards, Brazil has experienced a new stage at its economical development process. Due to the impossibility to promote investments at strategically segments, such as telecommunications, electrical energy and transport, and unable to attend the increasing society demands, the Government decided not to act as an entrepreneurship at the infrastructure sector, but to attract investments through private agents. It started developing a new role, as regulator of public services. The establishment of the regulatory agencies was an important step at the restructuring of the Government role.

Regarding the electricity segment, the need for changes was already perceived at the 80s. The model adopted at the time has increasing fragilities, requiring a fast-changing process. Nevertheless, this restructuring process involved a lot of political issues, and the 1998 Constitution maintained the important role of the State on the infrastructure sector development. Some years later, the State and most of its companies (stated-owned distribution, transmission and generation companies) started realizing that they had limited investment resources to expand capacity to meet desires growth rates.

As a developing country, Brazil has electricity consumption rates higher than the global energy consumption rates. The income-elasticity of electricity consumption (relation between the electricity consumption growth and the GDP growth) has been declining in the last years, as a consequence of structural reforms at the local economy (although still being much higher than rate at developed countries). But a dynamic inertial component of the electricity market accounts for its relative growth. The use of energy efficient technologies has contributed for this decline, but the increasing penetration of electricity in all economy sectors, reaching all levels of society and extending the electrical grid, has compensated the overall balance.

In order to assist the government in the energy segment restructuring, the National Development Bank – BNDES and Eletrobras have, through legal determination, the role to complement the financial agents with small participation in generation and transmission projects in private investments. Considering the difficulties to implement hydropower projects in the short term to attend the increasing electricity demand and the deregulation of the electricity sector, a new space is created through the creation of new agents, the Independent Power Producer and the Self Producer. Both would develop a new role in achieving the expansion needs for electricity generation, which is estimated in 4.5 GW per annum, according the “official” expansion plan from Eletrobras (figures from the expansion plan before the rationing period, which will be explained).

The need for expansion of energy offer can be noticed from the increase of electricity consumption over the last twenty years.
The following graphs show the evolution of electricity consumption and the growth rates for energy region of Brazil on the period 1983-1999. It is interest to realize that from the 80s onwards the growth rates from most of the regions (with exception of the North Region) present similar tendencies, following the country’s average.

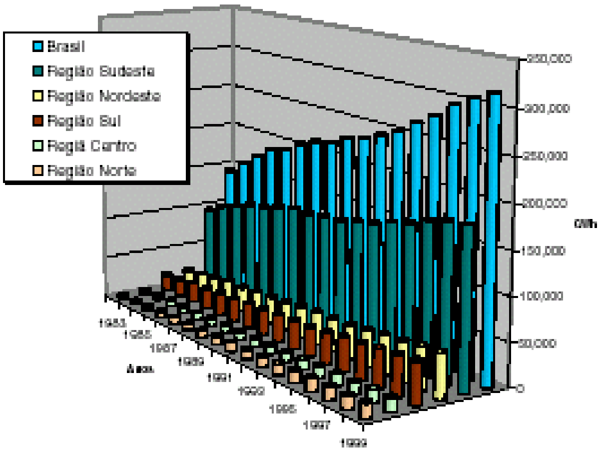


Figure 6 - Evolution of electricity consumption by region (Source: MME,2000)

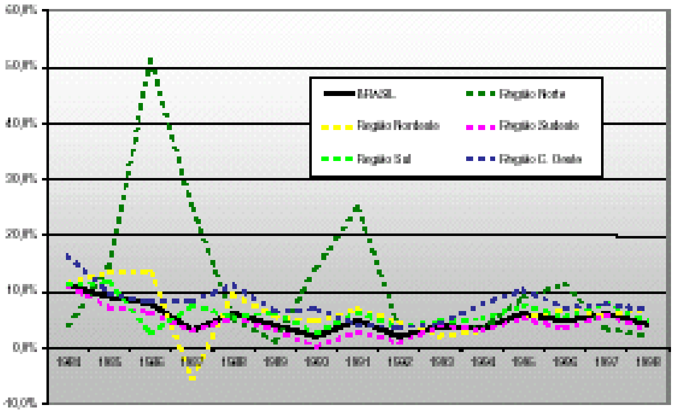


Figure 7 – Evolution of the electricity consumption growth rate in Brazil (Source: MME,2000)

Due to a period of restructuring, increasing demand and lack of investments, the electricity sector faced an outage period in 2001/2002, known worldwide as the “Brazilian Energy Crisis”. A Rationing policy, allied to the creation of a Crisis Management Chamber (which main attributions will be explained later) and energy conservation measures were established by the government. This shortage period promoted a whole revision on the expansion capacity targets and electricity consumption levels, as outlined below.

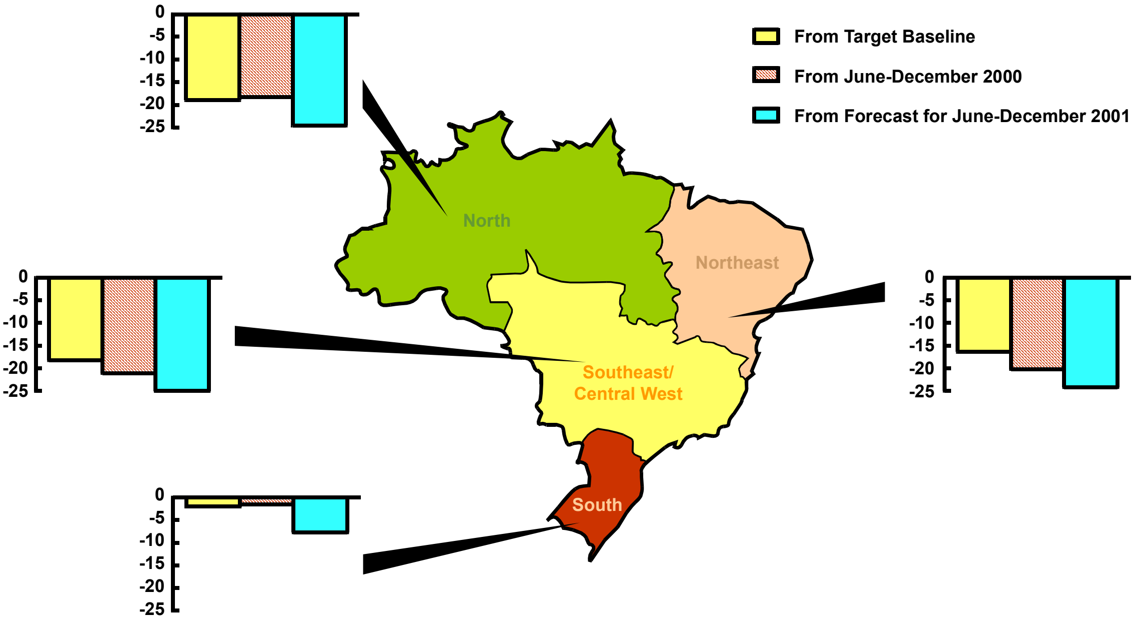


Figure 8 - Brazil Rationing Results - June – December 2001 (percent reduction on average megawatts)

In the rationing period due to the unavailability of electricity, the MWh was traded in the WholeSale Market with veru high prices, achieving the value of R$ 600/Mwh, corresponding to US$ 200/MWh. This has shown how dependent the hydro system was from natural events, and forced the Regulatory Body to estimate a deficit risk, reflecting the risk of not meeting demand. This risk was estiamted around R$ 450/MWh, US$ 150/mwh, giving room to and opening space to the development of new generation technologies, like renewables, since the development costs of those were lower than the deficit risk.

Of course, this was a punctual situation, and the generation costs cannot be compared to the deficit risk costs, but at least this opened space for a new discussions, emphasizing the risk of depending on one source of genertaion and the need to diversify generation capacity.

2.3.1 - Economy and the Electricity Market

At the 1970/1980s period, Brazil experienced a big economy expansion, with increase at the per capita income, and the per capita electricity consumption. It was noticed an increase at the participation of the “electrical content of the GDP”. Throughout this decade, the electricity consumption per product unit has increased from 0.162 to 0215 kWh/ US$ (GDP in average US$ of 1997) and the per capita consumption from 430 to 1025 kWh/habitant.

As a consequence, the participation of the electricity at the national energy balance jumped from 17% to 28%. The average income-elasticity at this decade was 1.37.

At the 80s, the economy had an unstable behaviour. The economy growth rate, at an average was positive, but inferior to the population growth, leading to a per capita income, in the 90s, lower than the 80s. This didn't occurred with the electricity consumption. Due to new projects developed under a National Development Plan (PND), which started being implemented at the 70s, and a constant tariff reduction, the electricity consumption remained increasing at high rates. The consumption per capita and the electrical content of the GDP, have reached 1531 kWh/habitant and 0.330 KWh/us$, respectively. The participation of electrical energy at the national energy balance ahs also increased, reaching 37%. The income-elasticity during the period was 3.75.

At the period 1990/1997 there is an important milestone: the Real Plan. This Plan had as a major consequence, not only thee control over the inflation process, but also a reduction at the inflation expectation, which started showing progressively lower indexes. Allied to the economy "opening", the stabilization plan has created the conditions necessary for the return of economy growth. This can be perceived from the triennial index 1995/1997, showing a recovery environment, when compared to the same indexes at the period 1990/1994. During this period, the average annual growth rate of electricity consumption was 3.3%, being above GDP, which was 2.3% p.a. Nevertheless, during 1994/1997, the consumption increased 5.5% annually and GDP 3.6%.

In 1998, the economic activity started to reflect the adjustments measures adopted by the government to face the difficulties from the "Asian Tigers" crises and the default from the Russian government (1997), which had an negative impact at the electricity market, resulting in a growth rate of 4.1% in this year.

The electrical content of the GDP in 1999, has reached approximately 0.383 kWh/US$, being among the larger in the world, and contributing to good environmental indicators, due to the hydro predominance, having low carbon dioxide emission, in tonnes per million, and per GDP thousands US$ (about 0.1 ton/103 US$). The electricity participation in the National Energetic Balance was around 38% in 1999.

On the other hand, the consumption-elasticity of electrical energy tends to be lower. After registering significant increases over the 80s decade, this index falls to around 1.74 at the period 1990/1999, reflecting structural changes at the national industry, due to its modernization and efficient use of electricity.

This brief analysis justifies the non-existence of an inertial component at the dynamic of the electricity market, which conducts to an increase even in periods of economic crisis. It also counts for the behaviour of the income-elasticity of the consumption, which tends to be closer to unit at the dynamic periods of economy, and to have higher values at the low economic increase periods.

To give additional support to this analysis, the table below shows the values for economic evolution indexes and energetic consumption in the country during the period 1970/19999. To be consistent, the electricity consumption represented refers to the supply of firm energy, summed up with consumption of interruptible energy, besides the consumption share being supplied by autoproduction.

The total consumption value for 1999 is composed by the following parts: firm energy: 290.8 TWh; interruptible energy 0.7 TWh; and autoproduction 20.9 TWh.

Indexes	1970	70/80 % p.a.	1980	80/90 % p.a.	1990	90/94 % p.a.	94	95/97 % p.a.	97	98/99 % p.a.	99
POPULATION											
million of habitants	93	2,5	119	1,9	143	1,9	154	1,5	160	1,5	165
GDP											
us$ billion of 1997	248	8,6	567	1,6	663	2,3	726	3,6	807	0,6	816
US$/hab	2662	6	4761	-0,3	4638	0,4	4716	2	5044	-0,9	4950
Energy Consumption											
millions tep	69	6,4	128	2,8	168	3,1	191	4,5	222	4,2	241
income-elasticity	-	0,74	-	1,78	-	1,35	-	1,27	-	7	-
tep/103 US$ (1997)	0,279	-2,1	0,226	1,2	0,255	0,8	0,263	0,9	0,275	3,6	0,295
tep/hab	0,74	3,8	1,08	0,9	1,18	1,2	1,24	3	1,39	2,6	1,46
Electricity Consumption											
TWh	40	11,8	122	6	219	3,3	249	5,5	292	3,4	312
income-elasticity	-	1,37	-	3,75	-	1,43	-	1,53	-	6,5	-
kWh/US$ (97)	0,162	2,9	0,215	4,4	0,33	1	0,343	1,8	0,362	2,9	0,383
KwH/HAB	430	9,1	1,025	4,1	1,531	1,4	1,671	4,1	1,825	1,8	1,893

Table 5 – Brazilian Index

2.3.2 - Restructuring the Market

In the 1990s, there was a clear need to restructure the electricity market and create conditions to the uptake of investments, improving the quality of service to general public. In this context, the Electricity National Agency (ANEEL) was created, being a strategic link to the transformation process responsible to boost the electricity sector development. Inspired at existing models of already running agencies throughout the world, such as the USA, Chile, and many countries from Europe, ANEEL has been acting the regulator agency role, aiming at balancing the interests of the sector agents and the consumers, with an overall benefit to the Brazilian society.

2.3.3 - The Pathway to Liberalization

The first legal basis for the restructuring of the Brazilian electricity system was created in 1993, with the approval of a constitutional amendment that allowed the participation of foreign investments in the segment. But it was only in 1995 that the modernization actually took place, with the regulamentation of Article 175 of 1998 Constitution, which attributed to the government the responsibility to supply public service, directly or through concession permit.

The situation started changing with the establishment of a series of regulatory measures that contributed to the development of the sector. In 1993, was approved Law 8631, which has permitted the financial recovery of companies of this sector, mainly the state-owned distribution companies, that would be privatised later on. In 1995, after the approval of Law 8976, about the concession of public services; and the Law 9074, about the concession of services of electricity, the minimal legal conditions for the restructuring of the sector were established. This effort was consolidated at the following year, with the creation of ANEEL through the Law 9427. This was the initial step to the transformation process, which would gain new instruments in 1998, with the establishment of the Wholesale Market (MAE) and the National Operator of the Electricity System (ONS), through the Law 9648.

Those new agents are important and essential elements for the implementation and function of the new institutional model defined by the State. They are the tombstones of a new energy market, strong and dynamic, which have as their main characteristics the deverticalization of the companies, the free competition at generation and commercialisation and the guarantee of free access to the transmission and distribution networks.

The following outlines the main legal milestones that contributed to the creation of those new market conditions.

Law 8631, from 4th March 1993, establishes the level of tariffs and abolishes the guaranteed remuneration regime for the electricity sector.
Law 8987, from 13th February 1995, implements Article 175 of Federal Constitution, which establish the concession and permission of public services.
Law 9074, from 7th July 1995, establishes rules for the execution and deadline extension of concessions and permissions of electricity services.
Law 9427, from 26th December 1996, establishes ANEEL and disciplinant the concession regime of electricity services.
Law 9648, from 27th May 1998, establish the wholesale market (mae) and the National Operator of the Electricity System (ONS), among other measures.

2.3.4 - The Agents of the Electricity Market

Energy and Mining Ministry (MME)

At the new institutional model, the Energy and Mining Industry (MME) is responsible for the definition of public policies for the sector. Being part of the Executive Power, the Ministry elaborates governmental programmes based on the directives given by the Energetic Policy National Council, and defines the aims and instruments for the provision of service to the consumers.

It also has, among its competencies, the determinative planning of the transmission system and the indicative planning of the expansion of generation, which are executed by the Expansion of Electricity Systems Planning Committee (CCPE).

National Electricity Agency (ANEEL)

The National Electricity Agency (ANEEL) is a special autarchy, linked to the Energy and Mining Ministry. Being a State Entity, autonomous, it regulates and controls the activities of the sector. On behalf of the Union, the Agency acts as a concession entity as well. As an important part of its mission, ANEEL must ensure the ordered and equalized development of the electricity sector, assuring the quality of service supplied to society and aiming at, as far as it may be possible, providing equilibrium between the interests of the economic agents and the consumers. It is the regulatory body's duty to implement the directives and the energetic policy of the executive power. ANEEL manage two programmes, inserted at Plano Plurianual (PPA) 2000-2003, from the Federal Government: the Quality Programme of the Electricity Service, which main aim is to guarantee the quality of the services supplied by the agents; and the Supply Programme of Electricity, which aim at increasing the supply offer.

National Operator of the Electricity System (ONS)

The operaation of the interconnected electrical system and the administration of the basic network of transmission are the main attributions of the National Operator of the Electricity System (ONS). Ons is a entity of private rights, composed by the generation, transmission and commercialisation, apart from the importers and exporters of energy and free consumers. The Ministry of Energy and Mining also takes part at ONS, and it has veto rights over questions that might generate conflicts with the directives and governmental polices for the sector. ONS coordinates and controls the generation and transmission activities and makes a closer observation of the energetic situation of the country.

Wholesale Electricity Market (MAE)

The implementation of the wholesale electricity market (mae) is one of the more important innovations of the restructuring of the electricity sector. Its implementation is essential for the effective establishment of competition between the economic agents. Institutionalised in 1998 and integrated by concession companies in generation, distribution and commercialisation of electricity, MAE is not yet operating at full load. In 2000, through Resolution 290, ANEEL established the permanent rules for the operation of MAE, besides defining the directives for its gradual implementation.

Independent Power Producer (IPP)

After the restructuring, other companies, beyond the concessionaires, started to produce and trade electricity. Those are the independent power producers, companies or consortiums authorized by ANEEL to produce energy and sell it, in all or only parts of the markets, by its own risk and account, having the guarantee to free access to the transmission system and having autonomy to sign bilateral contracts. In the new scenario, the maintenance of the independent power producer is fundamental for the sustainable development of the electricity sector.

Trading Agents of electricity

The new energy market counts with the participation of trading agents. They are companies which, even not being owners of generation plants or electrical systems, are authorized to act in the trading of energy, contributing to make the market more dynamic, increasing the competition, and, as consequence, promoting an equilibrium at prices. Two dozens of companies with this profile have already been approved by ANEEL. The importers and exporters of energy and the independent power producers can also act as trading agents.

2.3.5 - Recent Initiatives

As part of the liberalization process of the electricity market and to solve the outages experienced in 2001, due to lack of investment and proper planning of the sector, the Federal Government has created a special Chamber to analyse and create the new “modus operandi” of this industry.

The Crisis Management Chamber (GCE) was established in May 2001. Among its main objectives are: administrate the programmes of adjustment of energy demand; coordinate the efforts to increase the electricity offer and propose and implement emergencies measures depending on the hydrological situation.

The legal instrument that created this Crisis Management Chamber determines that the requests and demands of the same should be attended in priority, at a deadline established by the Chamber.

It is the Chamber responsibility:

1 – regulates and manages the Emergencial Programme to Reduce the Electricity Consumption and the Strategic Programme of Electricity;
2 – observe and evaluate the macro and micro economical consequences of the circumstantial reduction of availability of electricity and measures implemented to face this situation;
3 – propose measures to minimize the negative impacts of the reduced availability of electricity over the levels of employment, income and economic growth and identify situations of public calamity;
4 – establish limits for the use and supply of electricity and compulsory measures for the reduction of consumption and to suspend or interrupt the supply of electricity;
5 – propose a change in tariffs and taxes over goods and equipments that produce or consume electricity and decide about the implementation of rationing and the individual or collective suspension of electricity supply;
6 – define the Organ or entity responsible for the implementation and execution of all this measures;
7 – work jointly with the Union and other federal unities aiming at implementing programmes to face the lack or reduction of availability of electricity;
8 – impose restrictions to the use of the hydro resources, which are not used to human consumption and are essential to the operation of a hydro power plant;
9 – propose the adjustment of the investments limits at the federal and state levels of the electricity sector;
10 –establish other measures to reduce consumption and increase the transmission and electricity offer and negotiate with specific consumers sectors for a greater economy at the electricity consumption;
11 – establish specific procedures for the implementation and operation of the Wholesale Market (MAE) in emergency situations; and
12 – establish directives for the social communication actions among the organs and entities of the electricity sector, aiming at the proper promotion of the Government and the Chamber actions.

