MSc Program
Renewable Energy in Central and Eastern Europe

Analysis of the Promotion Strategies for Wind Electricity in Brazil versus Germany

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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7 November 2011, Vienna, Austria

Affidavit

I, **Magdalena Sanguinetti**, hereby declare

1. that I am the sole author of the present Master Thesis, "Analysis of the Promotion Strategies for Wind Electricity in Brazil versus Germany", 110 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

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Date Signature

Abstract

This aim of this work is to analyze, assess and compare the wind power promotion strategies implemented in Germany and Brazil, both qualitatively and quantitatively. This was achieved by calculating the effectiveness and efficiency of each promotion strategy, by means of indicators of effectiveness and efficiency defined in the literature.

It can be stated that Germany has implemented more effective and efficient wind power promotion strategies than Brazil. In order to verify if effectiveness has been triggered by high profits for wind power investors in each of the countries, annuities of hypothetical projects were calculated and plotted against effectiveness. While this could be deducted for Brazil, Germany's promotion strategies make clear that high effectiveness can be achieved with low investors' profits, minimizing "windfall" or unnecessarily high profits. Considering that wind power promotion strategies are decided and enforced by the governments and funded by the electricity consumers, this aspect is of key importance.

One of the plausible reasons of the differences in the effectiveness and efficiency of the promotion strategies between these two countries can be is that Germany has collected more experience than Brazil. Yet naturally, the qualitative differences of the promotion strategies applied in each country lead intrinsically to different results. Feed-in tariffs demonstrate once again their superiority, in achieving renewable electricity generation at relatively low costs to society.

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List of Abbreviations and Symbols

A	Area, in square meters
c_{fix}	Fix Costs
c_p	Parameter to represent the Betz limit
c_{var}	Variable costs
CO_2	Carbon dioxide
FiT	Feed-in Tariff(s)
FLH	Full Load Hours
GDP	Gross Domestic Product
Gm^3	Giga (10^9) cubic meters
Gt	Giga (10^9) tons
GW	Gigawatts (10^9 watts)
GWh	Gigawatt hours
GWEC	Global Wind Energy Council
HAWT	Horizontal Axis Wind Turbine
hPa	hectopascals (equals 100 pascals)
i	Interest rate
J	Joule, unit of work or energy
kg	kilogram
kW	kilowatt
kWh	kilo watt hours
LRMC	Long Run Marginal Cost
m^3	cubic meter
m/s	Meters per second
MSW	Municipal Solid Waste
MW	Megawatt (10^6 watts)
MWh	Megawatt hours
Mt	Million tons
Mtoe	Million tons of oil equivalent
NIMBY	Not in my back yard
P	Power (typically measured in Watts)
PJ	Peta (10^{15}) Joules
RE	Renewable energy
RES	Renewable energy sources
RES-e	Electricity generated from renewable sources (renewable electricity)

RES-E	Electricity generated from renewable sources (renewable electricity)
rpm	Revolutions per minute
R&D	Research and Development
R $	Brazilian Real
TGC	Tradable Green Certificate
toe	Ton of oil equivalent
TPES	Total Primary Energy Supply
TS	Transmission System
TW	Terawatt (10^{12} watts)
TWh	Terawatt hour(s)
TSO	Transmission System Operator
v	Wind speed, in m/s
VAWT	Vertical Axis Wind Turbine
W	Watt(s), a unit of power equivalent to one joule per second
2000 US $	United States Dollars with purchasing power of year 2000
η	Efficiency parameter
ρ	Air density, measured in kg/m^3
€/kWh	Euros per kWh
€/MWh	Euros per MWh
US $/kWh	US Dollars per kWh
US $/MWh	US Dollars per MWh

1 Introduction

Traditionally electricity has been generated mostly from fossil (coal, oil or gas) or nuclear sources, which are finite. Large hydroelectric power has been the only relevant renewable source for electricity generation. Other renewable sources like wind, solar, biomass, geothermal, tidal, wave and small hydro (all capable of generating electricity and in the literature referred to sometimes as the "new renewables"), have only contributed minimally.

As can be seen in the figure below, large hydroelectric power contributed to 21% of the world's electricity generation in 1973 and other sources like geothermal, wind, and solar only contributed to 0.6%. While in 2008 non-renewable fuels remain prevalent, the growth of new renewable sources shall not be ignored. These accounted for 2.8% of the world's electricity generation in 2008, which in comparison to 1973, grew from 6116 TWh to 20181 TWh, what represents a growth of approximately 330%.