Besides the Crisis Chamber, another ten organs were created to analyse and implement actions related to the reduction of electricity availability, being:

1 – Commission to Analyse the Hydrothermal Electricity System
The Commission aims at evaluating the electricity production policy, as well as identifying the structural causes for the non-equilibrium of demand and offer of energy.
2 – Technical Committee to Reach Essential Areas
This Committee aims at promoting actions to minimize the negative impacts of an eventual electricity supply interruption to the areas considered essentials by the Committee. This Committee works jointly with the Federal Public Administration, other federal entities and essential service suppliers.
3 – Technical and Tax Analysis Support Committee
This Committee promotes the suggestion of modifications in tariffs and taxes over goods and equipments that produce or consume electricity.
4 – Legal Support Committee
This Committee acts as a legal consultant, giving support to the Crisis Chamber.

5 – Load Reduction Programme Group

This Group prepares and determine the directives for the implementation of the compulsory load reduction programme, by the Crisis Chamber.

6 – Committee to Monitor and Control the Reduction of Electricity Consumption

7 – Technical Committee of the Wholesale Electricity Market

The Wholesale Committee main objective is to analyse and revise the operation rules of the Wholesale Electricity Market.

8 - Technical Committee of Environment

This Committee aim at analysing and revising the procedures for the environmental licensing process of projects that will increase the energy offer.

9 - Technical Committee To Increase Offer in the Short Term

This Committee analyses proposals and measures to increase generation and energy offer from any source in the short term, being composed by the following members:

10 – Committee to Revival the Electricity Sector Model

This Committee is responsible to make proposals in order to correct the actual problem and suggest improvements for the new model, taking into consideration:

I – the need to preserve the basic principles of the Model, which is based on the existence of competition, prevailing the private investments, energy offer compatible with the development needs of the country and maintenance of high standards of service quality;

II – the working results from the Commission to Analyse the Hydrothermal Electricity System.

As a consequence of the new model to be implemented and the Commissions and Comitees created, a new policy was established to expand generation offer. The contribution of renewables to achieve this objective was detailed, which will be presented later on this chapter, after an explanation of the actual status of the wind energy industry in Brazil.

2.4. - The Use of Renewables Sources for Electricity Generation in Brazil

Brazil is a country known all over the world by its continental dimensions and its biodiversity. Actually, huge natural resources reserves (sun, wind, biomass, tides, etc) are available, which brings to the question of why they are not used in a larger extent.

As presented before, the country's energy matrix is already 82% based on generation from renewable energy (hydropower), although some experts may argue that big hydroplanes are classified as "renewable", for the environmental impact they cause on their installation and implementation.

For decades, the use of other renewable sources for energy generation have been disregarded in Brazil, either due to cost issues, to easy availability of hydropower energy, to lack of a proper policy, of incentive schemes and competitiveness. As detailed before, with the experiences of countries where wind power has been implemented, it is made clear proper development mechanisms and policies are fundamental for the success of this industry.

Some initiatives have been very successful and recognized worldwide, like the "Pro-Alcohol" Programme, where it has been developed a combustion motor, which ran entirely on alcohol derived from sugar cane, and allowed the country to be less dependent on oil during the Oil Crisis in the 70/80s.

Actually, the main renewable sources used are biomass, wind and sun, with many different applications and projects. Regarding the use for electricity generation, those projects were developed mainly as "pilot projects", sponsored by the government and built to supply electricity to isolated communities where it would be more expensive to extend the network then to invest in those projects. Some small-scale commercial projects are also in place, which will be detailed later.

With the new electricity market scenario explained before and the need to expand generation to meet increasing demand, an opportunity for electricity generated from renewables is identified. Among the renewable technologies available in Brazil, wind has proven to be the more cost-effective, representing the most promising choice to be used for generating electricity in large scale in the short and medium term.

From the table below, we can see the costs for the different renewable technologies and the prices expected in the future, outlining the competitive advantage of wind energy related to other renewables.

Table 1 – Current Status and Future Prospects of Renewable Energy Technologies (RETs)

Sources	Current Unit Cost (in US$)	Estimated Cost (2020)
Renewables		
Bio energy combustion	3-5/GJ	3-5GJ
Bio energy power	0.06-0.09/kWh	0.05-0.06/kWh
Bio energy liquid fuels	15+/GJ	10-12/GJ
Hydropower	0.03-0.05/kWh	0.03-0.04/kWh
Solar heating	10-30/GJ	10-20/GJ
Concentrating solar power	0.12-0.15/kWh	0.04-0.05/kWh
Solar PV	0.25-0.65/kWh	0.10-0.15/kWh
Geothermal	0.03-0.12/kWh	0.025-0.08/kWh
Wind	0.05-0.11/kWh	0.02-0.03/kWh
Conventional Technology		
Heat	*5-61/GJ*	
Electricity	*0.03-0.05/kWh*	
Liquid Fuels for transport	*9-10/GJ*	

* - U.S. estimates from RET Characterisations report
* - U.S. DOE/EPRI's report on Electricity Technology Roadmap
Estimates from Japanese sources
* - EC Work Programme and Update

2.5 - Wind Energy in Brazil

Introduction

Wind energy has been used for a long time in Brazil, in isolated or small-scale projects. It has been used, mainly, for water pump systems using windmills. The latest years technological advance permitted a higher penetration of wind turbines for electricity generation, as shown in the first chapter. In Brazil, the use of small-scale wind turbines for residential electricity supply has been increasing, mainly to attend isolated communities non-connected to the grid. As part of the new programme to expand generation capacity, it will be explained throughout this dissertation how wind energy can be used for grid connected electricity generation in Brazil, explaining the country's potentials and the challenges faced to implement this technology under local conditions.

Brazil has several pilot projects in operation and some small scale commercial plants connected to the grid. During the 90s many national entities have signed cooperation agreements with foreign entities for the development of renewable sources in the country. The first solar and wind energy projects were implemented in the Northeast and North Regions of the country, places where the non-availability of electricity is harder. Due to the existence of many low-income communities, isolated, without supply of conventional energy sources, many projects were implemented with the installation of photovoltaic and wind systems for the distributed generation of electricity.

Today in Brazil there are many groups involved with wind energy, its technology and applications, besides the quantification and qualification of areas where this resource has proven to be abundant. The first studies focused on the development of a national technology dates from 1976, at the Aerospace Technical Centre (CTA). Initially, prototypes of aerogenerators of low power were developed (1 to 2 Kw), which gave place to the first evaluation of the wind potential on the Northeast Coast. The project had a great development when CTA established a partnership with the German Aerospace Centre – DFVLR, through which they started project DEBRA. This project would comprise the use of an aerogenerator of 100 Kw, with a rotor of 25m diameters. It was CTA responsibility the blades assembly, which in 1983 where ready and was shipped to Germany.

Many institutions all over the country, suppliers, universities, NGOs, federal organs among others have intensified their presence in wind energy on the second half of 90s, when the main projects from renewable energy sources were implemented in the county. The new market scenario, with privatisations of generation and distribution electricity companies opened new opportunities for the development of renewable energy sources. It was essential an accurate assessment of the real potential for the use of renewable resources, as a way of creating new generation options to expand capacity and comply with the new environmental standards. The assessment of the wind potential has proven to very important for the future development of an electricity generation source that could be available within a short period, faster than the big hydro power plants the system was used to.

Many initiatives to assess the wind potential of different areas of the country were started. The first successful result was issued in 1998, covering the Northeast Region of Brazil. The Wind Assessment of Northeast of Brazil, WANEB project, consolidated speed and directional wind data measured in wind stations.

After this project was officially launched, the Brazilian Centre for Wind Energy (CBEE) has focused its efforts in the development of the Brazilian Wind Atlas, a consolidation of different measurement centres and data gathered throughout the years, which was completed in July 2002. Part of the data will be presented subsequently, as well as an explanation of the metrology adopted.

2.5.1 - Assessment of Brazilian Wind Potential

The Brazilian Wind Atlas covers the whole national territory. Its main objective is to provide information that enables decision makers to identify areas suitable for the use wind to generate electricity.

One of the main constraints for the use of wind energy has been the unavailability of consistent and trustable data. A significant part of the wind registers available can be misleading by aerodynamic influence of obstacles, terrain and roughness. The availability of representative data is important in the Brazilian case, where this renewable resource has not been explored yet to a large extent.

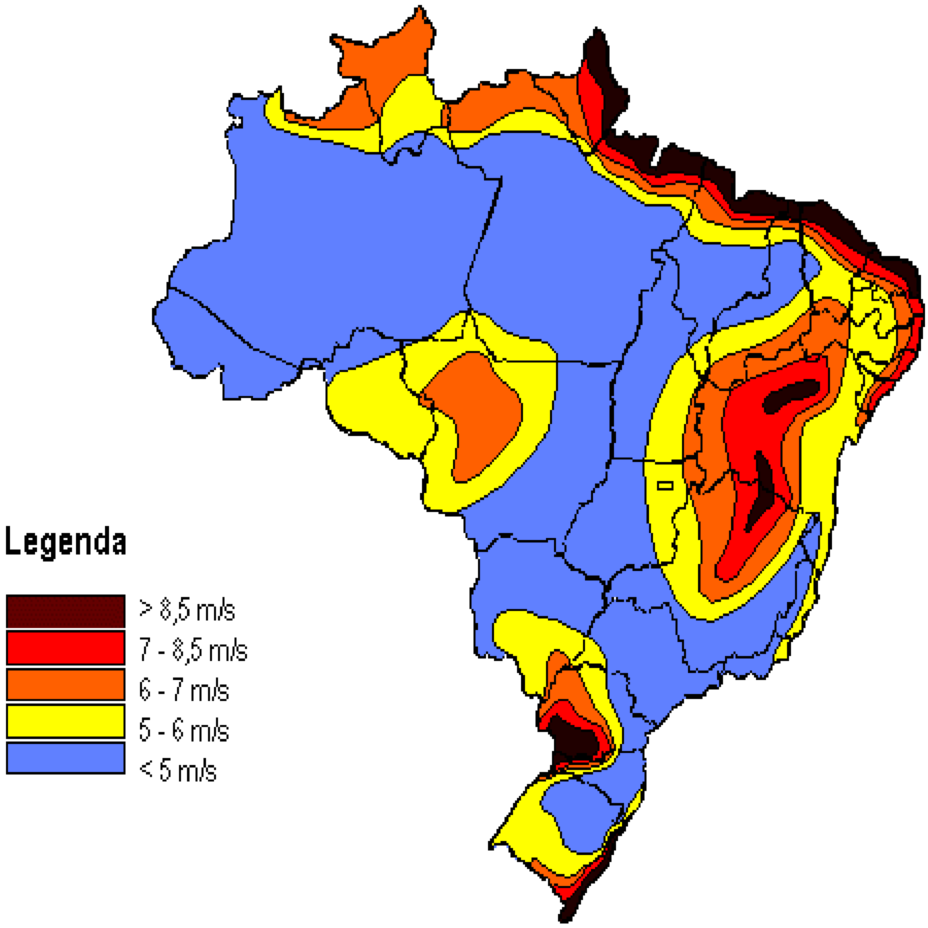
This Atlas was developed based on MesoMap, a numeric modelling software system for the superficial wind. This system simulates the atmospheric dynamic of wind regimes and meteorological variables related to it, through the use of representative samples of data validated for the period 1983/1999. The system includes geographical variables such as terrain, roughness induced by vegetation classes and use of soil, the thermic interactions between the earth surface and atmosphere, including effects from existent water vapour. This simulations are then adjusted to existent references, such as meteorological data resulted from reanalysis, radio sonars, wind and temperature measured over ocean and surface wind measurements already available for specific regions of Brazil. Among this, only measurements with proper suitable to make reference to the model were selected. The following table shows the stations used:

Institution	Region Covered	Number of Stations
CEPEL	North Region	7
CELESC	Santa Catarina State	6
COPEL	Parana State	17
COELBA	Bahia	13
SUDENE	Ceara	2
Navy – DHN	Coast of Brazil	2
	Total	**47**

This results of these simulations are presented in different maps, representing the average behaviour of wind (speed, main directions and static parameters of Weibull) and wind loads at a height of 50 meter, at an horizontal resolution of 1km x 1km, for the whole country.

Besides this general assessment of the best areas for wind energy developments and the main wind characteristics, it was also realized the integration of potential areas with geo process tools, using conservative premises.

A generic set of results for the different regions of the country can be seen from the table below. It is important to bear in mind, that the objective of the wind atlas is to identify potential areas, acting as an indicative for future developments, but those numbers do not consider any physical and geographical limitations, just taking into account the wind speed in the areas. The areas with wind speed equal or above 7 m/s were considered more suitable for the use of wind energy, but for further deployment of this technology a detailed study has to be conducted, considering all the local conditions of the areas. When looking at those, in some cases areas with wind speed lower than 7 m/s (as in many regions of Europe) may prove to be more feasible than areas with higher wind speed.



MAP 1 – Wind Potential of Brazil

	Integration per Wind Speed Ranges				
Region	Wind Speed (m/s)	Area (km2)	Installable Wind Power (GW)	Capacity Factor	Annual Energy (TWh/year)
North	6 - 6.5	11460	22,92	0.13	25,58
	6.5 - 7	6326	12,65	0.17	18,46
	7 - 7.5	3300	6,60	0.20	11,33
	7.5 - 8	1666	3,33	0.25	7,15
	8 - 8.5	903	1,81	0.30	4,65
	> 8.5	551	1,10	0.35	3,31
Northeast	6 - 6.5	146589	293,18	0.13	327,19
	6.5 - 7	60999	121,98	0.17	178,02
	7 - 7.5	24383	48,77	0.20	83,73
	7.5 - 8	9185	18,37	0.25	39,43
	8 - 8.5	3088	6,18	0.30	15,91
	> 8.5	870	1,74	0.35	5,23
Midwest	6 - 6.5	41110	82,22	0.13	91,76
	6.5 - 7	8101	16,20	0.17	23,65
	7 - 7.5	1395	2,79	0.20	4,79
	7.5 - 8	140	0,28	0.25	0,6
	8 - 8.5	6	0,01	0.30	0,03
	> 8.5	0	0,00	0.35	0,00
Southeast	6 - 6.5	114688	229,38	0.13	255,99
	6.5 - 7	46302	92,60	0.17	135,15
	7 - 7.5	11545	23,09	0.20	39,64
	7.5 - 8	2433	4,87	0.25	10,44
	8 - 8.5	594	1,19	0.30	3,06
	> 8.5	297	0,59	0.35	1,78
South	6 - 6.5	121798	243,60	0.13	271,86
	6.5 - 7	38292	76,58	0.17	111,77
	7 - 7.5	9436	18,87	0.20	32,4
	7.5 - 8	1573	3,15	0.25	6,75
	8 - 8.5	313	0,63	0.30	1,61
	> 8.5	57	0,11	0.35	0,34

Cummulative Integration			
Wind Speed (m/s)	Cumm Area	Installable Wind Power (GW)	Annual Energy (TWh/year)
> 6	24206	48,41	70,48
> 6.5	12746	25,49	44,9
> 7	6420	12,84	26,44
> 7.5	3120	6,24	15,11
> 8	1454	2,91	7,96
> 8.5	551	1,10	3,31
> 6	245114	490,22	649,51
> 6.5	98525	197,04	322,32
> 7	37526	75,06	144,3
> 7.5	13143	26,29	60,57
> 8	3958	7,92	21,14
> 8.5	870	1,74	5,23
> 6	50752	101,50	120,83
> 6.5	9642	19,28	29,07
> 7	1541	3,08	5,42
> 7.5	146	0,29	0,63
> 8	6	0,01	0,03
> 8.5	0	0,00	0
> 6	175859	351,72	446,06
> 6.5	61171	122,34	190,07
> 7	14869	29,74	54,92
> 7.5	3324	6,65	15,28
> 8	891	1,78	4,84
> 8.5	297	0,59	1,78
> 6	171469	342,94	424,73
> 6.5	49671	99,34	152,87
> 7	11379	22,76	41,1
> 7.5	1943	3,89	8,7
> 8	370	0,74	1,95
> 8.5	57	0,11	0,34

Total Brazil
Estimated Potential

> 6	667400	1334,79	1711,61
> 6.5	231755	463,49	739,23
> 7	71735	143,48	272,18
> 7.5	21676	43,36	100,29
> 8	6679	13,36	35,92
> 8.5	1775	3,54	10,66

Although the preliminary results shown above can be considered overestimated by some experts, they outline vast potential of wind energy use in the Brazilian territory. For a more accurate assessment of those potential areas, it is necessary to conduct a full analysis of the region, considering many different aspects, which will be detailed in the case studies.

Some of the maps obtained from the Brazilian Wind Atlas will be presented in the Annexes.

2.5.2 - Wind Energy in Brazil – State of the Art

The better potentials for wind energy use in Brazil are located in the North and Northeast Region. Compared to other renewable sources available for power generation in those regions (mainly solar and biomass), wind energy has many advantages that establish its position as an important option for new investments in power generation projects. Many institutions have already worked for the accurate assessment of both regions, mainly in the coastal shore, where strong and constant wind are observed almost the whole year. Studies conducted by CHESF (electrical utility that serves most of the Northeast states) and COELCE (electricity utility of Ceara state) shows that the Northeast coast between the states of Rio Grande do Norte and Ceara have wind resources estimated in 12,000 MW.

The Northeast Region is pioneer in the installation of wind energy power projects. As can be noticed from the table below, most of the projects already existents in Brazil are located in this region. The programmes of experimental implementation in Brazil sum up to 2.6 MW. The projects implemented by private companies' sum up to 17.5 MW (15 MW in state of Ceara and 2.5 MW in state of Parana).

Installation	Implementation	Investors	Capacity	Operational Start
Operational Projects				
Fernando de Noronha – PE	CELPE, UFPE/Folkenter	30% Denmark	75 KW	1992
Fernando de Noronha – PE	CELPE, UFPE, ANEEL	ANEEL	300 KW	1992
Morro do Camellinho – MG	CEMIG	70% Germany	1 MW	1994
Porto de Mucuripe – CE	COELCE	70% Germany	1.2 MW	1996
Hybrid System of Joanes – PA	CEPEL/ CELPA	100% USA	40 KW	1997
Wind Farm of Prainha – CE	Wobben Windpower/ COELCE	Private	10 MW	1999
Wind Farm of Taíba – CE	Wobben Windpower/ COELCE	Private	5 MW	1999
Wind Farm of Palmas – PR	Wobben Windpower/ COPEL	Private	2.5 MW	1999
Projects under negotiation				
Central Eolica -	Cinsel/COELCE	Private	5.4 MW	1999

CE				
2ND Phase – Palmas	Wobben Windpower/ COPEL	Private	9.5 MW	
Paracuru – CE	Ceara Government/ COELCE	100% Japanese		2000
Camocim - CE	Ceara Government/ COELCE	100% Japanese		2002
Feasibility Studies / Pre-Concession				
Barreirinha	C.E.X Clean Energy do Brasil		30 MW	1998
Fortaleza	C.E.X Clean Energy do Brasil		60 MW	1998
Preliminary Studies / Planning				
Jericoacara – CE	COELCE		100 MW	
Cabo Frio – RJ	UFF		10 MW	
Norte Fluminense – RJ	UFF		40 MW	
Pernambuco, R.G.Norte	UFPE/ Manufactures Consortium		30 MW	
3rd Phase – Palmas			75 MW	
Minas Gerais			150 MW	
Salinopolis – PA			50 MW	

Table 6 – Status of Wind Projects in Brazil (2001)

In the North Region, the Electric Research Centre (CEPEL), the national Electricity company (Eletrobras) and electricity utility of state of Para (CELPA) have been collecting data in different places with high wind occurrence, providing accurate and updated information, which favours the implementation of a wind farm. The construction of wind farms in the North and Northeast Region are facilitated by the following reasons:

- Decreasing generation costs, with the development of large scale projects and the mature of this new technology;
- The new legislation creating the Independent Power Producer (IPP);
- The importance of wind energy to reduce fossil fuels dependency, mainly in the North Region where fuel supply is essential;
- New legislation allowing open access in distribution and transmission network;

Even in a small number, the wind projects implemented in the country shows an important initiative from the concessionaires, responsible for the experimental projects, and for the self-producers power companies.

2.5.3 - Experimental Projects and Cooperation Agreements

The discussions about the Environment, during the Rio de Janeiro Conference, in 1992, contributed to the creation of partnerships to develop renewable-based projects. Governments from some industrialized countries created different cooperation programmes regarding renewables, such as: the Eldorado Programme from the German Government, the Programme from the Department of Energy (DOE) of the United States, through the National Renewable Energy Laboratory – NREL and the Sandia National Laboratory, and actions from France, mainly at Morocco and Denmark.

International agreements for the implementation of experimental projects have also included Brazil in many solar and wind projects. Some demonstration projects were implemented involving electricity companies, government, universities and research centres. The following table presents the projects in place since 1995, due to these international agreements.

Project	Capacity (kW)	Characteristic
Folkencenter/ CELPE/ UF	75	1 aero generator
Eldorado / CEMIG	1,000	4 aero generators
NREL – Phase 2		
State of Para	40	Hybrid wind and solar
State of Minas Gerais	27.5	Hybrid wind and solar
TOTAL	1,142.5	

Table 7 - Experiments from International Cooperation Agreements

2.5.4 - The Legal Framework for the Development of Wind Energy in Brazil

In this section will be presented the laws, decrees and resolutions that have directly contributed to the increase of wind energy use in Brazil. It is important to outline that there are specific laws to other renewable technologies that won't be presented here. It will be covered the Law that Regulates The Independent Producer and the Self-Producer, the ANEEL resolution about the normative value (VN), and Law n° 10438.

The study of the laws and regulation available is of extreme importance because through those, many countries have reached technology maturity and a significant contribution of renewable technologies for energy generation, as shown in Chapter 1. After the rationing crisis Brazil has faced in the last years, and considering that there is plenty of natural resources available in this country, it is very important that States and Governments participate actively, contributing for the development of wind energy projects. The need for a clear and specific legislation and the guarantee of the acquisition of energy generated from renewable is essential to attract investors. Only after the establishment of a local market in the country with enough critical mass it will be possible to promote a reduction in costs and improve the competitiveness when compared to the conventional energy sources.

2.5.4.1 – Independent and Self-Producer of Energy

The Legal Decree n° 2003, from September 1996, regulates the electricity production from Independent Producers and Self-Producers. This Decree regulates the electricity concession for legal entity or consortium of companies, designated totally or partially to the commerce or exclusively for self-consumption.
In the Article 2°, there are the final considerations about the Independent Producer and Self-Producer, as follows:

I. Independent Power Producer is the “pessoa juridica” or consortium of companies that are granted the concession or authorization to produce electricity aimed to be totally or partially traded, by its own account and risks;
II. Self Power Producer is the “pessoa fisica ou juridica” or consortium of companies which are granted the concession or authorization to produce electricity exclusively to its own use;

In Chapter 1, Section 1 of the Decree opens the possibility for the interested, through request, to precede the tender process by itself, which are usually determined by the Public Power. The concession, preceded by tender in the terms determined of the decree, is legally necessary for hydropower developments higher than: 1,000 KW for the Independent Producer and 10,000 KW for the Self-Producer.

The definition of optimal use of the hydro potential can be realized through technical studies conducted by the interested, as long as it has been previously authorized. This way, the implementation of thermal power plants with capacity superior to 5,000 KW can be authorized, destined to the Independent Producer and the Self Producer, as well as the use of hydropower potential superior to 1,000 KW and equal or inferior to 10,000 KW by self producer.

One important measure is detailed on the article 5°, which releases the need for concession or authorization for the use hydro power potential equal or inferior to 1,000 KW and the implementation of a thermal power plant with capacity equal or inferior to 5,000 KW, demanding only the communication for the responsible Organ, to registry. The following table shows the rules for concession of electricity generation in Brazil.

End Use of the Power	Installed Capacity of the Hydro Power Plant		
	Up to 1 MW	Up to 10 MW	Above 10 MW
Public Service	Free	Through Tender	
Self Production	Free	Authorization	Tender
Independent Producer	Free	Through Tender	
End Use of Power	Installed Capacity of a Thermal Power Plant		
	Up to 5 MW	Above 5 MW	
Self Production	Free	Authorization	
Independent Producer	Free	Authorization	

Table 8 - Rules for the Electricity Generation Concession

About the access to the distribution and treatment system, Article 13 states an important measure, guaranteeing the commercialisation and use of the electricity produced. The Independent Producer and the Self-Producer will have the free access to the transmission and distribution systems of concessionaires and permissionaires guaranteed, through the reimbursement of the transport cost. The Decree also: regulates the integration of the energetic operation of the Independent Power Producer and the Self-Producer to the electricity system (section IV) and establishes the financials charges to be paid by those producers (section V), determines standards of control and penalties (section VI), besides presenting a former authorization for the alienation of goods and installations used for the electricity production by those producers, as well as establishing standards referred to the final destiny of those goods at the end of the concession or permission period (section VII).

This decree covers, in a broad extent, the supply of electricity by private investors. Some limits and observations regarding hydropower and thermal systems are established, as noticed from Table 8 . Although it does not establish any limits or authorization for the use of renewable technology, this Decree is extremely important to regulate the Independent and Self Producers that use renewable sources for the generation and selling of energy.

The Wind Farms of Taíba and Prainha, in the state of Ceara, and the wind farm of Palmas, in the state of Paraná, are the first cases to sell electricity produced by Independent Producers to the local distribution electricity companies, COELCE and COPEL, respectively. The new initiatives to contribute to wind energy generation aims at creating ways to incentive the establishment of Independent Power Producers for the free commercialisation at the electricity market.

2.5.4.2 – Incentive Programmes and Laws

The Federal and Local Governments established many different incentive programmes and schemes for the use of renewable technology for electricity generation over the last years. Most of them included subsidies or tax exemptions, but a strong and definitive programme that supported the deployment of renewables were still lacking.

The rationing period faced in the last couple of years brought to attention the question of a proper expansion capacity planning, and the need to diversify the country's energy matrix. The large availability of renewable resources in Brazil, the decreasing generation costs of this technology and the interest to develop projects in this area from foreign investors, has reopened the debate over the need of a more concrete policy covering the issue.

As part of the restructuring process of the electric sector, it was issued in April 2002, Law n° 10438, which establishes the new agreement between the agents of the sector after the rationing period and deliberates a new policy for the use of renewables for electricity generation. Many experts are considering this Law as a definitive step for the implementation of renewable energy, although many uncertainties still remain. The Law will be detailed in the following item.

Law N° 10438

As a consequence of the Crisis Management Chamber work, a set of new laws and regulation were created to implement the new operational model of the sector and to plan the expansion of the generation capacity, aiming at preventing the reoccurrence of an outage period.

Among those initiatives, Law n° 10438 creates the Programme to Incentive the use of Alternative Energy Sources for Electricity Generation (PROINFA) and the Energy

Development Account (CDE, through its Article, which will be referred to sequentially, showing the importance of what it determines.

"Art.3°. Establishes the Programme to Incentive the Use of Alternative Energy Sources for Electricity Generation – PROINFA, aiming at increasing the amount of electricity generated through Independent Autonomous Producers, based on wind, small hydro and biomass resources, at the National Interconnected Electricity System, and making it feasible through the following procedures:

I. In the first phase of the programme:

a) The contracts will be granted by "Centrais Eletricas Brasileiras" (Central Brazilian Electricity System) – Eletrobrás in up to 24 months from the publication of this Law, for the implementation of 3,300 MW capacity, in installations with operational start until 30th December 2006, guaranteeing the purchase of the energy produced during 15 years, starting from the operational start date stated in the contract, following the floor value established in alinea b;

b) the contracts related to alinea a may be equally distributed, in terms of installed capacity, for each one of the sources participating in the programme, and the energy might be purchased by the economic value related to the specific technology for each source, value to be defined by the Executive Power, but having as floor value 80% (eighty per cent) of the average national tariff;

c) The value paid for the electricity acquired following alinea b and the administrative costs incurred by Eletrobras as the contract process will shared for all classes of end consumers supplied by the National Interconnected Electricity System;

d) The acquisition of the installations which this subsection refers to will be done through Public Call, for each specific source, giving priority initially to those who have already obtained the Installation Environmental License – LI and then, to those who obtained the Previous Environmental License – LP;

e) In the case of existing installations with LI and LP in a larger amount than the acquisition availability from Eletrobras, it will be contracted those whose environmental licenses have a shorter validity period remaining;

f) It will be allowed the direct participation of manufacturers of generation equipment, its controlled, colligated or controller in the constitution of the Independent Autonomous Producer, as long as the nationalization index of the equipments is, at least, 50%(fifty per cent) in value;

II. At the second phase of the programme:

a) After reaching the 3,300 MW target, the development of the Programme will be conducted in order to supply 10% (ten per cent) of the annual electricity consumption in the country from wind, small hydro and biomass, target to be achieved in up to 20 years, including the first phase in this period;

b) The contracts will signed between Eletrobras, with a duration period of 15 (fifteen) years and price equivalent to the economic value correspondent to the competitive generation, defined as the weighted average cost of generation of new hydro power projects, with capacity superior to 30,000 KW and gas fired thermal power plants, calculated by the Executive Power;

c) The acquisition will be done through an annual planning purchase programme of electricity for each producer, in order to have the refereed sources supplying a minimum of 15% (fifteen per cent) of the annual increase of electricity to be supplied to the national consumer market, offsetting the differences between the expected and actual for each exercise, in the flowing one;

d) The alternative energy producer will have access to a complimentary credit to be monthly supplied with resources from the Energy Development Account – CDE, which will determined by the difference between the economic value for each specific source, value to be determined by the Executive Power, but having as floor value 80% (eighty per cent) of the average national tariff supplied to the end consumer, and the value paid by Eletrobras;

e) Until 30th of January of each fiscal exercise, the producers will issue a Certificate of Renewable Energy – CER, in which will be included, at least, the juridical qualification of the producer, the source of the primary energy used and the amount of electricity actually traded in the previous fiscal exercise, to be presented to ANEEL (regulatory body) for the contrail and checking of the annual targets;

f) The Executive Power will regulate the procedures and Eletrobras will control so that the complimentary credits which are detailed in alinea d don't overpass 30 (thirty) days of the payment request done by the producer agent;

g) at the contract order, which will preceded by Public Call for the knowledge of the interested parties, Eletrobras will use the classification criteria detailed at subsection I, alinea d,e and f, respecting, yet, the minimum period of 24 (twenty-four) months between the signature of the contract and the installation operational start;

h) The contracts might be equally distributed, in terms of installed capacity, for each one of the generation sources of the programme, having the Executive Power, for each 5 (five) years from the implementation of this second phase, transfer to other sources the remain capacity of any of the others, which haven't been contracted for not having interested buyers;

i) The value paid for the acquired electricity and the administrative costs incurred by Eletrobras at the contract process will be shared through all classes of end consumers supplied by the National Interconnected Electricity System, proportionally to the verified consumption.

#1° The Independent Autonomous Producer is the one whose society is not controlled by or colligate to the generation, transmission or distributions electricity concessionaire, neither from its shareholders or society controlled or connected with the common shareholder;

#2 – The Executive Power will be allowed to grant permission to Eletrobras to establish contracts with Independent Producers that doesn't fulfil the criteria of #1, as long as the total to be contracted is not higher than 25% (twenty-five per cent) of the planned annual purchase and that from those contracts the Independent Producer offer is not chosen. It might be observed that in the case of wind energy, in the first phase of the programme, the total of contracts established can reach up to 50% (fifty per cent).

#2° – The Executive Power will be allowed to grant permission to Eletrobras to establish contracts with Independent Producers that doesn't fulfil the criteria of #1, as long as the total to be contracted is not higher than 25% (twenty-five per cent) of the planned annual purchase and that from those contracts the Independent Producer offer is not chosen. It might be observed that in the case of wind energy, in the first phase of the programme, the total of contracts established can reach up to 50% (fifty per cent)."

Article 13 defines the creation of the Energy Development Account (CDE), which covers most of the alternative resources. In the following reference to this Article, it will be presented the conditions related to wind energy, excluding the section related to other sources.

" Art 13. Establishes the Energy Development Account (CDE), aiming for the energy development of the States and to ensure the competitiveness of energy produced from wind, small hydro, biomass, natural gas and national mineral coal, in the areas served by the interconnected systems and to promote the universalization of electricity services in the whole national territory. The resources of this account might, following the constraints and limits detailed below, be destined to the following uses:

II – for the payment of energy agents that produces electricity from wind energy, gas fired thermal power plants and small hydroelectric, whose operation starts after the publication of this Law. This payment will be equivalent to the difference between the economic value correspondent to the specific technology for each source and the economic value of the competitive energy, when the selling and purchasing are realized with end consumer;

III – for the payment of the credit detailed in alinea d of "ïnciso" Ii of article 3°;

#1° - The resources of the Energy Development Account (CDE) will come from the annual payments obtained for the use of public good, the fines applied by ANEEL (regulatory body) to concessionaires, permissionaires and authorized companies, and from 2003 onwards, from the annual quotas paid by every agents that trade electricity with the end consumer.

#3° - The quotas mentioned in #1° will be readjusted annually, starting from year 2002, proportionally to the market growth of each agent, up to the limit that does not cause tariff increase for the consumer.

#6° - CDE will last for 25 (twenty-five) years, being regulated by the Executive Power and managed by Eletrobras."

This Law was issued on 26th April 2002, and has not been regulated yet. Discussions with the involved agents, governments and development agencies are still going on, and the prediction is to have it regulated by November, before the change in the Federal Government (elections will be in October, and the new President starts its mandate on 1ST January, 2003).

Resolution N°248

This resolution establishes the mythology to calculate the price limits that can be transferred to the supply electricity tariffs depending on the purchase prices.

This limit price, known as Normative Value (VN), became important during the restructuring of the electricity sector, due to the expire of the old bilateral contracts a general “fear” that new high prices could be transferred from the concessionaires to its customers. The maintenance of the transfer price control has always been an important issue for all the agents involved in the market, mainly to guarantee that clear rules and non-abusive were being used.

Law n° 9648, from My 1998, regulates, through article 10, a new relation for the buying and selling of energy. After this Law, the relationship between concessionaires and authorized agents of generation and distribution premissionaires becomes of free negotiation, as long as the transition conditions established in alineas aa,b and c from paragraph I are respected during 1998 and 2002. From 2003 onwards, the volumes of energy traded will be reduced gradually in the proportion of 25% p.a. This Law also defines that ANEEL will formulate the criteria to establish the transfer price limit based on the purchase price of electricity. Law 9074, from July 1995, opens the possibility that, from July 2003 onwards, any electricity consumer which is classified as a free consumer will have the option to choose its electricity supplier.

With the responsibility to define the criteria for the transfer prices, different versions of Resolutions were debated with the agents, resulting in the final version, which will be referenced below, showing the main relevant parts:

“ Art. 2° - The cost with the acquisition of electricity, to be considered in the readjustments determined in the Concession Contract, will be obtained using the following formula:

Where:

CE – cost of the electricity acquisitions necessary to meet the reference market, at the conditions at the date of readjustment in process and the previous readjustment , expressed in R$ (Reais, Brazilian currency);

MCI – volume purchased of electricity, through the initial contracts, at the reference period, expressed in MWh;

PCI – tariff of the electricity purchased referred to the initial contracts, at the conditions observed at the date of readjustment date in process and at the previous date of readjustment, expressed in R$

TCI – value of the charges incurred to use the transmission and distribution systems, referred to the electricity purchased through the initial contracts, at the conditions observed at the date of readjustment in process and the date of the previous readjustment, expressed in R$;

MCEi – volume of the electricity purchased, at the refereed period, related to the bilateral contract “I” negotiated freely, expressed in R$;

PCTi – transfer price related too the purchase of electricity related to the bilateral contract ‘I” negotiated freely, at the conditions observed at the date of readjustment in process and the date of the previous readjustment, expressed in R$;

MCRi – volume of the purchase of electricity from the concessionaires, at the reference period, related to bilateral contract “I”, expressed in R$;

PCRi – tariff of the electricity purchased related to bilateral contract "ï" signed with a public service concessionaire, at the conditions observed at the date of readjustment in process and the date of the previous readjustment, expressed in R$;

MCP – volume of the short term electricity purchases, needed to meet the reference market, at the reference period, expressed in R$;

VNC – normative value defined by for the valuation of the short term purchases, at the conditions observed at the date of readjustment in process and the date of the previous readjustment, expressed in R$;

TCE – value of the charges to use the systems of transmission and distribution, complimentary to the charges related to the initial contracts, at the conditions observed at the date of readjustment in process and the date of the previous readjustment, expressed in R$;

Art.3° - The transfer price of the electricity purchased at the reference period will be the Normative Value as upper limit, and that should obey the following procedures:

Electricity Purchase Price at the Bilateral contract "i" Pbi	Electricity Transfer Price – PCEi
Pbi > VNi	PCEi = VNi
Pbi < VNi	PCEi = Pbi + (VNi – Pbi) x Pbi/4 x VNi

Where:

PBi = purchase price of electricity acquired, at the reference period, through bilateral contract "I" freely negotiated, which will be expressed in R$/MWh;

VNi = Normative Value, defined by ANEEL, valid at the signature of bilateral contract "ï", expressed in R$/MWh;

PCEi = transfer of the electricity purchase price, expressed in R$/MWh;

Art. 5° For each electricity purchase contract with duration equal or superior to twenty-four months, it will be associated a Normative Value, taking it account the register date at ANEEL.

#1° For comparison with the Normative Value, the purchase price of the contract will be considered at the common reference point of the submarket where the electricity byuer is located, following what is established by art.15 of Decree 2655, from July 1998.

#2° In the moment of the contract register and when the revisions may occur, the concessionaire should present the weighting factors F1I (weighting factor of the IGPM index) and F2I (weighting factor of the foreign exchange) respecting the limits established in this Resolution

Art 6° For the annual readjustment of the electricity tariffs, it will consider the total purchased at the reference market, following what is established at the concession contract, valued for the prices at the "Readjustment Date in Process" - DRP and at the "Previous Reference Date"- DRA.

#1° For the calculus of the limit of the transfer price of the contracts, the Normative Value established for each electricity purchase contract will be updated for the month previous to the date DRP or DRA, depending on the case, through the formula:

VNi = Vno x (F1ox IGPM1i/ IGPMo + F2I x IVCi/ IVCo)

Where:

VNi = Normative Value updated for the last readjustment month of the electricity purchase contract previous to DRA or DRP;

VN0 = Normative Value at January 2001;

F1i = weighting factor of IGP-M index;

F2i = weighting factor of the foreign exchange rate;

IGPM1i = accumulated value of the general price index, established by Fundação Getúlio Vargas - FGV, until the month previous to the update of VN;

IGPM0 = 1,000;

IVC0 = average of the foreign exchange rate, issued by the Central Bank of Brazil, at the month previous to the update of VN;

IVC0i = R$ 1,9633/US$;

§ 2o The sum of the weighting factors F1i and F2i might be equal to 1,0.

§ 3o The weighting factors F1i and F2i will be revised after the tenth year of the bilateral contract duration, and after this period, at every five years

§ 4o If the variation of the IGP-M and/or the IVC index is considered expressive enough, between DRA and DRP dates, to cause significant impacts at the electricity purchase price, the concessionaire will be allowed to request to ANEEL the revision of the tariffs, as disposed in the Concession Contract.

Art. 7 The Unique Normative Value (VN), representing the competitive source, is established as:

Vno (R$/MWh)	F1o minimum
72.35	0.25

The normative Value will be revised, annually or as decided by ANEEL, in the case it happens relevant structural changes at the electricity production chain, following the aspects:
I. projects under development;
II. planned expansion of the generation park;
III. update of project costs;
IV. bilateral contracts signed between the agents; and
V. polices and directives of the Federal Government

Art. 8 The short term Normative Value – VNC will be the Normative Value valid at the readjustment in process 9drp) or the previous readjustment (DRA), using the formula presented at art.6 of this Resolution, considering F1I = 1.0

A Brief Analysis of the Law and Recent Initiatives

Law n°10438 sets very ambitious targets for the deployment of renewable, but still has some uncertainties that need to be clarified to the achievement of those.

Other programmes were created before this Law to incentive the use of renewable, but they were unsuccessful, failing to attract local or foreign investments in this area. The expectation is for the programme to be well accepted, because there is a strong willingness of private investors to develop projects related to this (many companies are already undertaking feasibilities studies in different regions of Brazil), and there is a clear need to expand the generation capacity, and renewable technology can help to increase this in a short term. Also, the conditions set, not only by this Law, but also from Local governments seems favourable, and the increasing environmental awareness and initiatives to create self-sustainable societies to reduce inequality will help society to push for the use of those technologies.