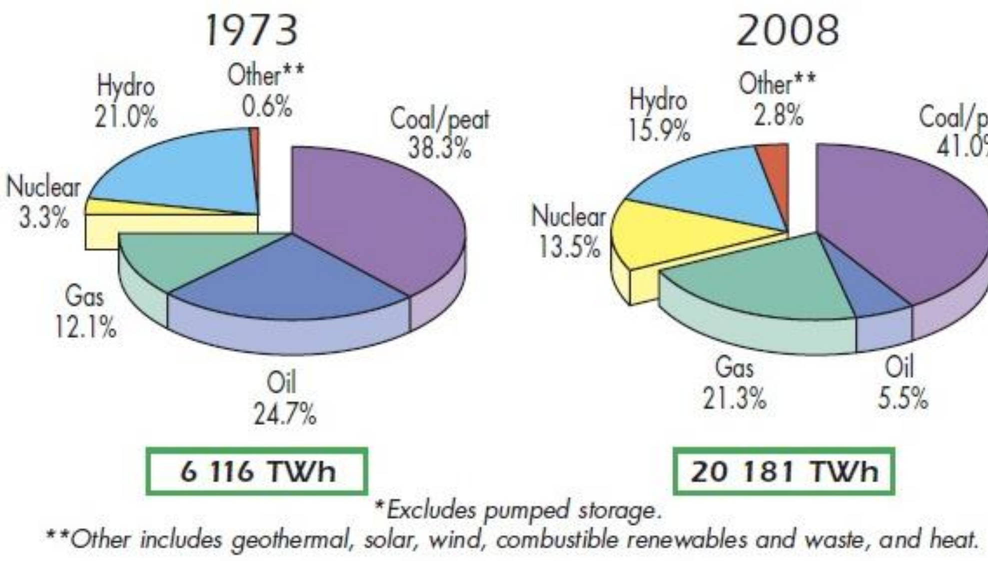


Figure 1.1: 1973 and 2008 fuel shares of electricity generation (excluding pumped storage). Source: IEA, Key World Energy Statistics, 2010.

The growing importance of renewable sources for electricity generation is indisputable. Several factors have stimulated many countries around the world to resort to renewable sources to generate electricity. These will be analyzed next.

Countries lacking fossil (or nuclear) fuels have been forced to import them, for which they must devote large amounts of their national budgets and of their foreign currency reserves. Since economic growth spurs energy and electricity consumption, national economies become highly dependent on energy imports. Fossil fuel prices are very volatile. All these factors combined lead to a very risky and instable situation that many countries now want to avoid. Last but not least, national governments have recognized the potential for renewable energies to create local jobs, especially in rural areas, and to develop a new local renewable energy industry. By investing locally the funds that previously were used to import fossil fuels, a significant improvement can be expected in the local economies.

Fossil fuel resources are limited and are irregularly located around the world. A few countries, many of them governed by non-democratic regimes, possess the majority of the world's oil and gas resources. Their political instability causes insecurity in the energy supply for importing countries and for this reason renewable energy sources for energy and electricity, essentially native sources, have gained momentum. The oil crisis in 1973 and the gas crisis in the 2006 European winter have been hard lessons for energy importing nations.

Worsening air quality due to fossil fuel burning and consequently increasing public health concerns have also motivated national governments to search for cleaner energy and electricity resources.

Renewable energies have an enormous development potential, especially in the electricity market. Definitely renewable energies will be part of the solution to address the above-mentioned problems, to satisfy the world's ever-increasing demand for energy, to increase energy security at the national level and to combat the climate change threat. The commitments to carbon emissions reductions made by many industrialized nations in the Kyoto Protocol to control climate change, have further contributed to giving renewable energy sources an increasingly important role.

Yet, evidently, the transition away from non-renewable or conventional energy sources is a challenge, touching very different aspects such as public policies and personal lifestyle decisions.

Policies, or promotion strategies, play a key role and exert a critical influence on investors' and general public's decisions. In the case of renewable electricity (hereafter RES-E), while in most markets RES-E (also referred to as green electricity) is more expensive than electricity from conventional sources (also referred to as gray electricity), promotion strategies are crucial to the development of the RES-E market.

Promotion strategies are necessary to enable the RES-E industry to achieve a critical mass, a steep experience curve and ultimately to reach grid parity. In this work, policies on wind power applied in Brazil will be analyzed in terms of effectiveness and efficiency and compared with those applied in Germany, taken as the reference industrialized country.

1.1 Motivation and Objective of this Work

The motivation of the author to write about this subject is to shed some light into what it takes to design and apply results-oriented, effective and efficient policies for RES-E, more precisely for wind power in Brazil.

As an emerging country, Brazil is expected to sharply increase its electricity consumption in the next decades and therefore RES-E deployment will be critical to enable this country to develop sustainably. Due to its high wind power potential, it is expected that this form of RES-E will play a central role in the reshaping of Brazil's energy mix.

The objective of this work is to analyze how effective and efficient are the present RES-E promotion strategies for wind power in Brazil. These will be analyzed and compared with similar strategies carried out in Germany, which has collected more than twenty years of experience in the development of national wind power promotions.

1.2 Intended Method of Approach

The cost of carried out promotion strategies in Brazil will be calculated with a defined "efficiency" indicator. The degree of RES-E deployment in that market will be assessed with an "effectiveness" indicator. The obtained results will be compared with those of Germany in order to identify potential for improvement and lessons learned.

1.3 Structure of this Work

In Chapter 2 “Global Wind Power Sector” an overview of the global wind power sector will be given, describing global installed capacity, global wind power potential and main players in the global wind power industry. A brief overview on how electricity is generated from wind power will complete the chapter.

In Chapter 3 “Analysis of Promotion Strategies for Wind Power” the RES-E promotion strategies used around the world in the past years will be analyzed. Next, a brief introduction on Brazil and Germany will be given, followed by an analysis of the wind power promotion strategies applied these countries.

The analysis of the efficiency and effectiveness of the wind power promotion strategies implemented in Germany and Brazil will be carried out in chapter 4 “Analysis of Effectiveness and Efficiency of Wind Power Promotion Strategies”.

Additionally the effectiveness indicators will be plotted against annuity factors calculated for hypothetical projects in each country in order to assess whether high effectiveness responds to high profits for investors. Lastly, a sensitivity analysis will be carried out for two variables of the annuity calculation (interest rate and full load hours).

The conclusions of this work will be drawn in chapter 5.

2 The Global Wind Power Sector

2.1 Global Wind Power Capacity Installed

The depiction below illustrates the global cumulative installed wind capacity from 1996 to 2010. A steady growth has been recorded in these 15 years, with more than a 30-fold capacity increase, from 6,1 GW in 1996 to 194,39 GW in 2010.