Some renewable energy projects were already approved before this Law was issued, resulting in a total capacity round 4 GW authorized Wind Energy Projects by ANEEL. This amount outlines the real willingness of the investors, but it only means that a permission has been given by the regulatory body. This does not guarantee that those projects will be executed, since most of the project developers are waiting for the Law to be regulated.

In a market research conducted with the main project developers (SIIF Énergies, Marubeni, Seawest and Enerbrasil) some points were raised:

- Uncertainty about the PPA conditions
- Need for a final definition over the Normative Value (VN), guaranteeing a competitive price that reflects real market conditions;
- Indefinition about how the resources of the Energy Development Account will distributed;
- the importance of a proper competitive value to be defined;

2.5.4 - The Financial and Tax Framework for the Development of Wind Energy in Brazil

As the equipment used for wind energy generation is still not produced in Brazil, for the development of a local project the import taxes and any other taxes incurred in the process, freight and insurance charges have to be included for a full analysis.
After some contacts with import agents, it was obtained an average value for the shipping from Europe (where most of the manufactures are located) to Brazil of around DM$ 200.00/TON or DM 200.00/m^3, being used the highest value. About the insurance the average value obtained was around 1% over the average cost of the turbine at its origin country. When it reaches Brazil, some other taxes are applicable over the cost of the turbine on its own origin country (FOB cost), which are added to the transport and insurance (CIF). Currently, those taxes are:

- Import Tax – II
- Tax over Industrialized Goods – IPI

- Tax over Circulation of Goods and Services – ICMS

As per the Brazilian Goods Classification – NBM, issued by the Aduana, the value of II (IPI) is: 3% over the CIF cost for wind generators and the 5% over the CIF cost for the wind turbine. As tax II (IPI) is applicable over the equipment, so it is III (ICMS). The value of ICMS varies for every state of Brazil, being 17% up to 18%.

Financing Conditions

The financing of a wind project in Brazil can be done with equity or with external capital resources. Currently, local financing is also available form the National Development Bank – BNDES, which has special financing lines for the electricity sector.

For the case where external financing is used, some simulations were done varying the percentage amount of external capital and the interest rates applied. It were analysed participations from 10% and 90% of the total initial investment, and interest rates of 10%, 12.5%, 15%, 17.5% and 20%. The financing conditions adopted were the same for each possibility of participation and interest rate, being:

- Use of constant amortization system;
- Grace period of 2 years;
- Total investment period of 12 years (grace period + amortizations);
- Annual Payments

Another financing source used at the economic study presented for the case studies were the credit lines from BNDES. The Bank provides credit lines known as FINEM – Projects Financing. The FINEM finances projects with investments superior to R$ 7 million, including the equipment and machines acquisition done directly through BNDES or through financial institutions catalogued.

The interest rates used by FINEM are:

Interest Rae = Financial Cost = Basic Spread = (Risk Spread or Agent Spread)

Where:

- Financial Cost
  - TJLP – Interest Rate of Long Term
  - Foreign exchange rate (dollars to R$) added up to Libor or
  - Variation of the monetary unity from BNDES (UMBNDES) added up the currency basket charges
- Basic Spread
  - Standard level: 2.5% p.a.
  - Special level: 1.0% p.a.

- Agent Spread: to be negotiated between the financial institution and the customer
  - Risk Spread: Up to 2.5% p.a. in the financial operations directly with BNDES; and at the other cases it will be negotiated between the financial institution and the customer

Using TJLP as the financial cost of 9.75% for the period of October to December 2000, it is predicted a daily capitalization of the remaining debt as the following formula:

$$FC = (1+TJLP / 1 + 6\%)^{N/360}$$

Where:

- FC is the capitalization factor of the remaining debt;
- N is the number of days passed between the financial event and the capitalization date

The interest rate may be calculated over the remaining debt, after using the capitalization factor, the BNDES spread added a the non-capitalized part of TJLP of 6% , following the formula:

$J = SD \times FC \times \{ (1 + (s+6))^{N/360} - 1 \}$

Where:

- J is the interest rate;
- SD is the reaming debt;
- S is the BNDES spread ate the operation (basic + risk) in % ;
- N is the number of days between the financial event and the capitalization data

The level of participation of BNDES in financing classified in FINEM is limited up to 80% in machines and equipments, and can reach up to 90% in the case of small companies, and projects classified under the Regional Programmes financed by the Bank. For the other investment items, the participation of BNDES investments can achieve up to 60%. For the special cases, such as projects belonging to the Regional Programme, the participation can reach up to 80%, and for small companies up to 90%.

The total financing period is determined as a function of the payment capacity of the developer, company or economic group involved in the project. In contracts signed with BNDES, it was observed that the maximum investment period was of 10 years. It is important to notice that there are specific credit lines from BNDES for electricity generation, mainly for the priority governmental investments.

All the process of requesting financing in BNDES is analysed and the values for the basic and risk spread, total financing period, participation levels and guarantee criteria may be altered from case to case. Using the possible variations for the credit variables used by FINEM, it was considered two types of financing used by FINEN: Basic Level and Special Level

FINEM	Basic Level	Special Level
TJLP	9.75%	9.75%
Basic Spread	2.5%	1.0%
Risk Spread	2.5%	0.0%
Participation Level – Machines	80%	90%
Participation Level – Other Items	60%	90%

Even not including wind energy projects, the Financial Support Programme for Priority Investments in the Electricity Sector, presents criteria aiming at developing expansion capacity projects. Following the same criteria of interest rates used by FINEM, the Support Programme for the Electricity Sector is different at the levels of financing participation in 1005 of local expenses, limited to 80% of total investments. This programme is limited to the cases of implementation hydroelectric projects, small hydro, and transmission lines. Using the possible variations of basic spread, two types of financing were considered in the Support Financing Programme for the Electricity Sector: Basic Level and Special Level.

FINEM	Basic Level	Special Level
TJLP	9.75%	9.75%
Basic Spread	2.5%	1.0%
Risk Spread	2.5%	0.0%
Financing of local expenses	100%	100%
Limit of total investments	80%	80%

The objective of analysing the rules for investments for priority electricity projects is to evaluate the possible effects of using wind energy as priority projects for electricity generation.

Other Aspects to Consider

Maintenance, Operation and Other Expenses

About the O&M costs of a wind farm, the main ones are: expenses with replacement parts, preventive maintenance, personnel costs, rental expenses with the land and also a margin for eventual unexpected expenses. The maintenance costs predicted in the catalogue Windenergy 2000, varies from 0.8% up to 1.3% over the turbine cost. The annual maintenance expenses may vary according to the local wind conditions and to the corrosive concentration levels of components at the local atmosphere.

Besides the maintenance costs of the turbines, there are also the operational personnel expenses and the expenses with use of the land. All those factors contribute for the annual expenses that have to be considered for the whole wind turbine useful life, which is around 20 years.

The total operation and maintenance costs of the wind farms are not a linear function of the wind farm size. For big projects, the annual costs with O&M have a smaller participation related to the turbine price. Generally, the big wind farm occupy a smaller area, and present a reduced operation personnel regarding the total of installed turbines.

In the case studies, it was considered a rate of 4% over the turbine price that would be used for the annual O&M costs. This fraction may be considered a conservative value, since the maintenance costs predicted by the manufacturers varies from 0.8 up to 1.3% over the catalogue value. Considering the costs practiced in German with the whole infrastructure installed, and that the technology transfer to local conditions requires investments in personnel training, equipment import, the value of 4% is considered reasonable, since it includes the personnel costs, training, land rental and other expenses.

2.6 - Conclusions

The current scenario in Brazil is favourable for the development of wind projects because:

- great advances were achieved in the Legal and Financial to use wind energy for electricity generation;

- the need to expand generation capacity in the short term benefits technologies that are able to produce electricity fast;
- the market reforms, “opening” the generation segment contributed to attract investors for the development of big wind projects (wind farms) for electricity generation, making economic sense in areas with high wind speeds, as expressed in the list of projects authorized by ANEEL;

But the regulatory and “economic country” risk is still considered high by many developers and market players.

Chapter 3 – Case Studies

In this chapter will be presented two different case studies, evaluating the economical and technical feasibility for the implementation of wind energy projects in those different regions. All the aspects that have to be taken into consideration for the development of a project locally and the establishment of a local wind industry will be covered.

For those analyses, it was used WASP for the identification of sites for the development of wind projects, as will be described below.

A special consideration for the complementary regimes of wind and hydro systems in Brazil will be explained, outlining the potential to use those technologies and the possibility to rationally manage the natural resources, proving a well planned expansion capacity.

3.1 - Procedures for the Evaluation of Wind Sites and the Use of Computational Tools

Usually, when a region has strong winds, it expected that it will be suitable for the implementation of wind energy power projects for electricity generation. But this factor only, is not enough to outline the feasibility of a wind development for the region. It is necessary to know, with as much details as possible, the wind behaviour and its seasonality. This way, due to the complexity involved in the wind assessment of a potential area, the identification of the accurate potential requires strict criteria. It is recommended to establish a basic procedure to identify the elements that concludes if the place presents (or not) the requirements needed for the implementation of a wind system.

This procedure can be divided in two stages. The first stage is to conduct a pre-qualification analyses of the region through a questionnaire to identify the main factors that influence the wind regime, such as soil conditions, vegetation, the terrain complexity and the presence of obstacles. The pre-qualification also includes the knowledge of the local electric system, its availability and the distance to the nearest distribution network.

It is necessary to have some information about the wind behaviour at the region. It might be verified the existence of a measurement station at the region, or, if this is not available, data might be collected form neighbour regions. Having this wind data and the surface map of the region, the wind behaviour must be analyses in order to identify if the region is suitable or not for the implementation of a project.

After finishing the pre-qualification, it is possible to have subsidies to conclude over the potential of the region being studied. If the results of the first stage are considered satisfactory, a deeper evaluation of the place with specific measurements at the region might be conducted, in order to obtain an estimated local capacity production.

The second stage is the more strategic one. In this phase is determined the feasibility of the project. It requires a lot of investment in the human resource quality, working tools and monitoring equipment. In this stage, a more elaborated assessment is done and the project is proposed. This consists at mapping the place, acquiring all data needed. With those, the wind farm map is proposed, the wind measurement stations

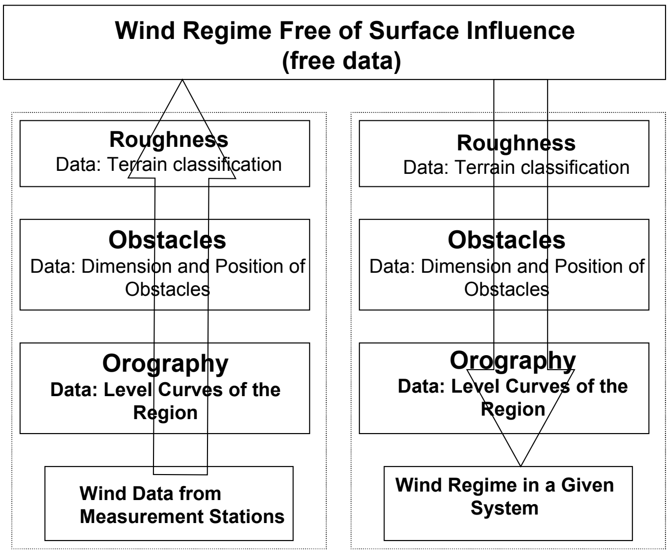
are positioned to ensure the wind regime and the positions of the aerogenerators are rehearsed.
Afterwards, with the data obtained from the wind measurement stations, a correlation with data obtained from the neighbourhood is done, and the turbine type most suitable to the place is chosen and the energy production is estimated. This results, associated with the area and equipment costs, will be used to calculate the plant capacity and the cost of the energy (in $/MWh).

The use of computational tools have been increasing in the last years, and provide a simulation of the behaviour of the speed distribution of a region.
Computational Tools are also used for the simulation of the wind turbines behaviour distributed in a certain region. This simulation is based on the wind behaviour of the region, and generally are used in a joint analyses. The optimal position of the turbines in a region is influenced by the wind speed, its direction, the surface and roughness characteristics of the region. One of the most popular programmes for this purpose is WasP (MORTENSEN, 1993).

The Programme WAsP (*Wind Atlas Analysis and Application Program*) was developed by the Danish Lab Riso (*Riso National Laboratory*) during 1987 and 1993, and it used by researchers interested in defining the wind climatologic, i.e., the speed behaviour and the wind direction, corrected for the local effects. Besides that, this Programme has capabilities to estimate the energy production of a turbine, helping at the location of wind systems and the analyses of wind farms.
The programme also enable to evaluate the influence of local topographic conditions at the wind regimes, such as the variation with the height, roughness, surface and existence of obstacle. Those factors are analysed independently in the Programme, which needs the flowing basic information's:

- Data that define the wind regime, which can be a wind time series or the distributions Weibull parameters;
- Data that describe the roughness of the terrain;
- Data that describe the location of obstacles;
- Data about the region orography;
- Data about the wind system intended to be used, mainly the power curve of the wind turbine too be used;

The working principle of WasP can be seen in the figure below. The programme requires the knowledge of the wind regime and the local orography. It is also needed an historical record of wind data, which allow the construction a seasonal distribution for different directions. As a simpler alternative, the Weibull parameters can be used in each one of the directions.



After knowing the wind regime, the influence factors are withdarwn (roughness, obstacles and orography). This way, is obtained a wind distribution free of the external effects of the place, i.e. a wind regime corresponding to a perfect land (no roughness), plain and free of obstacles.
This data, which can be called “clean data”, are the references available in most of the wind atlas, such as the *European Wind Atlas,* developed by Riso Lab.

Apart from WAsP, other programmes are available in the market. Most of them works at optimisation of calculus, attributing new models to the effects of roughness, land, and obstacles. Some of them enable a more detailed level of information.

Potential Complimentarily of Hydro and Wind Systems in Brazil

Due to a hydrogenation dominance of the electric system in Brazil, as detailed before, the seasonal stability of energy offer has become a big challenge in the historical planning of the interconnected electricity systems. This happens because the hydro systems have a stochastic profile with seasonal fluctuation of great amplitude.

The risks of not attending demand in the dry season have worsened in the last years, resulting in the rationing period experienced, due to a delay in expanding generation capacity in the restructuring period of the electricity sector. Nevertheless, in the last decade, wind power generation has demonstrated the capability of reaching Gig watts scale, necessary for an effective contribution to electric systems.

Based on existent data, it will be shown that it is feasible to achieve seasonal stability of energy offer through the complimentarily existent between the wind and hydro systems, if the vast natural resources in the country are used.

The cases for the South, Southeast and Northeast Region will be presented , where significant gains are observed due to electricity produced using natural sources that are seasonally complimentary.
Using hydro and wind energy jointly produce a stabilization in the energy offer.

International Experiences of Wind/Hydro Interaction

In 1997/98, it was realized a study with simulation in hourly resolution to two different scenarios of insertion of wind energy in the Danish electricity system, interconnected to the European electricity system. Those studies were coordinated by Roskilde University, Denmark, with contributions of energy and transmission concessionaires from Denmark, Norway and Sweden.

In the first scenario, an insertion of wind energy equal to 37% of total consumption (54% of demand) in Denmark would meet complimentarily in the hydro system of Swiss and Norway. This would assure the energy offer in the "dry" months of those countries, without any prejudice to the safely level of regional supply.

In the second scenario, it was analysed an insertion of wind energy of approximately 100% of the Danish system consumption level, interconnected to the Nordic system, including Germany, Finland and Holland. According to the simulations, this scenario would be would be technically feasible, without prejudice to the regional supply safety level, as long as complimentary investments were realized in the transmission system of Denmark /Sweden.

Including Wind Energy in the Brazilian Electricity System

The regions of Brazil that present more benefits with the use of wind complementary to hydro are the South and Northeast Regions.
In both cases, the evidences presented of the seasonal complimentarily between wind and hydro, and the tendency of seasonal stabilization of the energy offer if the hydro-wind system is put in place in a proper scale will be shown. The studies were realized at: COPEL (distribution electricity company of Parana State – South of Brazil) and CHESF (generation electricity company for the Northeast Region), where there was available enough information to indicate a complementary potential.

In those Regions, the hydro power potential is next to its limit, and the immediate alternatives considered to meet the increasing demand, have been the addition of thermal power generation or imports from remote regions, not taking into account the environmental and macroeconomic impact.

Regions South and Southeast

During the feasibility study of a wind farm of 200 MW in Palmas, in the state of Parana, COPEL conducted studies and simulations of the inclusion of the wind farm in the interconnected system. It was analysed the energetic availability of Palmas Wind Farm, with installed capacities of 50 and 200 MW. On of the aim of the study was to evaluate the complimentarily between the generation of the wind and hydro in the electrical subsystems South/Southeast. For this purpose, it was used a historical series of monthly wind generation for the period 1972 to 1993, besides the series of monthly hydro loads for the subsystem South/Southeast, with the final configuration of the generation expansion 10 year plan of cycle 1996. The wind data series was obtained from the correlation of data effectively measured at Palmas, since 1995, with data from Agro business Institute of Parana – IAPAR, IN Clevelandia, municipality situated 50 KM form the wind farm local. The scenarios were elaborated with the simulation model to equivalent subsystems – MISSE. The figure below shows the results of those simulations.

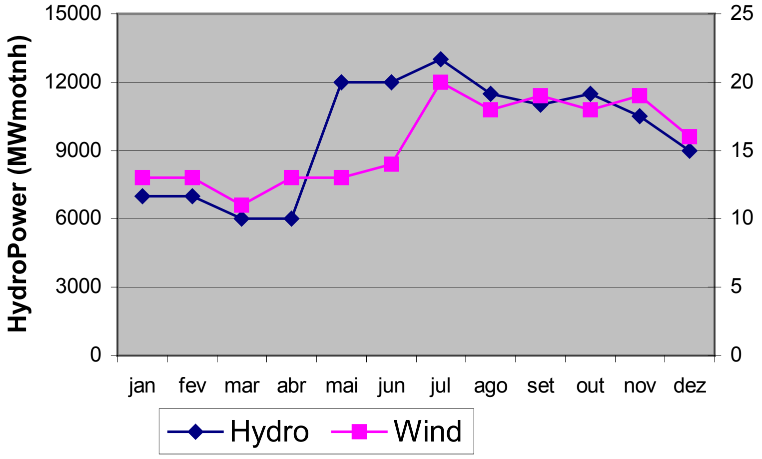


Figure 1 – Seasonal Regimes: Wind in Plamas (PR) and Hydro at South

It can be observed that the seasonal behaviour of wind generation is similar to the hydro generation at the subsystem South. The correlation coefficient was 0.226.

A relevant data can observed when comparing the monthly average wind speeds and the natural flow of Igaçu River, as observed in Figure 2. Although the wind speed is very variable in the scale of minutes or hours, the variation in the monthly averages is lower than the hydro. In statistical terms, the series of average speeds has, in average, 3.8 m/s AND 0.43 M/S of standard deviation, and the average monthly flows have an average of 863 m^3/s and 725 m^3/s of standard deviation.

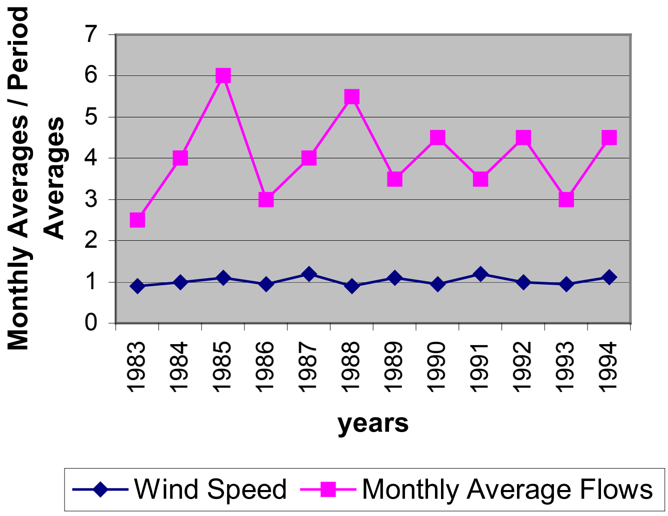


Figure 2 - Monthly averages: Wind and Water Flows

Wind Generation x Hydro Generation at Southeast Subsytem

The southeast subsystem is the one with highest contribution to the Brazilian electricity system and the relation of wind generation in Plamas 9pr) to this subsystem can been seen from figure 3.