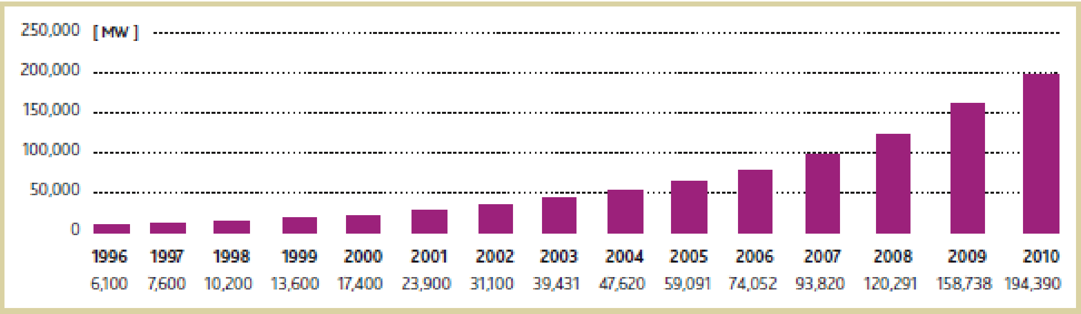
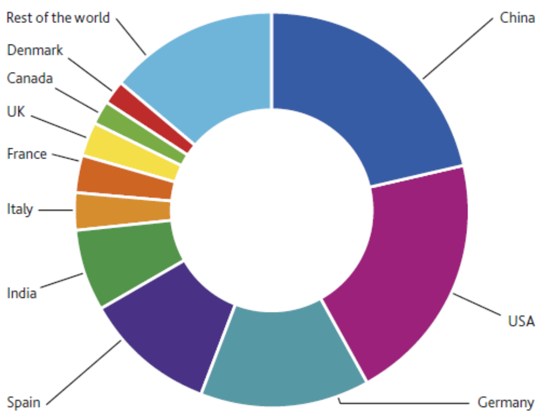


Figure 2.1: Global cumulative installed wind power capacity 1996-2010. Source: Global Wind Energy Council (GWEC), 2010.

Ten countries concentrate 86,3% of the world wind power installations as of 30 December 2010: China, USA, Germany, Spain, India, Italy, France, UK, Canada, and Denmark. Moreover, the above-mentioned top five countries concentrate 73,8% of the installations.



Country	MW	%
China	42,287	21.8
USA	40,180	20.7
Germany	27,214	14.0
Spain	20,676	10.6
India	13,065	6.7
Italy	5,797	3.0
France	5,660	2.9
UK	5,204	2.7
Canada	4,009	2.1
Denmark	3,752	1.9
Rest of the world	26,546	13.7
Total TOP 10	167,844	86.3
World Total	194,390	100

Figure 2.2: Top ten countries by cumulative installed wind capacity as of December 2010. Source: GWEC, 2010.

As already suggested by the depiction above, global wind power capacity is not equally distributed. Asia and Europe and North America are the front-runners while

Latin America, Africa & Middle East and Pacific are at the bottom of the list, separated by a rather wide margin. While Europe is currently the continent with largest installed wind power capacity (with 86.075 MW or 44,28% of the total), Asia is the second strongest continent with 58.641 MW (30,17%).

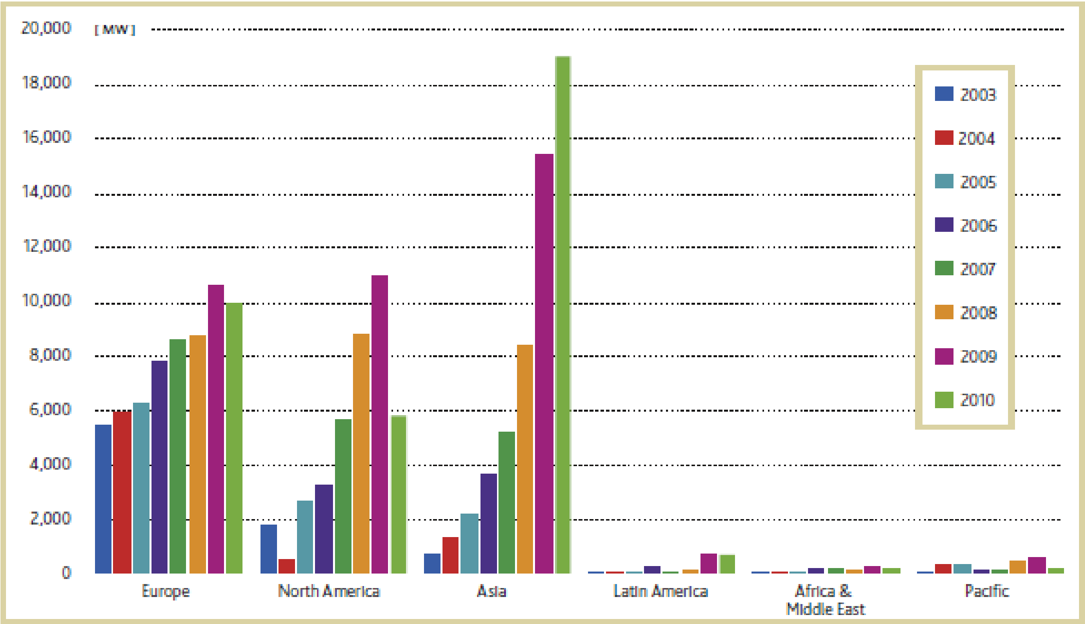
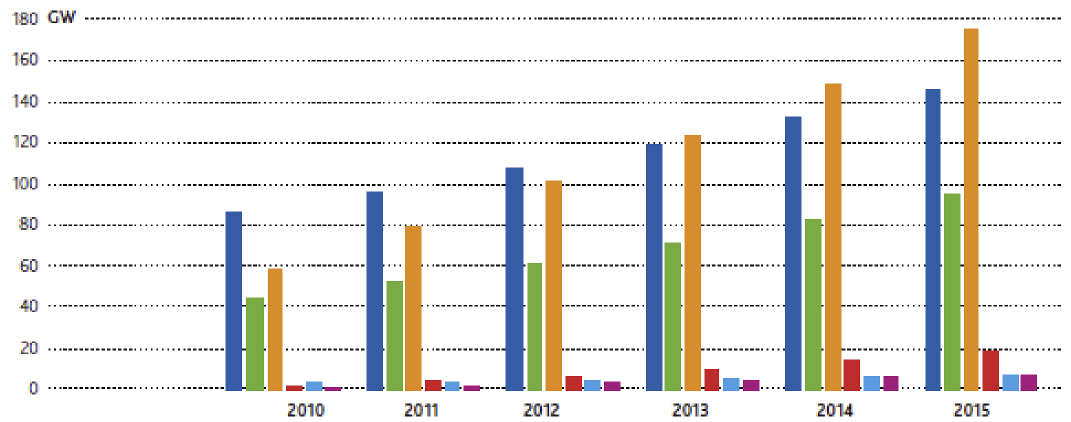


Figure 2.3: Annual installed wind capacity by region 2003-2010. Source: GWEC, 2010.

Due to the recent financial crisis, Europe and North America saw a decrease in annual installations in 2010 respect to 2009, interrupting the continuous growth trend until then. Asia, on the contrary, consolidates itself as the undisputed global leader with exponential growth rates. China and India alone concentrate 28,5% of the global wind power installations in 2010. According to GWEC, it is forecasted that by 2015 Asia will have 38,9% of the global wind power installed capacity.



	2010	2011	2012	2013	2014	2015
Europe	86.1	96.1	107.1	119.1	132.1	146.1
North America	44.2	52.2	61.2	71.2	82.2	94.2
Asia	58.6	79.1	101.1	124.1	148.6	174.6
Latin America	2.0	3.5	6.0	9.5	14.0	19.0
Pacific	2.4	3.1	3.9	4.9	5.9	7.4
Middle East and Africa	1.1	1.9	2.7	3.9	5.5	7.5

Figure 2.4: Cumulative market forecast by region 2011-2015. Source: GWEC, 2010.

2.2 Global Electricity Generation Capacity and Potentials of Wind Power

The global installed electric generation capacity was of approximately 4016 GW in 2006 (EIA, 2006). As depicted in figure 2.5 below, conventional thermal was in that year the absolute leader with 69% of the capacity, followed by hydroelectric (19%) and nuclear (9%). The remaining 3% was the share of wind (74 GW as reported in the GWEC Global Wind 2006 Report), geothermal, solar, wood and waste.

As of 30 December 2010, already 194,39 GW of wind power are installed in the world. These generated approximately 430 TWh in 2010, contributing to 2.5% of that year's world's electricity demand (WWEA, 2011).

But how much more can global wind power capacity grow, or what is the global wind power potential? No exact answer can be given to this question with currently available scientific instruments. As a result of different methodologies of assessment and different assumptions, the literature shows global wind power potentials of a significantly broad range.

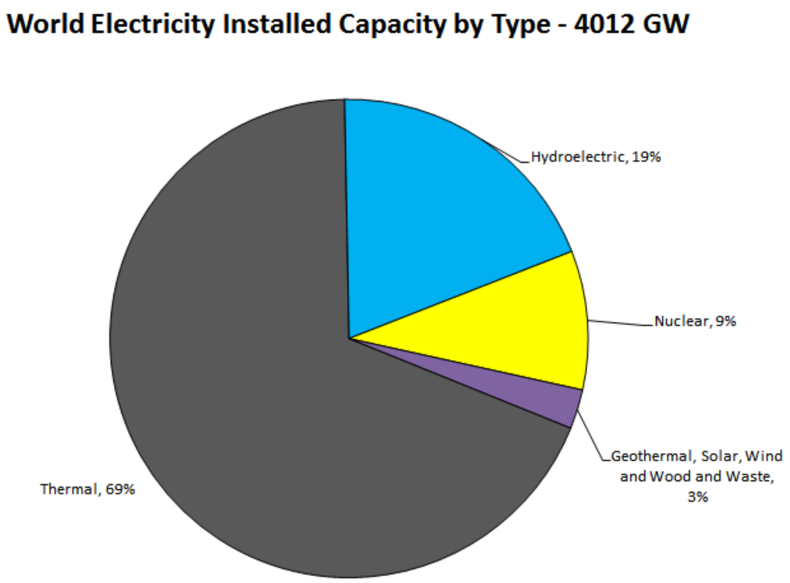


Figure 2.5: World Electricity Installed Capacity by Type. Data corresponds to year 2006. Source: EIA, 2006 (http://www.eia.gov/iea/elec.html).

The table below shows a summary of some of the most cited authors, who estimate wind power potentials of 1000 GW (or 1 TW; economic potential) and up to 1500 TW (technical potential). In a recently published article, de Castro, C. et al. apply a top-down approach and conclude that the global wind power electric potential is 1 TW, which, if correct, would mean that almost 20% of this potential has already been installed.