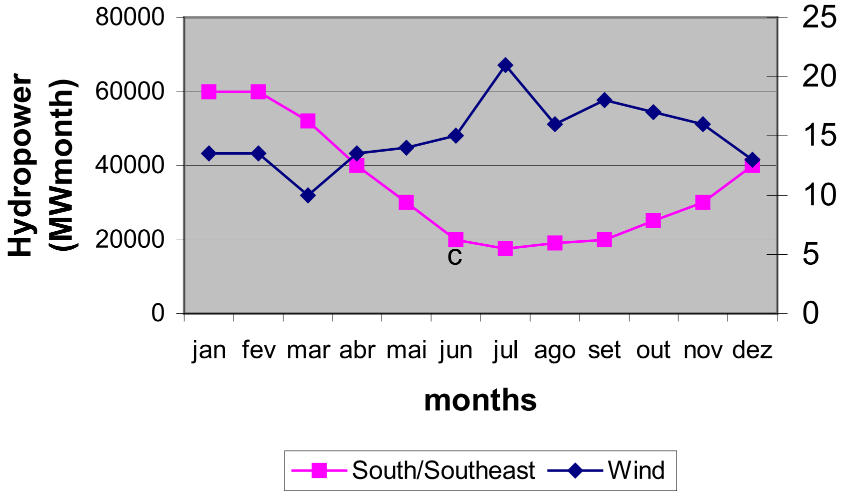


Figure 3 – Seasonal Regimes: Wind in Palmas (PR) and Hydro at Southeast

In this case, it was observed that the behaviour of the two energy sources are complimentary at the seasonal scale: the correlation coeficient was –0.48.

The simulation with installed capacity of 200 MW has shown results quantitatively similars. Other aspect covered in the study was the quantification of the frim energy generated from the wind farm, interconnected to the South and Southeast subsystems. The values obtained at the simulations were very close to the energy value measures at the porwer plant, which had a capacity factor estimated in 30%.

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From the results of this study, it can be concluded that the implementation of wind farms in wind regimes similar to the Palmas Region brings benefits to the interconnected electricity system. This happens because it will add more energy to the system in the period of the that a reduction in the hydro regime occurs at the Southeast, where the highest loads are concentrated.

To assess the wind potential for state of Parana, through the study coordinated by COPEL, 25 measurement stations were installed in the state. It was verifies that there is a high correlation between the wind regimes in the whole stat, which induces that that wind farms at the South and Southeast Region would have similar seasonal behaviour. Another relevant information concerns the size of the wind potential estimated for the state, which was induced by integrations over the mapping results, calculated in the resolution of 2km x 2km, as presented below:

Using wind starting from (m/s)	6.0	6.5
Potential technically	11.0	2.7

installable (GW)		
Energy technically useful (TWh/year)	20.5	5.8

Table – Wind Potential of state of Parana, Brazil

As a reference for comparison, the current electricity consumption in the state of Parana is around 20 TWh/year.

Northeast Region

Simulations conducted by CHESF (REF11) presented a monthly electricity production from wind turbines installed in 10% of Ceara state coast. In this scenario, the following consideration were assumed:

- wind data from the period 1993/95 were used, from wind measurement stations of five different sites along the cost of Ceara;
- the capacity curves for wind turbines of 500/600 kW were used as a base for the conception of a hypothetic wind farms, with an availability factor of 95% and other loss factors of 90%;
- for an arrangement of wind turbines with a distance of 5x7 diameter between each other and a installed capacity of around 3 GW.

Joining the production data of the wind farms with natural hydro flow of Sao Francisco River (the main River of the Northeast Region, crossing all its states), using the historical series of 1931-1992 (ref 12) with the productivity (MW m3/s) of the power plants of CHESF along Sao Francisco River , this study was elaborated.

Initially, it were used monthly wind generation data and the productivity accumulated from 2.731 MW m3/s, regarding the annual production of the power plants of Sobradinho, Itaparica, Paulo Afonso I, II, III and IV, Apolonio Sales and Xingo, with a capacity of 9974 MW of installed capacity. This way, it was converted the total electricity produced monthly for the wind farms in equivalent flow, which was theatrically located in the storage of Sobradinho, corresponding to the same production of the hydro power plants situated before it.

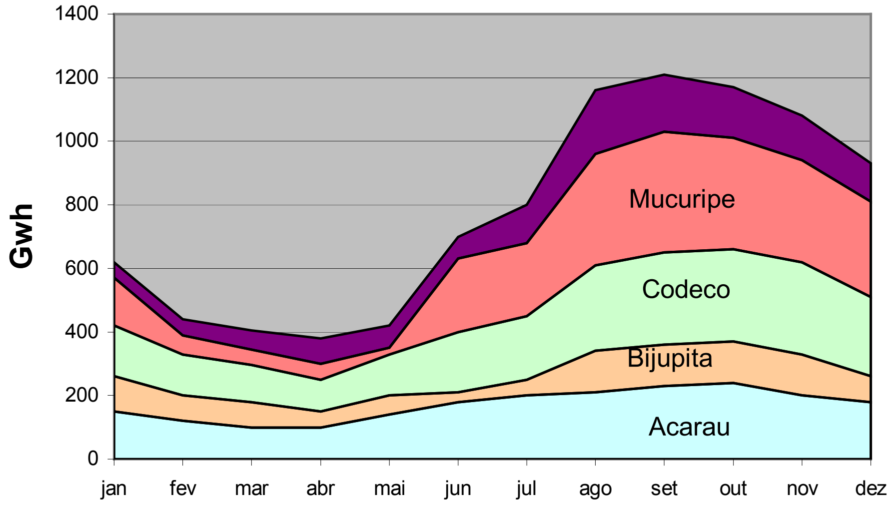


Figure 4 – Production of Wind Frams in 10% of Ceara Coast, Brazil

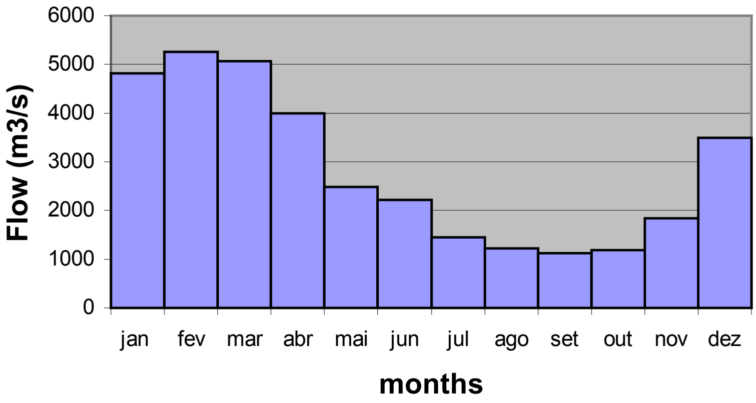


Figure 5 – Income Flow of Sobradinho Storage System, 1931/1992

Figure 6 shows the normalization of wind energy and hydro energy, i.e., the relationship between the monthly average values and the annually averages of the two systems, where it can be observed complimentary systems with positive contribution of the wind source to the electric system. This system is mainly fed by hydro generators, mainly in the dry season of Sao Francisco River and the maximum peak of the wind system, occurring in September.

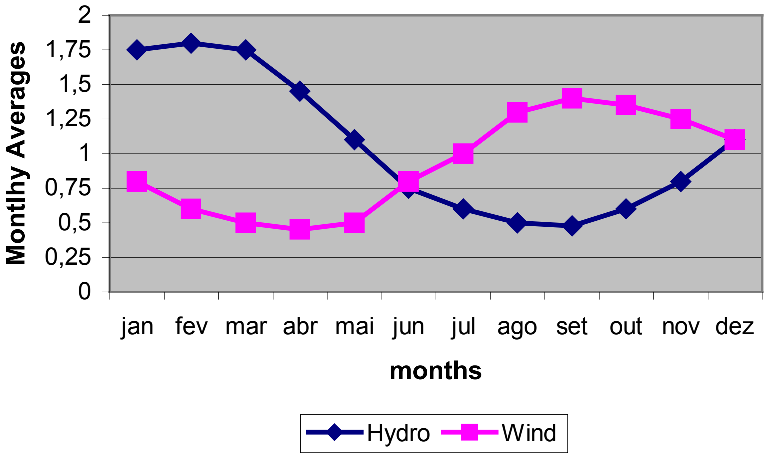


Figure 6 – Seasonal Regimes of Wind and Hydro Energies

Having the monthly average flows of São Francisco River, hypoteticalflows were added relative to the annual contribution of wind generation equivalent to 1.090 MWh/h. This was equivalent to an average flow of 400.8 m3/s, representing 14.3% of the average river flow at Sobradinho, which is 2800.5 m3/s.

Additional scenarios of including more 30% or 60% in the average river flow, resulting in a higher wind generation, are presented in figure below.

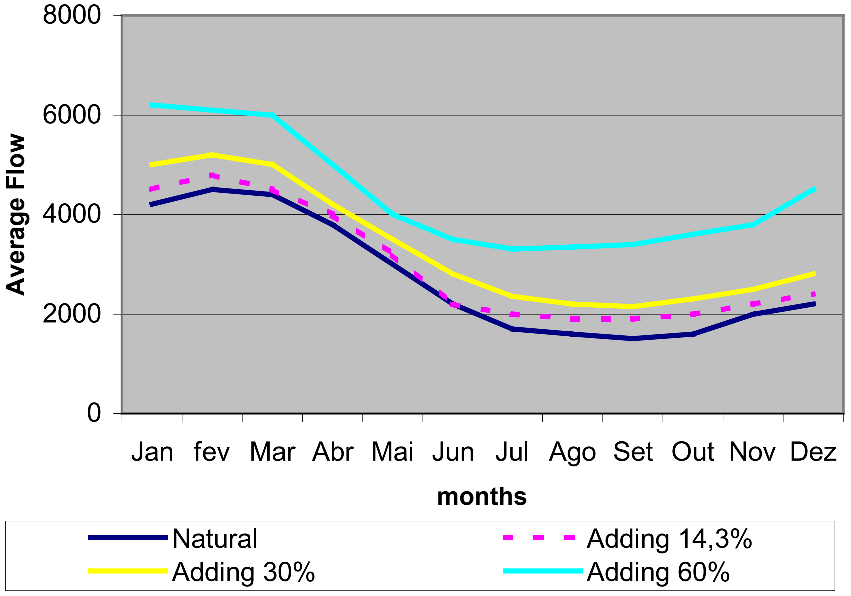


Figure 7 Increase at Average Ntural Flow (m3/s) due to Wind Generation

It can be observed that the river flow profile doesn't change as a function of the wind generation participation, specially by a higher volume increase at the river dry period.

From all the contribution that wind energy can provide to the volume increase in Sobradinho, replacing partially hydro power by wind generation, the most interesting is the one happening during the dry season of Sao Francisco River, i.e, from May to October. This way, in the table below, it was illustrated thee water volume equivalent to the energy production generated from wind developments. The first column shows the average annual electricity capacity from wind sources, needed for an equivalent percentual increase in the average flow of the River, at Sobradinho. The third column brings the corresponding hypothetical volume to be accumulated during the dry season. And finally, the fourth column presents the electricity average capacity at the wet periods, produced by wind farms.

MWh/h yearly	Wind Contribution (%)	Billion m3 – dry season	MWh/h dry period
1090.0	14.3	7.4	921.4
2286.7	30.0	15.5	1933.0
4573.4	60.0	31.0	3866.0

Table 3- Capacity at Dry and Wet Periods

After November, it can be considered the beginning of the wet period, which is critical in term of energy, because it happens at the same period when Sobradinho has the lowest storage volumes. As an example, it can be outlined the volumes of 100.92% and 11.33% of the total volume for the years 1987 and 1999, respectively. At this period, a similar approach can be conducted, using the benefits form the wind energy production, still high in this month.

As it can be observed, the control over the flow of Sao Francisco River can receive good contribution from the wind potential use. This contribution can happen, not only from wind from Ceara, but also from other states from North and Northeast, where the highest potential is observed in the second semester, due to incoming aliseos winds.

Additionally, it wasn't accounted the losses for the transmission systems which serves the North system of CHESF. This value was predicted for September 2000, as being 8.7% or the equivalent to 118 MW, because of the long distances between the transmission lines. This value, even if discounted from the losses, would contribute to a positive perceptual for the wind resources, increasing proportionally the values presente at Table 3.

One of the characteristics of Sobradinho storage is that it hardly overflows, even in the wet period, as observed in all its operations (ref12).

The Northeast is known by its constant winds and of high intensity in the cost. It is also observed the existence of dunes in areas next to the sea, with very low roughness index and possibility to experience orography accelerations f the wind. The State of Ceara, for example, has more than 400 Km2 of dunes in its coast, having wind farms operating over dunes at the beaches of Taiba and Prainha.

One of the arguments against wind energy is the fact that it does not produce firm energy (hydroelectric stores potential energy in storage systems, while wind farms count on the kinetic energy from atmosphere). But, as it has been demonstrated, the operational integration of hydroelectric with wind power plants tends to optimise the use of the hydro storages and add seasonal stability to the interconnected electric system.

Nevertheless, the storage of water takes to different interests, once the Northeast is vulnerable to extensive dry periods. The waters of Sao Francisco River are used for diverse purposes, mainly to land irrigation by the government. One of the alternatives, with the use of wind energy, would be change the river course, through channels and bomb systems, to the regions historically dry.

The case studies presented in the sequence will explore this potential for integration, since they are situated in the South and Northeast Region of Brazil. The first case study presents a general assessment of the potential of a whole State, identifying the better areas for development, whereas the second case is more focused in a specific site.

3.2 - Case 1 - Wind Energy in the South of Brazil – The case of Rio Grande do Sul -RS

Introduction – State Wind Atlas

In August 2001, it was issued The Wind Atlas of Rio Grande do Sul. This was the fruit of the initiative of the Secretariat of Energy, Mines and Communication SEMC and has been elaborated from wind data obtained as a result of institutional partnerships.

This work forms part of the incentive of wind energy in the State of Rio Grande do Sul (RS) began in 1999 when the first steps were taken, of note being the 1st Seminar on Wind Energy in Rio Grande do Sul, sponsored and organized by SEMC, and the signing of the first letter of intention for the recording of wind measurements in RS, between SEMC and the CEEE, and the following companies: Gamesa (of the group Iberdrola), Energia Regenerativa Brasil Ltda- ERB, Enerfín (of the group Elecnor) and Raiko Engenharia e Consultoria Ltda. A further two protocols were signed between the SEMC and Wöbben and the following entities: the Departamento Municipal de Energia de Ijuí-DEMEI (the Municipal Department of Energy of Ijuí) and the Cooperativa Regional de Eletrificação Teutônia CERTEL (the Regional

Electrification Cooperative of Teutônia).

By the second half of 2001, the SEMC already had sufficient information and measurement time to take the first steps in the elaboration of the first Wind Atlas of Rio Grande do Sul. Anemometric data from 21 towers has been used in the Atlas, covering a period equal to or greater than 12 months, valid for climatologically comparison and the filtering of local effects such as topography and ruggedness.

At present there are 26 towers in the State and, until the end of the year 2002 the number of sites with high quality wind measurements should reach 36, as shown in the Table below.

Protocol Signatures	**Measurement Towers**		
	Nº	**Municipalities**	**Start of Measurements**
SEMC / CEEE / WOBBEN 9/12/1999	1	Imbé	7/7/2000
	2	Cidreira	8/2/2000
	3	Arroio do Sal	5/4/2001
	4	Santa Vitória do Palmar	1/29/2001
	5	Cassino	7/20/2001
SEMC / WOBBEN / CERTEL 17/9/2000	1	Progresso	1/3/2001
SEMC / CEEE / Gamesa 3/4/2000	1	São Francisco de Paula	1/16/2001
	2	Imbé	1/17/2001
	3	Palmares do Sul	1/19/2001
	4	Tapes	1/22/2001
	5	São Lourenço do Sul	1/23/2001
	6	São José do Norte	1/25/2001
	7	Rio Grande	1/26/2001
	8	Santa Vitória do Palmar	1/28/2001
	9	Jaguarão	2/6/2001
	10	Piratini	2/7/2001
	11	Livramento	2/12/2001
	12	Faxinalzinho	2/13/2001
SEMC / CEEE / ERB 15/5/2001	1	Arambaré	10/27/2001
	2	Santa Vitória do Palmar	11/11/2001
	3	São Francisco de Paula	12/8/2001
	4	Mostardas	1/11/2002
SEMC / CEEE	1	Balneário Pinhal	3/04/2002
	2	Mostardas	3/7/2002
	3	Osório	7/31/2002
	4	Mostardas	To be installed
	5	Jaquirana	To be installed
	6	Vacaria	To be installed
	7	Canguçu	To be installed
	8	Rio Grande	To be installed
	9	São José do Norte	To be installed
	10	Sta Vitória do Palmar	To be installed
	11	Giruá	To be installed
	12	Santiago	To be installed
SEMC / CEEE / ENERFIN 26/11/2001	1	Osório	4/19/2002
SEMC / WOBBEN / DEMEI 26/2/2002	1	Ijuí	To be installed
SEMC / CEEE / RAIKO		To be defined	To be defined

All measurements are being obtained with the use of shell type calibrated and certified anemometers, installed in 26 towers, with heights of between 40m and 50m, located in specially selected sites. Technical staff from the Secretariat and CEEE participated in the selection of the measurement sites, installation of the towers and equipment and performed the collection and treatment of the wind data collected. These activities conform to the rigorous technical procedures and recommendations of the German Institute of Wind Energy DEWI and the International Energy Agency IEA. As well as the elaboration of this Atlas, this work has made it possible to wind turbine projects, some of which are registered with the ANEEL (National Electrical Energy Agency) and currently being considered for environmental permission. Their implantation, dependent upon Federal regulation, will represent the concrete introduction of wind energy into power network of Rio Grande do Sul.

Along the length of the 630km of the coastline of the State of Rio Grande do Sul; there are 986km2 of sand and dunes, fanned by intense and constant winds. Also inland, many winds come together with the Minuano to compose one of the most promising sources of wind power in Brazil. Add to this scenario an electrical power network that has recently received substantial investment in the areas of generation and transmission in order to meet the increased demand for electrical energy resulting from the industrialization and economic development of the State.

In this context, wind energy represents an alternative capable of contributing to the strengthening of the state electrical network, and even to the Brazilian national grid, given the high degree of seasonal complementarity between the natural wind and hydraulic flow rates in Brazil. In the socio-economic field, the potential fringe benefits, known to be associated with large scale wind-generated electrical energy: self-sustainability, with the use of natural resources existing within the State, the attraction of a manufacturing investment, such as in electrical generating plants and wind turbine component factories, the generation of employment, technological advancements, decentralized economic development, as well as the conservation of the environment.

The Atlas contains detailed mapping of the main parameters related to the wind and its energy potential, at a resolution of 1km x 1km for the entire State of Rio Grande do Sul, using mesoscale modelling tools and three-dimensional boundary-layer simulation, state-of-the-art methodologies in the sector. To the institutional action of the Secretariat of Energy, Mines and Communications of the State of Rio Grande do Sul was added the invaluable support of the most important companies of the wind energy sector operating in Brazil, that made available anemometric data of the highest quality, measured in high towers, constructed in especially favourable locations and equipped with calibrated and certified instrumentation.

RS – Geography and Demography

With a territorial area of 282, 062 km2 (3.30% of the Brazilian territory) and occupying the southern extreme of Brazil, the state of Rio Grande do Sul has boundaries with the State of Santa Catarina to the N-NE, the Argentine Republic to the W-NW, the Republic of Uruguay to the S-SW and is bathed by the Atlantic Ocean on its eastern edge. It is located between the longitudes 57°36'14"W - 49°42'00W and the latitudes 33°45'37"S - 27°05'20"S.

According to the Demographic Census 2000-IGBE (Brazilian Institute of Geography and Statistics) the population of the state is 10,187,798 inhabitants. There was an increase of 11.4% in the decade from 1991 to 2000 (1.02% per year in recent years).