Table 2-1: Potentials of wind power according to several authors (most technical powers are primary, not electrical). Source: de Castro, C., et al. (2011).

Authors	Technical power (TW)	Economic/sustainable power (TW)
Archer and Caldeira (2009)	1500 (jet stream, % feasible?)	
Capps and Zender (2010)	39 (offshore)	
DeVries et al. (2007)		4.5 (in 2050)
EEA (2009)	8.6 (Europe)	3.5 (Europe 2030)
Elliott et al. (2004)+Musial (2005)	1 (EEUU)	
Greenblatt (2005)	70.4 (global)	
Greenpeace (2008) Greenpeace 2010		1 (in 2050) 1.2 (in 2050)
Hoogwijk et al. (2004)	11	2,4-6 (economic)
Lu et al. (2009)	78 (onshore), > 7 (offshore)	
Miller et al., 2010	17–38 (onshore, geographical potential)	
Schindler et al. (2007)		6.9 (sustainable)
WEC (1994)	55.2 (global)	
Wijk and Coelingh (1993)	2.3 (onshore, OCDE)	
Zerta et al. (2008)		6.9 (sustainable)

2.2.1 The Global Wind Turbine Production Industry

The wind turbine production industry is concentrated in a few countries. In less than a decade China has set itself at the leading position, and is now followed by Germany, Denmark, United States of America, Spain and India. Except for Denmark (the industry's precursor in the 1970s), the above-mentioned are the top five countries in the global ranking of wind power deployed capacity, having a combined share of 73,8%.

According to data of 2010, the top ten wind turbine producers had a share of approximately 79% of the global market. Of these, four companies were from China, two from Germany, one from Denmark, one from United States of America, one from Spain and one from India.

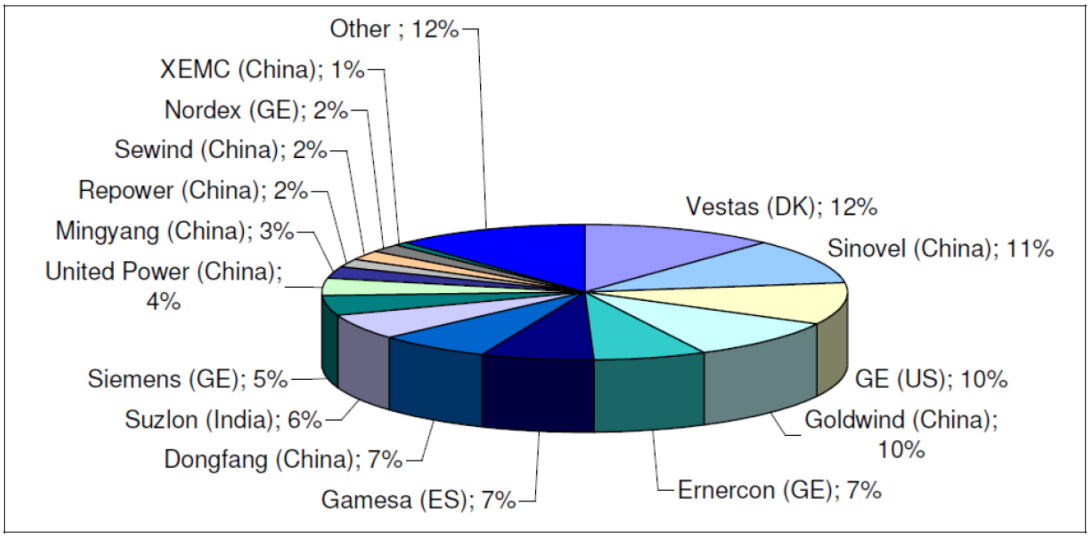


Figure 2.6: Wind turbines global market shares. Source: Wallasch, A. K., et al., BTM Consult, 2011. Taken from „Vorbereitung und Begleitung der Erstellung des Erfahrungsberichtes 2011 gemäß § 65 EEG, Vorhaben IIe Windenergie, BMU, 2011" (http://www.bmu.de/files/pdfs/allgemein/application/pdf/eeg_eb_2011_windenergie_bf.pdf).

According to the World Wind Energy Association (2011), "the wind industry employed 670.000 worldwide in 2010, directly and indirectly in the various branches of the wind sector", who will generate a market value of €66 billion in 2011 (BTM Consult, 2011).

2.3 Wind Power Generation

The electricity generated from the energy contained in the wind is referred to as wind power or wind electricity. A wind turbine is the device required to convert that energy into electricity. The conversion process uses the aerodynamic lift force to make the axis of the wind turbine rotate, resulting first in the production of mechanical power and then in its transformation into electricity with the use of a generator.

Wind turbines can only generate electricity with the wind that is immediately available and at the place where the wind is blowing. Wind can neither be stored nor used at a later time. Therefore when the wind is not blowing, other sources of energy must be used to generate electricity and to balance these fluctuations in electricity generation. Or else, batteries have to be put into use in order to store wind electricity when it is generated in excess, for those moments when the wind is not blowing.

The first windmills were recorded to have been used by the Persians in year 900 AD (Manwell, J. F., et al., 2008). In the middle age windmills were used in Europe, but these were still used to generate mechanical force (not electricity) for grinding grains or for pumping water. It was at the end of the XIX century when the first windmills were connected to a generator and the mechanical force was utilized to produce electricity, with some cases in Europe and in the United States as well.

Nowadays wind turbines can be found in a wide range of power capacities, from a few kW until 7MW. The historic trend shows that towers become higher (what enables to harvest higher, stronger winds), and rotor diameters get bigger (what enables to harvest more energy from the wind).

Wind turbines have evolved greatly in the past 30 years, reaching more cost effectiveness and reliability, and will certainly develop further in the years to come.

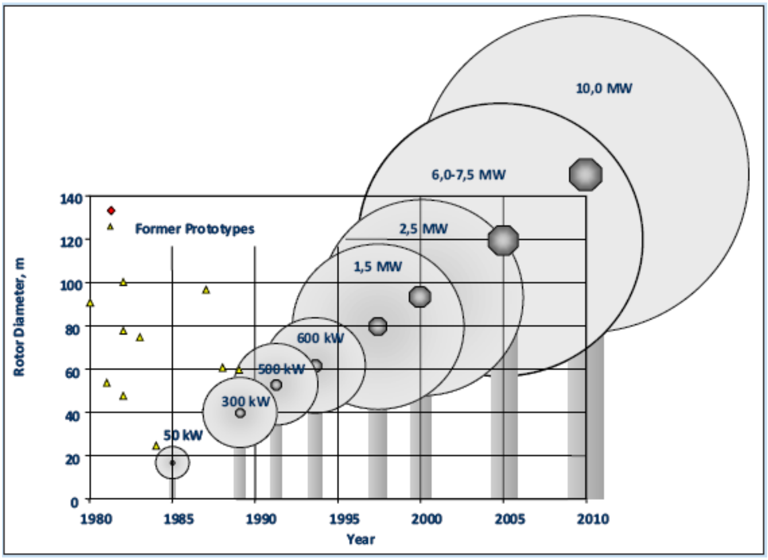


Figure 2.7: Wind turbine size growth in rotor diameter and power installed. Source: DEWI Magazine Nr. 34, February 2009.

2.3.1 Composition of a wind turbine

The typical three-blade Horizontal Axis Wind Turbine (HAWT) is schematically composed of the following parts:

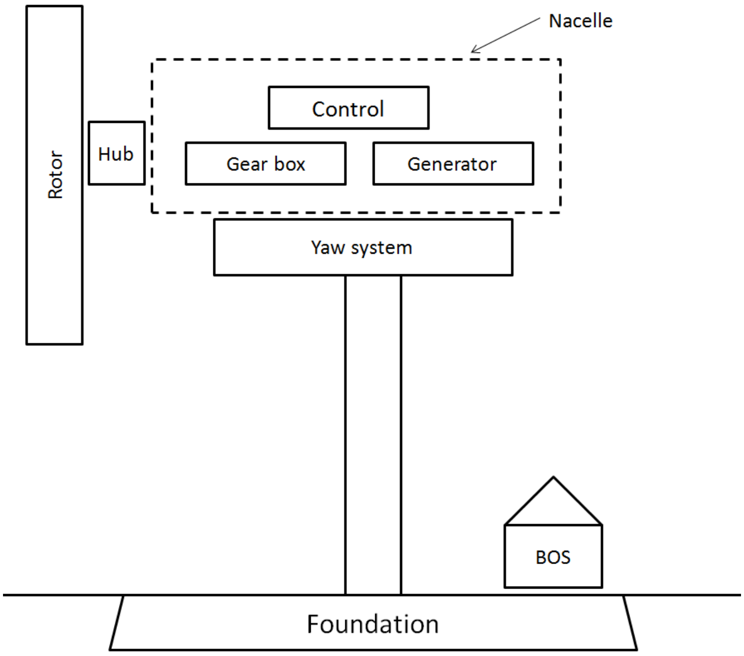


Figure 2.8: Schematic composition of a three-blade HAWT. Source: adapted from Manwell, J. F., et al. (2008).

The rotor is composed of the three blades, which determine the performance of the wind turbine. The blades are made of different composites, glass fiber, reinforced plastic and sometimes wood/epoxy laminates. Electricity production depends on the interaction between the rotor and the wind, therefore the design of the blades has to be in accordance with the aerodynamic forces involved. The larger the rotor surface, the more energy can be harvested from the wind.

The hub connects the nacelle with the rotor.

The gear box is necessary to increase the rate of rotation of the rotor, from a value in the range of the tens of rpm, to a value in the hundreds or thousands of rpm, necessary to make the generator work.

The generator transforms the mechanical energy into electrical energy. Some wind turbines have been designed in such a way that there is no need for a gear box and the generator is built in the hub.

A number of control systems are necessary in the wind turbine, like sensors of speed, position, flow, temperature, current, voltage, controllers of electrical circuits and computers, switches, motors, pistons, magnet, and many others to keep the complex machinery running and to allow controlling and monitoring it remotely.

The nacelle is the casing in which the control systems, the gear box and the generator are found, to protect them from the weather. It is normally made of glass fiber.

The yaw system is necessary to keep the rotor orientation aligned with the wind direction. This mechanism is controlled by an automatic wind direction sensor and a yaw direction control.

The tower is normally made of pre-fabricated steel parts that are assembled on site, but concrete is also used. The height of the tower is typically 1 to 1.5 times the rotor diameter. The foundation is a concrete structure under the surface able to support the wind turbine in spite of the movements caused by the wind, the load-unload cycles caused by every pass of each blade by the tower. Foundation design will vary according to the soil and other conditions (i.e. if the wind turbine will be installed on-shore or off-shore).

The balance of system house protects a number of electrical components like cables, transformers, power electronic converters, among others.

Stand-alone systems are typically installed in rural areas or areas with difficult access to the electricity grid. Rechargeable batteries are necessary to store the excess electricity generated when the wind is blowing and to make it available during those moments of no wind or when the wind is not blowing strongly enough to cover the electricity demand of the system.