In this period the urban population increased from 76.6% to 81.6%, while the rural population also diminished in absolute terms: of the 2.14 million rural inhabitants recorded in the census of 1991, 1.87 million remained in 2000. This represents not only the migration of rural population to the urban centers, a recurrent phenomenon throughout Brazil in recent decades, but also the migration of rural entrepreneurs and workers to the new important agricultural frontiers of the Midwest and North of Brazil, where there is a notable presence of Gaucho pioneers. Around 28% of the population of Rio Grande do Sul is located in municipalities that form the Metropolitan Region of Porto Alegre - the main center of energy consumption in the State. Also notable are the large industrial centers of Caxias and Pelotas, cities with populations of over 300,000 inhabitants.

Map 1, in Annex II illustrates the distribution of the population in the State, while the Population Map, Map 2, in Annex II quantifies the number of inhabitants in each one of the 467 municipalities of the State, according to the Demographic Census of 2000 IGBE.

Transport

The internal road network of the territory of State is 24,580 km in total length; of which the paved state and federal roads total 10,543 km and the unpaved 5,437km. For maritime transport the State has two important ports: Rio Grande and Porto Alegre, which are also linked to the hinterland and the extreme west of the State by an extensive rail network. The road network and the main ports in operation are included in the Population Map.

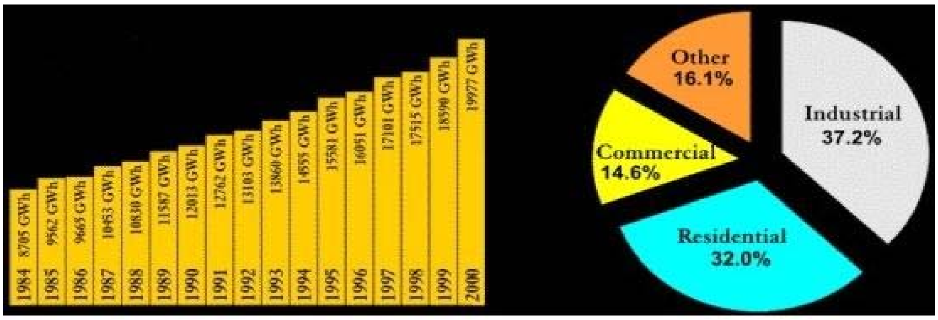
Electrical Energy Consumption

Figure above shows the participation by sector and evolution of electrical energy consumption in the period 1984-1999 [20]. In the period shown, the average expansion of consumption was 5.5% per year. At present, the beginning of the 21st century, the consumption of electrical energy in the State exceeds 20 TWh/annum, with an annual per capita consumption in excess of 2,000 kWh.

Electrical System

As shown in Map3, in Annex II, the electrical transmission infrastructure in the state of Rio Grande do Sul is inserted in the Brazilian national system, while at the same time it is connected to the Argentinean electrical system (through the Garabi and Uruguaiana converter stations) and to the Uruguayan electrical system (Rivera converter station, at the frontier with Sant'Ana do Livramento). The grid frequency used in Argentina and Uruguay is 50Hz while that of Brazil is 60Hz, hence the necessity for conversion stations in transnational energy integration.

Electrical Energy Consumption



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Hydroelectric	**MW**
Itá	725
Machadinho	570
Itaúba	500
Passo Fundo	226
Jacuí	180
Passo Real	158
Dona Francisca	125
31 Peq. Centrais Hidrelétricas	46.7
Canastra	44.8
Total 2576MW	

Thermoelectric	**MW**	**Fuel**
Uruguaiana	600	Gás Natural
Presidente Médici	446	Carvão
Canoas I	160	Gás Natural
Charqueadas	72	Carvão
Oswaldo Aranha(Alegrete)	66	Óleo Combustível
Nutepa	24	Óleo Combustível
São Jerônimo	20	Carvão
Piratini	10	Resíduos de Madeira

Uruguaiana II	8	Casca de Arroz
Total 1406 MW		

Situated at the extreme of the Brazilian national system, the Rio Grande electrical system has historically been dependent on additional supply transmissions, as well as the expansion of thermal generation. Table above shows the installed generating capacity in Rio Grande do Sul, as in 2002 [22].

Maximum demand in the state electrical system occurs in the evening, in the summer months, caused by the widespread necessity for ambient refrigeration. This peak has reached values close to 4,000MW (2001-2002). Since 1999, the investments in transmission and sub stations, coordinated by the Secretariat of Energy, Mines and Communication of the State have guaranteed the margin of safety necessary to attend the consumption peaks within the State.

The State possesses 6,400 km of basic network transmission lines in 525 kV and 230kV, 5,200km of sub-transmission lines in 138kV, 69kV and 44kV, and around 100,000 km of distribution lines in 23.1kVand 13.8kV[25]. The electrical system of Rio Grande do Sul is composed of three specifically generating companies, 1 transmission company, 1 in energy interconnection, 8 concessionaires and 15 cooperatives, as shown in Table 2.2. The distribution of electrical energy in Rio Grande do Sul is carried out mainly by the companies CEEE - Companhia Estadual de Energia Elétrica S.A, AES-SUL - Distribuidora Gaúcha de Energia S.A., and RGE - Rio Grande Energia S.A.

Power Generation	
	AES Uruguaiana LTDA.
CGTEE	Companhia de Geração Térmica de energia Elétrica
	Tractebel Energia S.A. (Ex GERASUL)
Power Transmission	
ELETROSUL	Empresa Transmissora de Energia Elétrica do Sul do Brasil.
International Interconnection	
CIEN	Companhia de Interconecção Energética
Power Distribution	
AES Sul	Distribuidora Gaúcha de Energia Elétrica S.A.
CEEE	Companhia Estadual de Energia Elétrica
RGE	Rio Grande Energia S.A.
DEMEI	Departamento Municipal de Energia de Ijuí
ELETROCAR	Centrais Elétricas de Carazinho S.A
HIDROPAN	Hidrelétrica Panambi
UHENPAL	Usina Hidroelétrica Nova Palma Ltda
	Muxfeldt Marin & Cia Ltda
Cooperatives	
CELETRO	Cooperativa de Eletrificação Centro Jacuí Ltda
CERFOX	Cooperativa de Energia e Desenvolvimento Rural Coprel Ltda
CERILUZ	Cooperativa Regional de Energia e Desenvolvimento Ijuí Ltda
CERMISSÕES	Cooperativa Regional de Eletrificação Rural das Missões Ltda
CERTAJA	Cooperativa Regional de Energia e Desenvolvimento Rural
CERTEL	Cooperativa Regional de Eletrificação Teotônia Ltda

CERTHIL	Cooperativa de Energia e Desenvolvimento Rural Entre Rios
CERVALE	Cooperativa de Eletrificação Rural do Vale do Jaguarí Ltda
COOPERLUZ	Cooperativa de Eletrificação Rural Fronteira Noroeste Ltda
COOPERNORTE	Cooperativa Regional de Energia e Desenvolvimento do Litoral
COOPERSUL	Cooperativa Regional de Eletrificação Rural Fronteira Sul Ltda

Climatology

The seasonal rain pattern in Rio Grande do Sul is presented in Map 4, Annex II. The climatological series exhibit one of the main characteristics of the temperate subtropical climate of southern Brazil, with rainfall distributed throughout the year. The inter-regional fluctuations within the State are of small magnitude, with a noticeable tendency for annual precipitation levels to increase from the south to the north, varying between 1,200mm and 2,500mm.

On the other hand, as it is situated at the southern extreme of Brazil, Rio Grande do Sul has the widest annual temperature range, reaching temperatures as low as 0°C in the winter and experiencing hot (30°C >), humid days in the summer. The coldest region is, naturally, situated among the highest mountain plains, while the hottest region is the extreme west of the State. The following maps respectively, show the average seasonal temperatures and the average annual temperature in Rio Grande do Sul, elaborated from climatological data extracted from Map 4, corrected for altitude from the digital elevation model.
This degree of fluctuation in temperature in the course of the year may imply variations of over 10% in air density, with a consequent impact on wind power generation. The air density [kg/m3] varies with the altitude and the temperature as shown in Appendix III, where dry air was considered. Additional fluctuations in density, though less accentuated, occur due to variations in air humidity indicator. The following maps show, respectively, seasonal and annual average air densities in the State of Rio Grande do Sul.

Wind Patterns

Despite apparent unpredictability, the wind shows a continual movement of the atmosphere, resulting from the circulation of masses of air provoked by the radiant energy of the Sun and the rotation of the Earth. Among the principal action mechanisms, the unequal heating of the Earth´s surface, that occurs at both a global (latitudes and day-night cycle) and local (sea-land, mountain-valley) scale, stands out. Thus, it is natural that wind speeds and directions exhibit daily and seasonal tendencies within a stochastic character.

Figure 1, Annex II synthesizes the daily and seasonal patterns in the different regions of Rio Grande do Sul, based upon 10 minute average recordings obtained from anemometric towers. The graphs show the normalized average hourly speeds - i.e. divided by the value of the average annual speed - and the variation over the 24 hours of the day and the 12 months of the year. In seasonal terms, the intense winds of the second half of the year stand out, as they occur in all regions, with slight discrepancies in the occurrence of the peaks between the extreme east and extreme west of the State. This seasonality is also shown in the Wind Maps. In the atmospheric flow over Rio Grande do Sul, the effects dictated by the dynamic between the Atlantic sub-tropical anticyclone, the intermittent displacement of masses of polar air and the barometric depression to the north-east of Argentina dominate.

The Atlantic sub-tropical anticyclone is a high pressure center, the average annual position is close to 30°S, 25°W. The resultant atmospheric circulation, in an anti-clockwise direction, leads to the predominance of east-northeasterly winds over the entire area of Brazil situated below latitude 10°S.

The barometric depression to the northeast of Argentina is an almost permanent area of low pressure, generally stationary, located to the east of the Andes, the average annual position of which is approximately 29°S and 66°W. This depression is caused by the general atmospheric circulation blockage imposed by the mountainous wall of the Andes and accentuated by the intense heating of the lowland plains of the region. The atmospheric pressure gradient between the depression of the northeast Argentina and the Atlantic sub-tropical anticyclone provokes a persistent flow from the east- northeast throughout the region of Southern Brazil. This flow results in average annual wind speeds of 5.5m/s to 6.5m/s over large areas of the region. However, in this general picture of atmospheric circulation there are significant variations at the mesoscale and micro-scale, due to differences in the properties of the surface, such as geometry and altitude of the terrain, vegetation and distribution of the land and water surfaces. These variations may give rise to local wind conditions that are significantly different from the general picture of the large scale atmospheric circulation in the region, as can be seen from the Wind Maps. Thus, wind speed in excess of 7m/s may be found at more favorable elevations of the continent, always associated with a low level of roughness of the plain. Another large area with speeds exceeding 7m/s is that along the extensive coast that extends from Imbé to the extreme south of the State, where the predominant winds from the east-northeast are accentuated by the daily action of the sea breezes, during the months of spring, summer and the beginning of autumn.

Up to now, the predominant wind patterns have been emphasized, but it is very important to highlight the dynamic character of the circulation over Rio Grande do Sul, especially the intermittent passing of cold fronts. These are more intense in winter and spring, bringing the well known Minuano, a strong, cold cutting wind that blows from the SW over the plains, and lasts for about three days with the passing of each mass of polar air.

An example of this dynamic is presented in Figure2, Annex II : above are shown the speed vectors during the displacement of a mass of polar air, represented by the color blue. The cold air has greater density and the barometric pressure in the area occupied by these parcels of chilled atmosphere is high, that have a horizontal dimension of around 1,000 km and are generated in the South Pole, within the process of atmospheric circulation. Being denser, the mass of cold air advances, raising the masses of warmer air in its path, which causes the rains on the leading edge.

The arrival of the front is preceded by winds from the north-northwest, that bring more intense winds, though of short duration. The passing of the front is followed by the Minuano, a blast of cold air from the southwest, with speeds that can exceed 10 m/s for several days. Gradually, with time, the general condition of the winds from the north-north-east tends to re-establish itself, until the passing of a new front. In the period presented in above figure - a sample July-August from the Coxilha de Santana- it is possible to observe the passing of at least 5 cold fronts, marked by variations of 360° in the wind direction. On one occasion the average wind at 10 minutes (at a height of 40m) reached 27m/s (97.2 km/h) with the arrival of a front. Three times in the sampled period, the Minuano persisted for days, as shown in yellow. Certainly the Minuano is a wind of great significance to the gaucho riding on the open plains, for the strong blasts of arctic air that persist throughout the days.

Although it is not predominant, the Minuano represents an important contribution to wind potential of Rio Grande do Sul.

Some of the Wind Maps obtained, such as: Directions x Frequency, Direction x Wind Speed, Wind Speed Seasonal and Annual at different Heightsand the Weibull Shape factor, are presented in Annex II.

Analyses and Diagnoses

Most Favorable Areas

- **The Mission Plateau** - areas that alternate steppes, seasonal forest and agricultural activity, with annual average winds close to 7.0m/s at the higher elevations. Two sub-stations are situated in the region in Santo Angelo and Santa Rosa, with transmisson lines of 230kV and 500kV. The main potential consumption centers are the cities oj Ijuí (78.5 The main potential consumption centers are the cities oj Ijuí (78.5 thousand), Santo Angelo (76.7 thousand), Santa Rosa (65.0 thousand) and Palmeira das Missões (38.2 thousand).
- **Serra Gaúcha** - areas that alternate mixed ombrophile forest (araucaria forest) and open grassy-wooded areas, with annual average winds in the range of 7.0 to 7.5m/s at the highest elevations, standing out those elevated areas situated to the notheast of the city of Canela and highest elevations, standing out those elevated areas situated to the notheast of the city of Canela and pincipally the upper mountain plains, in the vicinity of Bom Jesus and São José dos Ausentes. Of note in the eletrical system are the sub-stations of Vacaria and Caxias do Sul with transmission lines of 138kV and 230kV. The main cities are Caxias do Sul (360.4 thousand), Bento Gonçalves (91.5 thousand), Vacaria (57.3 thousand), São Francisco de Paula (19.7 thousand) and Bom Jesus (12.0 thousand).
- **The Lagoa dos Patos Shoreline** - a flat area with predominately low scrub vegetation and agricultural activities, there is an extensive region of sand and dunes along the shore, with annual average winds of 7.0 to 8.0m/s. A promising region for the installation of largewind power plants. The access from the BR101 consists of a long stretch of unpaved road, hampering transit. There is a transmission line of 138kV linking yhe cities of Mostardas, Palmares do Sul and Osório. The main consumption centers of the region are the cities of São José do Norte (23.8 thousand), Palmares do Sul (10.9 thousand) and further north, the cities of Osório (36.1 thousand), Tramandaí (31.0 thousand) and Imbé (12.2 thousand). The latter cities are coastal resorts and experience a considerable increase in population and energy consumption in the summer period (December-January-February).
- **Coxilha de Santana -** an extensive area of low lying hills on the Gaucho plains (vegetation grassy-wooded), with annual average winds of 7.0 to 7.5m/s at higher elevations. There is a transmission line of 230kV, linking the sub-stations of the city of Sant'Ana do Livramento, the main center of consumption of the region (90.8 thousand inhabitants(, to the cities of Bagé, Alegrete and to the Uruguay (Rivera converter station).
- **Rio Grande Shield** - areas of steppes, alternated with grassy-wooded vegetation (fields) and tree cover, with average annual winds in the range of 7.0 to 8.0m/s at the higher elevations. The region is crossed by transmission lines of 230kV, linking the sub-station of Bagé and the thermal eletric power of Presidente Médici to the state eletrical system. The mais cities are Bagé (118.8 thousand), Canguçu (51.4 thousand), Piratini (19.4 thousand)and Pinheiro Machado (14.5 thousand).
- **South Coast -** extensive area of coastal plain, covered by low scrub, dunes and low roughness of predominating rice plantations and pastures. It has large

extensions with annual average wind plantations and pastures. It has large extensions with annual average wind power plants. There is a wide extension of dunes alond the shore of the Lagoa Mangueira (Margueira Lagoon), where the annual averages exceed 8.0m/s. The area is acessible by existing roads between the Lagoa Mangueira and Lagoa Mirim (Mirim Lagoon). A transmission line of 138kV links the municipalities of Santa Vitória do Palmar to Rio Grande. Among the potencial consumption centers are the cities of Pelotas (323 thousand inhabitants), Rio Grande (186.5 thousand inhabitants) and Santa Vitória do Palmar (33.3 thousand), according to data from IBGE-Census 2000.

Those regions are shown in the Maps, Annex II.

Estimated Wind Resource

From the calculations of the annual average wind speeds in the entire State of Rio Grande do Sul, it is possible to estimate the wind-electric power that can be effectively utilized given the present level of wind power plant technology, by integrating the wind speed maps, applying geoprocessing tools and calculations of the performance and electrical energy production of typical wind power plants. In this process the following conditions were presumed:

- To each of the 3 heights of calculated wind speeds, 50m, 75m and 100m, average performance curves of commercial wind plants in the following classes were considered, 500kW, 1500kW and 300kW, with rotor diameters of 40m, 80m and 100m and heights of 50m, 75m and 100m, respectively. The class 3000kW was included, as there is a recognized tendency for increased capacity of wind turbines in wind power industry. In this case the performance was extrapolated from the typical power curves of 1500kW and 2500kW turbines, taking into consideration the power is proportional to the area swept by the rotor. The power classes and dimensions considered were not based upon any one specific turbine available on the market, and the results do not indicate significant variations for turbines of dimensions proximal to those considered. For example, the power does not alter significantly when turbines of 600kW to 750kW are considered in place of 500kW, or 1200kW-1800kW in place of 1500kW.

- Standard criteria of aerogenerator spacing and density in commercial wind power plants, together with the simulation of the aerodynamic interference caused by clusters of aerogenerators, according to an aerodynamic wake mathematical model [19], considering an average representative wind-rose of the most promising areas in Rio Grande do Sul, an average occupation rate of 7.5MW/km2, is estimated, with an energy efficiency rate of 97% on flat, obstacle-free terrain. However, in practice there is the possibility of technical restrictions that may reduce this rate of terrain occupation: unfavorable topography, inhabited areas, difficult access, areas prone to flooding or other restrictions that may limit the use of the terrain. Thus, an average occupation rate of 20% of that possible in flat, obstacle free terrain was considered a sufficiently conservative premise, resulting in an average occupation rate of 1.5 MW/km2.
- The areas with annual average speeds from 6m/s, in bands of 0.5m/s have been integrated into the respective maps with a resolution of 1km x 1km, covering the entire territory of Rio Grande do Sul.
- The integration and the potential generation calculation were performed separately in cases of wind plants implanted on:
  - LAND (onshore), in which the areas covered by the main lagoons, reservoirs, lakes, rivers and sea are discarded;

  - WATER (offshore), covering only the main lagoons of the State: the Lagoa dos Patos, the Lagoa Mirim and the Lagoa Mangueira. As they are situated on the extensive coastal plain, these lagoons are naturally shallow and extensive in area, being potentially suitable for the future installation of offshore wind power plants. The Lagoa dos Patos, which is 265km long and has a surface area of 10,000 km2 has a relatively flat bed and an average depth of 6m to 7m and points of less depth along its west bank. The Lagoa Mirim, with an extension of 180km and total surface area of 3,750 km2 (part of which is in Uruguayan territory), has depths of the order of 1m to 2m in the north, reaching 4m in the central area and 5-6m in the south. The shore and banks which are low and sandy and marshes and reed banks are common. The Lagoa Mangueira, which is 123km in length and has a surface area of approximately 800km, is the smallest and shallowest of the three lagoons considered in the calculation of the utilizable offshore wind power in Rio Grande do Sul.
- In each wind speed integration band, the capacity factors corresponding to the minimum threshold of the speed band were considered. Such capacity factors were corrected for the local density effects, from the Air Density Map presented on page 11 which was elaborated at a resolution of 1km x 1km, from climatological data and the relief model;
- The local Weibull Form Factors (k) were considered, as shown in the corresponding wind map in Annex II.
- An availability factor of 98%, and a plant efficiency (aerodynamic interference between rotors) of 97% were considered in the performance calculation.

The following table shows the result of the integration of the maps, by speed bands.

		LAND(Onshore)				WATER(Offshore)			
	Wind [m/s]	Area [Km2]	Installable Power [GW]	Capacity Factor	Annual Yeld [TWh/year]	Area [Km2]	Installable Power [GW]	Capacitye Factor	Annual Yeld [TWh/year]
50m	6.0-6.5	74157	111.24	0.20	192.51	121	0.18	0.21	0.32
	6.5-7.0	29045	43.57	0.25	92.03	760	1.14	0.25	2.48
	7.0-7.5	8191	12.29	0.29	30.99	6144	9.22	0.30	23.72
	7.5-8.0	1993	2.99	0.34	8.82	5363	8.04	0.35	23.90
	8.0-8.5	363	0.54	0.39	1.82	827	1.24	0.39	4.16
	8.5	11	0.02	0.43	0.06	12	0.02	0.43	0.07
75m	6.0-6.5	86035	129.05	0.19	206.18	72	0.11	0.19	0.18
	6.5-7.0	73197	109.80	0.023	215.12	204	1.31	0.23	0.62
	7.0-7.5	28211	42.32	0.27	98.83	3074	4.61	0.28	11.09
	7.5-8.0	6744	10.12	0.32	27.70	6653	9.98	0.33	27.87
	8.0-8.5	1246	1.87	0.37	5.88	3209	4.81	0.37	15.27
	8.5	83	0.12	0.41	0.44	70	0.11	0.41	0.37
100m	6.0-6.5	74157	111.24	0.20	192.51	43	0.06	0.16	0.09
	6.5-7.0	29045	43.57	0.25	92.03	105	1.16	0.20	0.27
	7.0-7.5	8191	12.29	0.29	30.99	1075	1.61	0.24	3.36
	7.5-8.0	1993	2.99	0.34	8.82	7206	10.81	0.29	26.54
	8.0-8.5	363	0.54	0.39	1.82	4636	6.95	0.33	19.66
	8.5	11	0.02	0.43	0.06	242	0.36	0.37	1.16

The Estimated Wind Resource of the state of Rio Grande do Sul is presented in the table above.

		LAND(Onshore)			WATER(Offshore)		
	Wind [m/s]	Area [Km2]	Installable Power [GW]	Annual Yeld [TWh/year]	Area [Km2]	Installable Power	Annual Yeld [TWh/year]
50m	>6.0	113760	170.64	326.23	13227	19.84	54.64
	>6.5	39603	59.40	133.72	13106	19.66	54.32
	7.0	10558	15.84	41.69	12346	18.52	51.84
	>7.5	2367	3.55	10.70	6202	9.30	28.12
	>8.0	374	0.56	1.88	839	1.26	4.22
	8.5	11	0.02	0.06	12	0.02	0.07
75m	>6.0	195516	293.27	554.16	13282	19.92	55.40
	>6.5	109481	164.22	347.98	13210	19.82	55.22
	>7.0	36284	54.43	132.98	13006	19.51	54.61
	>7.5	8073	12.11	34.02	9932	14.90	43.52
	>8.0	1329	1.99	6.32	3279	4.92	15.64
	8.5	83	0.12	0.44	70	0.11	0.37
100m	>6.0	230820	346.23	607.55	13307	19.96	51.08
	>6.5	173044	259.56	490.68	13264	19.90	50.99
	>7.0	76797	115.19	247.11	13159	19.74	50.72
	>7.5	21695	32.54	79.93	12084	18.13	47.36
	>8.0	3298	4.94	13.93	4878	7.32	20.82
	8.5	230	0.34	1.08	242	0.36	1.16

The attraction thresholds for the investment in wind power generation depend upon the economic and institutional context of each country, varying in terms of the annual average speeds, between 5.5m/s and 7.0m/s. Technically, annual averages from 6.0m/s constitute favorable conditions for the operation of wind power plants. In the following analysis a threshold of 7.0 m/s will be presumed as reference.

The results of the cumulative integration suggest great magnitude for the estimated usable wind energy on land (onshore) in Rio Grande do Sul, in the order of 15.8GW, 54.4GW and 115.2GW, for areas with winds equal to or greater than 7.0m/s, at heights of 50m, 75m and 100m, respectively.

The magnitude of the wind power over water (offshore) is also noteworthy, considering only the three main lagoons, the result of the integration of the annual average wind speeds calculated for the lagoons, dos Patos, Mirim, and Mangeira, is estimated at 18.52GW, 19.51GW and 19.74GW, for winds equal to or greater than 7.0m/s, at heights of 50m, 75m and 100m, respectively. Having low roughness, in these areas the boundary-layer recovers part of the kinetic energy lost upon passing over the terrain of the Atlantic coast, recording the highest average speeds in Rio Grande territory. It can be observed that, due to low roughness the over the water, the wind power at the three heights differ little, since the variation of the vertical wind speed profile in the atmosphere is a function of the roughness of the terrain, as well as the vertical thermal stability.

The estimated wind power for the State of Rio Grande do Sul is relatively high. As a comparative reference to the values resulting from the integration, the Brazilian nation system possessed a total installed capacity of 77.0GW, up to the end of

2001[22], and the total Brazilian hydraulic resources (inventoried plus estimated) is 143.4GW[20]. The State occupies an area of only 3.32% of the Brazilian territory and possesses a wind power generating potential, at 50m height over land and for speeds from 7.0m/s, equivalent to 15% of the estimated wind power for Brazil [27], compared under equal criteria. The total consumption of electricity in the State was 19.31TWh in the year 1999[20], that is, 46.3% of the estimated annual wind generation (41.7TWh/year).

Strategic Aspects

Wind energy is the energy source that has shown the highest rates of growth in the world in recent years, generating, apart from energy for production and development, important fringe benefits, such as the creation of employment in the cycle of manufacture, installation and operation/maintenance, economic development and the improvement in the quality of life, the decentralization of generation and the benefits to the global environment as a substitute for thermal power generation. In 2001, 6.77GW were added to the installed world wind capacity, resulting in an annual growth rate of 38% and reaching a total 24.50GW [21].

The modularity, inexhaustibility, speed of installation, decentralization of generation, ever lower installation costs, non-aggression to the environment and the co-use of the land occupied by the wind plant with other activities such as cattle farming and agriculture, make wind energy the energy source of the future.

The wind is an abundant natural resource in the State of Rio Grande do Sul. The potential generation capacity could be used gradually, at the technical limits of the insertion of the wind capacity in the regional electrical system, elevating economic growth and the energy self-sustainability of the State.

The utilization of wind resources in the most favorable areas identified such as the center-south coast of the State, would potentially permit the strengthening of the electric grid extremities.

The winds over the State of Rio Grande do Sul are sufficient to help meet the energy demand for the well being and economic development for many generations to come.

Wind Energy in the Southeast of Brazil – An experimental case at Minas Gerais – MG

In 1992, CEMIG, the elctricty utility of Minas Gerais started a feasibility study for the implementation of a wind power plant at Morro do Caelinho, at the municipality of Gouveia. In 1994, CEMIG installed the Experimental Wind Power Plant of Morro do Camelinho. This was the first wind power plant connected to the interconnected electricity grid.

This project was developed with subsidies from Eldorado Programme of the German Governemnt, and the manufacturer Tacke Windtechnick was selected as the wind turbine provider.

The carachteristics of this project were:

- Turbine Implementation costs: US$ 1.54 million (51% financed by BMTF – Research and Technology German Ministry);

- Average Annual energy production: at the experimental phase, it was produced 800 MWh/year. The cost of energy was US$ 116.38/MWh, considering useful life of 20 years, O&M of 3% and rate of return of 14% p.a.;
- Connected to the subtransmission of CEMIG through line Parauna-Gouveia of 34.5 Kv;
- It was implemented in a complex terrain and high resisitivity;
- Integrated to the hydroelectric of Paraúna;
- High atmospheric discharge index at the local;

The graphs showing the wind distribution at the local are presented in Annex II.

3.4 - Wind Energy in the Northeast of Brazil – The case of RN – Macau

The region with higher potential for the use of wind power generation in Brazil is the Norteast. States like Ceara and Rio Grande do Norte presents steady constant wind, with high speeds, aand can also use the complimentarity with hydrogeneration for a better use of the electricity system.

In the following graphs will be presented the case of the Macau Region, in Rio Grande do Norte, where the feasibility study for the implementation of a wind farm of 40 MW capacity was conducted, using the WindPro tool and considering the local conditions.

The study considered the implementation of 27 wind trubines of 1.500 Kw, which eas the model considerd mores suitable for the wind consitions at the region.

The first graph is illustrated below, the other are presented in Annex II.

Project:
Macau

Description:
Based on Weibull parameter A=7.53, k=2.79

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Licensed user:
Demo Version
For evaluation purpose only

Calculated:
31.05.02 07:35/2.2.1.12

PARK - Power Curve Analysis

Calculation: Macau, Brazil **WTG:** 1 - NEG MICON MN72C-1500-62-60 1500-400 72.0 !O! NM72C/1500/62/60 Macau-Brazil, Hub height: 62,0 m

Name: NM72C/1500/62/60 Macau-Brazil
Source: PCB` ark 30 June 02

Source/Date	Created by	Created	Edited	Stop wind speed [m/s]	Power control	CT curve type
30/05/02	USER	30.05.02	30.05.02	25,0	Active stall	User defined

Power curve

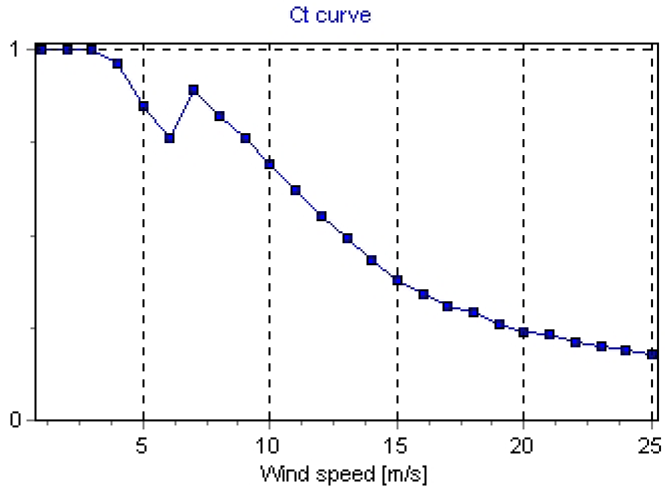
Original data from Windcat, Air density: 1,170 kg/m3

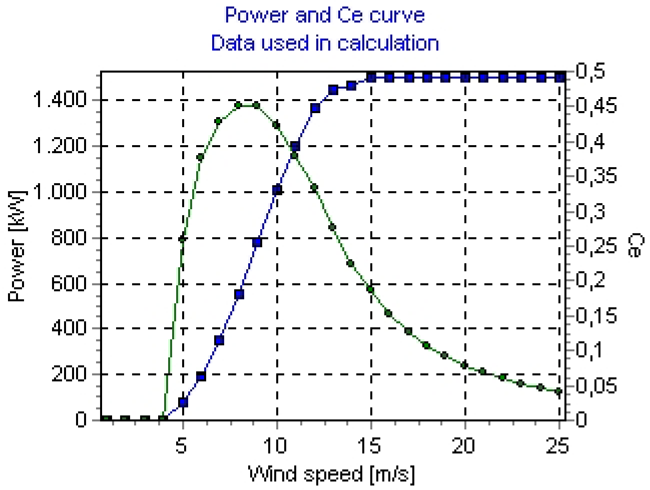
Wind speed [m/s]	Power [kW]	Ce	Wind speed [m/s]	Ct curve
4,0	0,0	0,00	4,0	0,96
5,0	77,0	0,26	5,0	0,85
6,0	195,0	0,38	6,0	0,76
7,0	352,0	0,43	7,0	0,89
8,0	553,0	0,45	8,0	0,82
9,0	784,0	0,45	9,0	0,76
10,0	1.010,0	0,42	10,0	0,69
11,0	1.204,0	0,38	11,0	0,62
12,0	1.372,0	0,33	12,0	0,55
13,0	1.449,0	0,28	13,0	0,49
14,0	1.467,0	0,22	14,0	0,43
15,0	1.500,0	0,19	15,0	0,38
16,0	1.500,0	0,15	16,0	0,34
17,0	1.500,0	0,13	17,0	0,31
18,0	1.500,0	0,11	18,0	0,29
19,0	1.500,0	0,09	19,0	0,26
20,0	1.500,0	0,08	20,0	0,24
21,0	1.500,0	0,07	21,0	0,23
22,0	1.500,0	0,06	22,0	0,21
23,0	1.500,0	0,05	23,0	0,20
24,0	1.500,0	0,05	24,0	0,19
25,0	1.500,0	0,04	25,0	0,18

Power, Efficiency and energy vs. wind speed

Data used in calculation, Air density: 1,174 kg/m3

Wind speed [m/s]	Power [kW]	Ce	Interval [m/s]	Energy [MWh]	Acc.Energy [MWh]	Relative [%]
1,0	0,0	0,00	0,50- 1,50	0,0	0,0	0,0
2,0	0,0	0,00	1,50- 2,50	0,0	0,0	0,0
3,0	0,0	0,00	2,50- 3,50	0,0	0,0	0,0
4,0	0,0	0,00	3,50- 4,50	18,6	18,6	0,5
5,0	77,0	0,26	4,50- 5,50	95,8	114,3	2,9
6,0	195,0	0,38	5,50- 6,50	240,2	354,5	9,1
7,0	352,0	0,43	6,50- 7,50	418,4	772,9	19,9
8,0	553,0	0,45	7,50- 8,50	578,7	1.351,6	34,8
9,0	784,0	0,45	8,50- 9,50	660,1	2.011,7	51,8
10,0	1.010,0	0,42	9,50-10,50	628,7	2.640,4	68,0
11,0	1.204,0	0,38	10,50-11,50	507,3	3.147,7	81,0
12,0	1.372,0	0,33	11,50-12,50	350,1	3.497,8	90,1
13,0	1.449,0	0,28	12,50-13,50	206,1	3.703,9	95,4
14,0	1.467,0	0,22	13,50-14,50	104,7	3.808,6	98,1
15,0	1.500,0	0,19	14,50-15,50	47,1	3.855,7	99,3
16,0	1.500,0	0,15	15,50-16,50	18,8	3.874,5	99,8
17,0	1.500,0	0,13	16,50-17,50	6,6	3.881,1	99,9
18,0	1.500,0	0,11	17,50-18,50	2,1	3.883,1	100,0
19,0	1.500,0	0,09	18,50-19,50	0,6	3.883,7	100,0
20,0	1.500,0	0,08	19,50-20,50	0,1	3.883,8	100,0
21,0	1.500,0	0,07	20,50-21,50	0,0	3.883,9	100,0
22,0	1.500,0	0,06	21,50-22,50	0,0	3.883,9	100,0
23,0	1.500,0	0,05	22,50-23,50	0,0	3.883,9	100,0
24,0	1.500,0	0,05	23,50-24,50	0,0	3.883,9	100,0
25,0	1.500,0	0,04	24,50-25,50	0,0	3.883,9	100,0


Ct curve


Power and Ce curve
Data used in calculation

Economical Feasibility

3.5 – Economical Feasibilty

Once proved from the case studies presented that different regions of Brazil present the technical conditions to the development of wind projects, in this section it will be analysed the economical feasibility of a wind project, given the current legal and financing conditions explained in Chapter 2.

For the economic feasibility study the following assumptions were used:

- Cost of the wind turbines: Catalogue Windenergie 2000
- Initial Costs (additional costs compared to the turbined price):
  - · 15% - Low Costs
  - · 30% - Average Costs
  - · 40% - High Costs
- Operational Life: 20 years
- Freight Costs: DM$ 200,00/t.
- Insurance Costs: 1% over turbine preice
- Taxes:
  - · II - 3% (over CIF price)
  - · IPI - 5 % (over CIF price)
  - · ICMS - 18% (over CIF price)

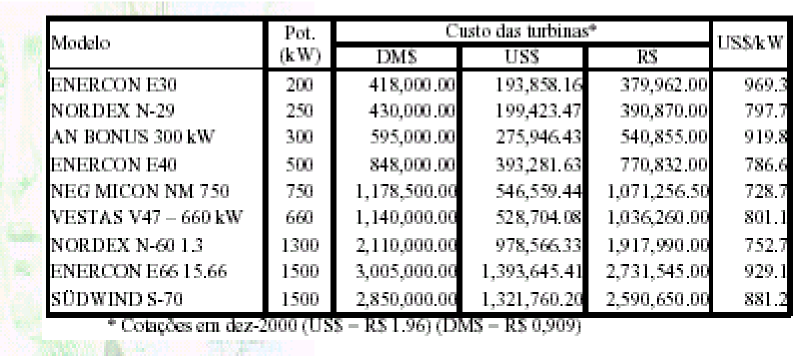
Maintenance: 4% over the turbine price

Investments:
- Equity Capital
- Investments Programmes from BNDES
- Market Interest Rates: (10%, 12.5%, 15%, 17.5 e 20%)
- Payment Period (2 years grace period + 10 years amortization)
- Constant Amortization System Used

Wind Potential:
- Wind Potential Class 2: Capacity Factor: 20%
- Wind Potential Class 2: Capacity Factor: 30%
- Wind Potential Class 2: Capacity Factor: 40%

Sensitivity Analyses:
- Energy Cost
- Turbine Cost
- Foreign Exchange Rate
- Tax reduction

The following table shows the cost of the turbines analysed, as provided from Catalogue Windenergie 2000:



Modelo	Pot. (kW)	Custo das turbinas*			US$/kW
		DM$	US$	R$	
ENERCON E30	200	418,000.00	193,858.16	379,962.00	969.3
NORDEX N-29	250	430,000.00	199,423.47	390,870.00	797.7
AN BONUS 300 kW	300	595,000.00	275,946.43	540,855.00	919.8
ENERCON E40	500	848,000.00	393,281.63	770,832.00	786.6
NEG MICON NM 750	750	1,178,500.00	546,559.44	1,071,256.50	728.7
VESTAS V47 – 660 kW	660	1,140,000.00	528,704.08	1,036,260.00	801.1
NORDEX N-60 1.3	1300	2,110,000.00	978,566.33	1,917,990.00	752.7
ENERCON E66 15.66	1500	3,005,000.00	1,393,645.41	2,731,545.00	929.1
SÜDWIND S-70	1500	2,850,000.00	1,321,760.20	2,590,650.00	881.2

* Cotações em dez-2000 (US$ = R$ 1.96) (DM$ = R$ 0,909)

The treshold internal rate of return for wind projects was considered as 15%, in US$.

Energy Production

To facilitate the analysis for the use of wind potential and the economic feasibility calculus, different capacity factors levels were adopted for each turbine. This procedure allowed the groupment of wind measuremnt stations, from where the average speed annual data and the Weibull parameters were described and analysed.

All those stations were grouped following the Capacity Factor – FC of each turbine model. in the use of wind potentia for the economic feasibility analysis, only the potentials classified as Classes 3 or 4 were considered, using a capacity factor of 30% for Classs 3 and of 40% for Class 4.

In some the tests, places where the wind potential is less than 30% show low attractiveness, and in some cases, are even unfeasible, since the energy production costs are a function of the capacity factor. For this reason, even including just a few wind measurement stations, only stations Class 3 with higher than 30% and stations Class 4 were considerd in the economic feasibility analysis, showing the the best results of energy production for each Class.

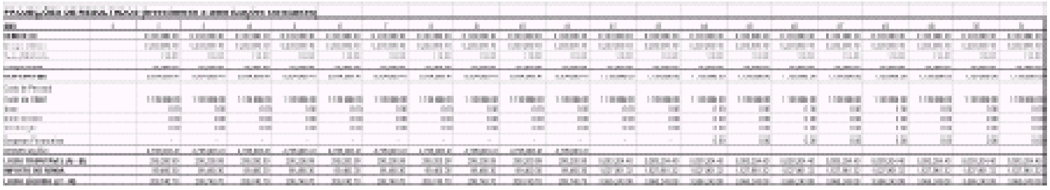
It is important to bear in mind that the energy production may vary from year to year. The safety margin to predict the wind regime is directly influenced by the data quality and the observation period. In the model used, it is addopted the same energy production during the whole useful life of the turbine, without any adjustment in the behaviour variation of wind regime.