Grid-connected wind turbines can be found isolated or in groups, what is called a wind farm or wind park. Wind parks (a group of turbines in the same location) have been installed in many countries in the world, on and off-shore, feeding the electricity generated into the power grid.

Figure 2.9: Images of onshore and offshore wind parks. Sources: see footnote[1].

2.3.2 Wind turbine types depending on the position of the rotation axis

2.3.2.1 Horizontal axis wind turbines

In horizontal axis wind turbines (HAWT) the rotation axis is parallel to the ground.

The figures above depict examples of different types of horizontal axis wind turbines (HAWT):

[1] Sources of figure 2.9: http://www.yourrenewablenews.com/news_item.php?newsID=32958, http://forcechange.com/wordpress/wp-content/uploads/2008/12/e-on-offshore-wind-farm-germany.jpg and http://conradgroupinc.com/dev/wp-content/uploads/2011/06/pn200826-02_300dpi.jpg

Figure 2.10: Different horizontal axis wind turbines. Sources: see footnote[2].

In HAWT, the rotor can be found at the front of the unit (so called up-wind turbines) or at its rear (so called down-wind turbines). While in up-wind turbines the wind hits the rotor first, in down-wind turbines the wind hits the tower first. This causes interferences in the wind flow, which increases the fatigue to which the turbine is exposed. For this reason up-wind turbines are more popular.

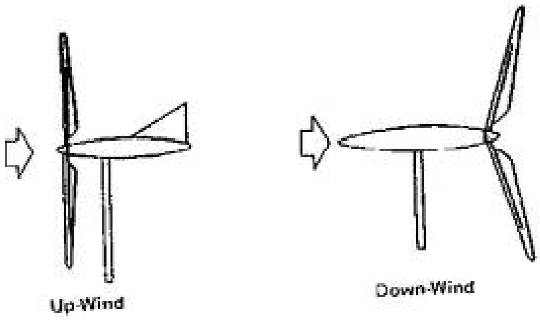


Figure 2.11: Up-wind and down-wind turbines. Source: adapted from Manwell, J. F., et al. (2008).

2.3.2.1.1 Wind turbine types depending on the number of blades

One-blade and two-blade turbines have been deployed in the past and are still in use in certain locations, but due to uneven loads and mechanical problems these are gradually being discontinued.

[2] Sources of figure 2.10: http://apps.carleton.edu/campus/facilities/sustainability/wind_turbine/ http://www.123rf.com/photo_3251989_wind-engine-in-motion.html http://www.monstermarketplace.com/wireless-network-products/tycon-power-systems-400w-24v-hawt-horizontal-wind-turbine-tpw-400-24

Three-blade turbines are nowadays the most widespread type, thanks to their better aerodynamics and mechanical strength. The figure below schematically depicts one-blade, two-blade and three-blade turbines, as well as their corresponding dynamic effects.

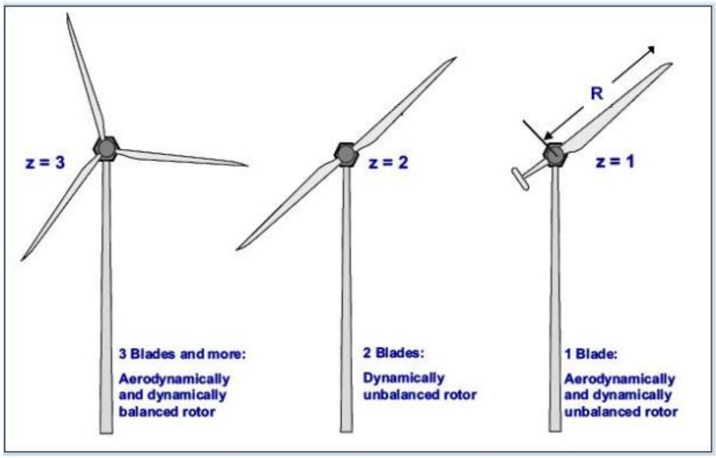


Figure 2.12: Number of rotor blades and the corresponding dynamic effects. Source: DEWI Magazine Nr. 34, Feb. 2009.

2.3.2.2Vertical axis wind turbines

In vertical axis wind turbines (VAWT), the rotation axis is parallel to the ground. The figures above depict examples of different types of vertical axis wind turbines (VAWT):

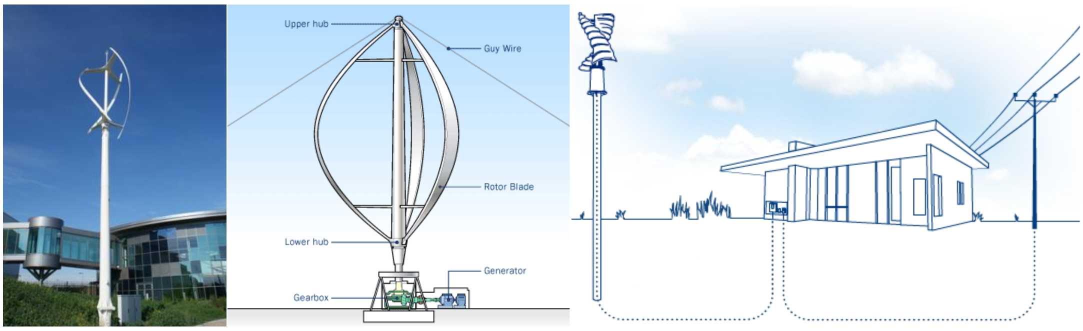


Figure 2.13: Examples of vertical axis wind turbines (VAWT). Sources: see footnote[3].