Results

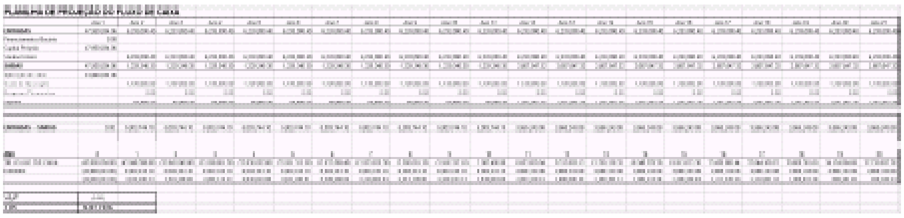
Using the assumptions detailed before, to obtain an IRR of 15%, the electricity price from wind generation under the Brazilian conditions is of US$ 65/MWh.

For the Profit and Losses results and the Cash-Flow projections, it was used a depreciation criteria approved by the Brazilian Laws. It was used a linear depreciation, with a 10 year period.

The Proft and Losses spreadsheet is important for tax charges, once from the results of these projections is obtained the taxable profit. The tax income rate used was 30% (following Brazilian Legislation), and the results obatined are presented in the following table:



The cashflow spredsheet shows the inflows and outflows of the investor’s capital, as presented below:



Both spreadsheets are icluded in Annex II for a better visualization.

Aiming at identifying the parameters of main relevance to results validity, a series of sensitivity analysis were conducted, altering the values of: financing options; O&M; turbine costs, taxes, electricity price, and Normative Value. The results fom those analysis are presented in different the graphs in Annex II.

The best results were obtained for Turbines Classes 3 and 4, achieving attractive rates of return (equal or higher to 15%).

Chapter 4 – Conclusion

Wind energy is the renewable source of generation that presents greater advantages at the generation of big blocks of energy. In many countries, the use of wind energy for generation of complimentary energy has been vastly used and a significant increase is expected for the nest years.

Among the many attractives of the wind energy use, it can be outlined the supply diversity at genertaion park, the fast development of this industry and the technology innovation existent in manydifferent project conditions. The possibility of presenting short period betweenpreliminary project and installation is also an advantage. Evn considering that the “fuel”used if free, plentiful and unlimited, wind energy still is a technology that is not taken into account for electricity supply decisions due to barriers still existent.

Under the perspective of the new environmental concerns and climatic questions, a new consensus is emerging that the analysis of a project might consider not only the economic aspects, although this still is the screening criteria . The economic methods available don’t represent a proper option for the investment analysis, and it is society duty to create ways for significant changes in economy, establishing a new balance, considering the social, economical and environmental aspects.

The interest for the wind energy potential of Brazil is not limited to a local whish to improve and expand the renewable contribution to electricity genertaion. Many foreign companies have showed interest in the new and promissing wind energy market in Barzil. The strong interest from German companies, can be identified through the installation of Woobben WindPower, company from the group Enercon GbH, which initially contructed the wind tubine blades, and nowadays, already have infrastructure to produce model E-66.

Even being in an initial stage of big investments in wind energy, there are many reasons that transform this technology in one of the most promissing energy sources for the Brazilian Energy Matrix. As shown form the Brazilian Wind Atlas, and the case studies presented, the depolyment of this technology in the country is feasible. For a more developed stage to be achieved, it is necessary the establishment of a local wind industry, where turbines and equipments would be produced locally, making possible a decrease at costs, with large scale projects and a mature market.

The Regulatory Agency – ANEEL has benen working at the creation of incentives for the use of wind energy in the country, as seen from Programme established through Law 10438. A big advance in the regulation norms propoed by ANEEL is estblished in Resolution, defining the refernce prices for the supply tariffs.

Many policy initiatives have been taken to sustain the increase of wind energy usei all over the world. The removal of barriers and the subsidies that penalize renewable resources is an important strattegy for the increase of wind energy in the next decades. The barrires related to the electricity sector are, many times, in the legislation of the sector, at planning activities and access to network, which has been develpoed for big capacity generation plants. This is an institutional obstacle, that shouldn’t be considered for promissing area for wind generation, being the electricity sector responsibility to promote transparent and fair prices for the electricity services.

Many policy and economic measures were adopted for the development of wind energy. Due to its technical and economic carachteristics acquired in the commercial development over the last 15 years, wind energy needs more and more political will to promote its increase in the future. The technology is ready and avilable and is capable of overcoming challenges of new projects. Besides the political will, it is necessary the consciouness of society topromote the contribution of energy supply.

Legislation is one of the most important tools for the development of renewable resource in Brazil. Tha existent Laws show an initiative for the absorption of thei energy source in the energy matrix, in remote isolated systems and in interconnected systems. Law 10438 was an essential step for the depolyment of this technology, but as the Law is very recent and some aspects are still undefined, the results will be seen in the years to come.

The development of wind energy in Brazil might be acompained not only from political and legal actions, but also with reaserach and development initiatives. Many institutions in Brazil already promote resaerch in different segments of wind energy use, with results already applied in the utilization of wind genertaion systems. Brazil, presenting its own carachteristics, needs validation studies and adjustments from renowned European models. To make it viable a more effective share of wind energy at the national energy matrix, it can be the destacados main research and development lines:

- Computationl models suitable for the climate and topography of Brazil;
- Statistical distribution of wind data and standardization at data avialability;
- Research over the quality of wind farms and impact at the network;
- Development of turbines suitable for the tropical conditions of Brazil;
- Research over the use of wind energy in hydrid systms (Solar-Wind or Solar-Wind-Diesel);
- Better aerodynamic models, new intelligent structures and materials,
- Improved understanding of mechanical loads, more efficient generators and converters, reliable
- Small machines for remote locations and large sea-based machines

And to minimise environmental impacts there is a need for:

- Combined land use, visual integration, reduced noise from machines and increased knowledge of effects on flora and fauna;

And to enable large-scale use there is a need for:

- Improved forecasting of power output, better power quality and hybrid systems, Including hybrids with natural gas

All those improvements, inherent to new technologies, and expected in the next years, will contribute to a more effective use of wind energy as viable option for a more sustainable energy supply.

References

[1] European Wind Energy Association, for the Commission of the European Communities, 1998, Market & Industry reports (under publication).

[2] Danish Wind Turbine Manufacturers Association, 1997, Wind Power Notes.

[3] Ib Troen and Erik Lundtang Petersen, 1989, European Wind Atlas.

[4] Elselskabernes og Energistyrelsens Arbejdsgruppe for havvindmøller, 1997, Havmøllehandlingsplan for de danske farvande.

[5] Energi & Environmental Data, (Quarterly), Vindstat.

[6]Landsplanafdelingen, Miljøministeriet, 1994, Vindmøller i kommuneplanlægningen.

[7] Bekendtgørelse nr. 1148 af 13. December 1996 om vindmøllers tilslutning til elnettet.

[8] Danish Wind Turbine Manufacturers Association, 1998, Danish Wind Energy, 4th Quarter 1997, WindPower Note no. 17.

[9] Mijø & Energiministeriet,1995, Danmarks Energifremtider.

[10] Miljø & Energiministeriet, 1996, Energy 21, The Danish Government=s Action Plan for Energy 1996.

[11] Energiministeriet, 1988, Energi 2000.

[12] Bekendtgørelse nt. 108 af 23. Marts 1977 om driftsmæssige afskrivninger og henlæggelser mv. Ielforsyningsvirksomheder.

[13] Danish Wind Turbine Manufacturers Association, 1996, Er 10 og 27 Lige? Offentlige finanser og vindkraft, 1996, Wind Power Note no. 7.

[14] ELTRA, 1998, Udkast til tarifblade.

[15] Miljø- og Energiministeriet, 1994, Cirkulære for planlægning for vindmøller af 28. Januar 1994.

[16] Energistyrelsen, 1997, Kommunernes vindmøllepalnlægning. Status januar =97.

[17] Andreas Wagner, 1998, Bundesverband Wind Energie, personal communication.

[18] Energiministeriet, 1991, Kortlægning af vindenergi i Danmark.

[19] Vindmølleindustrien, 1994, Perspektiv 2004.

[20] Danish Wind Turbine Manufacturers Association, 1996, Employment in the Wind Power Industry, WindPower Note no. 2.

[21] Jesper Munksgaard, Mogens R. Pedersen, Jørgen Rahbæk Pedersen, 1995, Samfundsmæssig værdi af vindkraft, AKF Rapport.

[22] Calculation made by the Danish Wind Turbine Manufacturers Association on the basis of data from Energi & Miljødata, (quarterly magazine, 1998).

[23] Rambøll for Energimiljørådet, 1998, Undersøgelse af støtte til vedvarende energi, Copemhagen.

[24] Per Dannemand Andersen, 1993, En analyse af den teknologiske innovation I dansk vindmølleindustri, Handelshøjskolen I København.

[25] BTM Consult ApS, 1998, International Wind Energy Development, World Market Update & Forecast 1998-2002, Ringkøbing.

[26] Peter Hjuler Jensen & Per Dannemand Andersen, 1997, Wind Turbine Technology in the 21st Century, Proceedings of the EWEC =97 Conference in Dublin.

[27] Peter Karnøe, 1991, Dans Vindmølleindustri, en overraskende international succes, Samfundslitteratur, Copenhagen.

[28] Eguene D. Cross, Legal Frameworks for the Promotion of Wind Energy and other Renewable Energy Resources in the EU Member States, 1997, Rijksuniversiteit Leiden.

[29] BTM Consult ApS, 1995, Undersøgelse af konkurrencen på det internationale vindmøllemarked.

Bibliography:

1 - AGÊNCIA NACIONAL DE ENERGIA ELÉTRICA (ANEEL**). The State of Renewable Energy in Brazil.** Brasília, 1998. CD-ROM

2 - **Nota de Esclarecimento dos Valores Normativos – 26/10/199.** Available in the internet http://www.aneel.gov.br/Ementa/Nota_Esclarecimento_VN

3 - ALVARENGA, C.A., COSTA, H.F.F., GREGO, I.P.R. Experimental Wind Power Plant at Morro do Camelinho – Periodo 94/96 In: National Porduction and Transmission of Electricity Seminar – SNPTEE, 14, 1997. Belém: **Anais**... 1997. FL-GPT-08.

4 - AMARANTE, O.A.C. do, SCHULTZ, D.J., Wind Energy Resource Map of the State of Paraná, Brazil.

5 - **Dewi Magazin,** Germany, n. 15, p. 70-75, Aug. 1999.

6 - ARAÚJO, M.R.O.P**. Comparative Study of Wind Systems Using Probabilistic Speed Models** Rio de Janeiro: COPPE/UFRJ, 1989. Dissertation (MSc).

7 - BANCO NACIONAL DE DESENVOLVIMENTO ECONÔMICO E SOCIAL. **Interest Rates for Long Term - TJLP. Available in the internet** www.bndes.gov.br/atuar/exes/tjlp.exe

8 - BEURSKENS, J. Going to sea – Wind goes offshore. **Renewable Energy World**, v. 3, n. 1, p. 19-29, 2000. 251

9 - BITTENCOURT, R.M., AMARANTE, O.C., SCHULTZ, D.J. *at all*. Seasonal Stabilization of Energy Offer Through Wind-Hydro Complimentarity. In: National Electricity Production and Transmission Seminar – SNPTEE, 15, 1999. Foz do Iguaçú: **Anais**... 1999. GPL-17.

10 - BTM CONSULT APS, **World Market Update 1999**. March 2000.

11 - BUNDESVERBAND WINDENERGIE e.V. – BWE, **Windenergie 2000**, Osnabrück: März, 2000. BUNNEFILLE, R..

11 - French Cntribuition to Wind Power Development – by EDF 1958 – 1966, **Proceedings, Advanced Wind Energy Systems**, Vol. 1 (published 1976), O.Ljungströn, ed., Stockhholm: Swedish Board fo Technical Development and Swedish State Power Board, 1974 pp 1-17 to 1-22 *apud* DIVONE, 1994 .

12 - CENTRO BRASILEIRO DE ENERGIA EÓLICA . **Wind Atlas for the Northeast Region for Brazil**,. Brasília, 1998. CD-ROM Série Estudos e Informações Hidrológicas e Energéticas n.

13 – **Objectives, projects, team and others** Available in the internet www.eolica.com.br/ Arquivos consultado em 2000.

14 - COMPANHIA HIDROELÉTRICA DO SÃO FRANCISCO. **CHESF – 50 Anos Gerando o Futuro**. Recife: 1998. CD-ROM.

15 - COMPANHIA HIDROELÉTRICA DO SÃO FRANCISCO, COELCE. **Wind Potential in the Coast of Ceara and Rio Gande do Norte for Electricity Generation .** Recife: out. 1996. CHESF-DEFA-EO-RT-002/96 rev.1.

16 - CHIGANER, L. **Electricity Offer** In: TOLMASQUIM, M.T., SZKLO, A.S**. The Energu Matrix in the New Millenium**. Rio de Janeiro: COPPE-UFRJ, ENERGE, 2000. p.501-518.

17 - UFRJ/COPPE, 1999. 164 p. Dissertação (Mestrado em Planejamento Energético) COPEL. **Wind Project of Palmas .** Available in the internet www.copel.com/copel/port/negocios-ger-energiaeolica.html.

18 – **Wind and Solar Generation in Brazil**. Rio de Janeiro, 1997. CD-ROM.

19 - DEUTSCHES WINDENERGIE INSTITUT. Environmental Aspects and Acceptance of Wind Energy, In: **ELDORADO Summer School**. Wilhelmshavenm,

20 - **Wind Energy Use in Germany**. Available in http://www.dewi.de/statistics.html.

21 - DIVONE, L.V. Evolution of Modern Wind Turbines. In: SPERA, S.A. **Wind Turbine Technology – Fundamental Concepts of Wind Turbine Engineering**,. New York,: ASME Press, 1994. P. 73-138.

22 - ELDRIDGE, F.R **Wind Machines.** 2 ed. New York: Van Nostrand, 1980. *Apud* CHESF/BRASCEP, 1987. *Op. cit.*

23 – Wind Atlas of Brazil – CDRom

24 - SSLEMONT, E., MOCCORMICK, M, Sociological Impact of a Wind Farm Development. In:

JAMESxJAMES. **The World Directory of Renewable Energy: Suppliers and Services**, London, 1996.

25 - EWEA. EUROPEAN COMMISSION. Technology. In: **Wind Energy – The Facts**.

26 - GIPE, P., **Wind Power for Home & business: Renewable Energy for the 1990s and Beyond.** Vermont: Chelsea Green, 1993.

27 - **Wind Energy - Cames of Age**. New York,: John Wiley & Sons, 1995.
GREENPEACE INTERNATIONAL, EUROPEAN WIND ENERGY ASSOCIATION/ EWEA.

28 - FORUM FOR ENERGY AND DEVELOPMENT – FED. **Wind Force 10 – A Blueprint to Achive 10% of the World's Eletctricity from Wind Power by 2020.** London. 1999.

29 - GRUBB, M, MEYER, I.N. "**Wind Energy: Resources, Systems, and Regional Strategies", Renewable Energy Sources for Fuels and Eletricity.** Washington, DC: Island Press, 1994. *apud* GREENPEACE, 1999 *Op. cit.*

30 - HINSCH, C. Wind energy continues to boom, **New Energy**, n.2, May 1999a. p. 14-15.

31 - The politicians have to move as fast as they can, **New Energy**, n.4, May 1999b
p. 14-17

32 - Review of Development in West-Germany. **Proceedings, Workshop on Advanced Wind Energy Systems***,* Vol. 1, 1974 (published 1976), O. Ljungströn, ed. Stochkholm: Swedish Board fo Technical Development and Swedish State Power Board, pp 1-51 to 1-72 *apud* DIVONE, 1994 *Op. cit.*

33 - INTERNATIONAL ENERGY AGENCY. **World Energy Outlook – 1998.** Paris: IEA/OECD, 1998.

34 - JACOBS, M. L. Experience with Hacobs Wind-Driven Electric Generating Plant, **Proceedings, First Wind Energy Conversion Systems Conference**, NSF/RANN-73-106, 1973 Washington, DC: National Science Fundation, pp 155-158. *apud* SHEFHERD, 1994 *Op. cit.*

35 - JANNUZZI, G.M., SWISHER, J.N.P. **Integrated Planning of Energy Resources**

36 - JULL, J. Design of Wind Power Plants in Denmark **Wind Power, Procedings of United Nations Conference on New Sources fo Energy**, Vol. 7, New York: The Union Nations, 1964, pp 229-240 *apud* DIVONE, 1994 *Op. cit.* 256

37 - KOEPPL, G.W. **Putnam's Power from the Wind,** 2. ed. New York: Van Nostrand Reinhold, 1982. *apud* SHEFHERD, 1994 *Op. cit.*

38 - KROHN, S. Offshore Wind Energy: Full Speed Ahead. In: JAMESxJAMES, **The World Directory of Renewable Energy: Suppliers and Services**. London. 1997.

39 - MORTENSEN, N.G et al.. *Wind Atlas Analysis and Applicantion Program (WasP).* Roskilde: RisØ National Laboratory, 1993.

39 - MURACA, R.J., *et al*. **Theoretical Perfomance of Vertical Axis Windmills,** NASA TMX- 72662, 1975, Hampton, VA: NASA Langley Research Center. *apud* DIVONE, 1994 *Op. cit.*

40 - PUTNAM, G. C. **Power from the Wind**,. Van Nostrand Reinhold Co.,1948, New York. *Apud* SHEFHERD, 1994 *Op. Cit*

41 - RETSCREEN INTERNATIONAL. **Wind Energy Project Model**, Softweare available in the internet http://retscreen.gc.ca/ang/g_win.html. File consulted in 2002

42 - ROHATGI, J.S., NELSOIN, V. **Wind Characteristics – An Analysis for the Generation of Wind Power.** Canyon: West Texas A&M University, 1994.

43 - SANDIA. **Vertical Axis Wind Turbine: The History of the DOE Program**. Available ine the internet at http://www.sandia.gov/Renewable_Energy/wind_energy/topical.htm.

44 - SEKTOROV, V. R., 1934, **The First Aerodynamic Three-Phase Electric Power Plant in Balaclava**, L'Elettrotecnica, 21(23-24), pp. 538-542; Traduzido por Scientific Translation Service, NASA TT-F-14933,1964, Washington, DC: National Aeronautics and Space Administration, pp. 13 *apud* SHEFHERD, 1994 *Op. cit.*

45 - SHEFHERD, D.G. Historical Development of the Windmill. In: SPERA, S.A. **Wind Turbine Technology – Fundamental Concepts of Wind Turbine Engineering**,. New York,: ASME Press, 1994. p. 1-46 SHELTENS, R.K, BIRCHENOUGH, A.G.,

46 - **Operational Results for the Experimental DOE/NASA Mod-0A Wind Turbine Project**, NASA TM-83517, DOE/NASA/20320-55, 1983, Cleveland, Ohio: NASA Lewis Research Center. *apud* DIVONE, 1994 *Op. cit.*

47 - SPERA, S.A., Introduction to Modern Wind Turbine. In: **Wind Turbine Technology – Fundamental Concepts of Wind Turbine Engineering**. New York:, ASME Press, 1994. Cap. 2 p 47-72.

48 - VOADEN, G.H., 1943, The Simith-Putnam Wind Turbine – A Step Forward in Aero-Electric Power Research, **Turbine Topics**, 1(3); reprinted 1981 in NASA CP-2230, DOE CONF- 810752, pp. 34-42, 1943, Cleveland, Ohio: NASA Lewis Research Center. *Apud* SHEFHERD, 1994 *Op. cit.*

49 - WAGNER, A. 2000, Set for the 21st century: Germany New Renewable Energy Law,**Renewable Energy World** , v. 3, n. 2, Mar-Apr, 2000, p.73-83

50 - WIND ENERGY for the world. **Windblatt***,* n. 4, 1999.

51 - WINROCK INTERNATIONAL, USAID. **Trade Guide on Renewable Energy in Brazil** Apr., 1999, Salvador, April, 1999. 100p.

52 - WORLD ENERGY COUNCI., **New Renewable Energy Resources: Opportunities and Constraints 1990-2020**. London: Kogan Page, 1993.