[3] Sources of figure 2.13: http://www.quietrevolution.com/gallery.htm
http://science.howstuffworks.com/environmental/green-science/wind-power2.htm and adapted from http://www.helixwind.com/en/

Currently the most common wind turbines are up-wind horizontal axis wind turbines with three blades.

Figure 2.14: Enercon Wind turbine E-70, with a rated power of 2.3 MW. Source: http://www.enercon.de/.

2.3.3 Parameters that govern the wind electricity generation process

Wind turbines extract the power contained in the air that flows through the rotor and blades, and convert it into mechanical energy and subsequently into electrical energy. The formula to calculate the power that a wind turbine can achieve is:

$$P = \rho.A/2.v^3.c_p.\eta$$

"P" represents the power (typically measured in Watts) contained in the wind.

The air density, measured in kg/m^3 is represented by "ρ". For the standard atmosphere, the air density is $1,225 kg/m^3$ (at 15° Celsius and an air pressure of 1013,3 hPa). This is the case at sea level.

"A" represents the vertical area (in m^2) covered by the rotor at a right angle with the wind. The larger the area covered by the rotor, the greater the power. This explains partially why the evolution of wind turbines in the last years has been towards larger rotor areas.

The wind speed is represented by “v” (in m/s) and is the most important parameter, since a two-fold increase in the wind speed results in an eight-fold increase in the power “P”.

Nevertheless only up to 59,3% of the kinetic energy contained in the wind can be transformed by the wind turbine, due to what is known as the “Betz limit” (represented by “c_p”).

Lastly, “η” represents the efficiency of the wind turbine, which results from the multiplication of the efficiencies of the rotor, the gear box, the control systems, the yaw and the generator.

Each wind turbine has a certain “power curve”, which describes the turbine’s actually achievable power according to the wind speed, considering the limits of the machine. The figure above depicts the different power curves, going from the unrestricted power in the wind, through the maximally theoretical usable power due to the “Betz limit”, to the real power curve of a wind turbine, taking into consideration its mechanical and electrical efficiency (efficiency of rotor, gear box, control systems and yaw and efficiency of the generator).

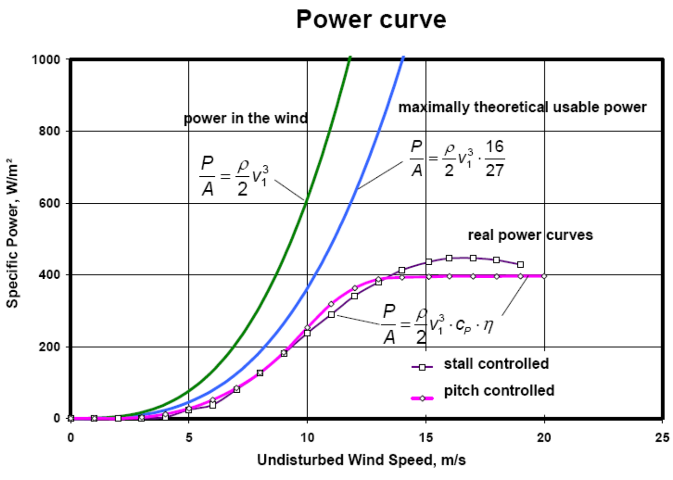


Figure 2.15: Power per m² of rotor swept area over the undisturbed wind speed (in m/s). The mechanical and electrical efficiency of the wind turbine is represented by “η”. Source: Krenn, 2010.

3 Analysis of Promotion Strategies for Wind Electricity

The objective of this work is to analyze how effective and efficient are the promotion strategies for wind electricity in Germany and Brazil. In the next section the most common promotion strategies for renewable electricity in general will be surveyed and explained.

Furthermore, carried out promotion strategies for wind electricity in Brazil and Germany will be analyzed. In the next chapter, the "effectiveness" and "efficiency" of promotion strategies will be defined. Effectiveness and efficiency will be calculated for both countries and the obtained results will be analyzed in order to identify lessons learned and potential for improvement.

3.1 Promotion Strategies for Renewable Electricity

It is said that promotion strategies for renewable electricity are the main drivers of their growth. But why are promotion strategies necessary to drive RES-E growth? The first answer to this question could be that renewable electricity is presently more expensive than electricity from conventional sources, therefore to stimulate its deployment and RES-E generation, promotion strategies are required.

RES-E technologies are rather new in comparison to the conventional electricity, having a steep learning curve ahead. To achieve lower RES-E unit costs, further RES deployment is required. Promotion strategies are key drivers of RES-E deployment, but should also stimulate RES-E generation.

However, this is not the only reason why RES-E is more expensive than conventional electricity. Apart from the fact that the conventional electricity industry (fossil and nuclear) has received subsidies from the governments for years, negative externalities play a fundamental role. Gray electricity's price does not contain all incurred costs and therefore it costs less than its "actual" cost if all of its negative externalities were internalized.

Negative externalities are negative effects caused by an agent in the economy, which are incurred by other agents in the economy whose interests were not taken into consideration. In the case of conventional electricity generation, the social cost of this electricity is higher than the cost for the producer, since CO_2 emissions exert a negative effect on the atmosphere causing air pollution and health problems in society –of regional impact- and greenhouse effect, which leads to climate change –of global impact-. The cost of all these negative effects to society is not included in the price of the gray electricity generated. Renewable electricity generation has as well environmental externalities as there is some pollution involved in the production of the technology, but these are of lower magnitude and hence do not distort the market so significantly.

Promotion strategies for renewable electricity therefore intend to correct the above mentioned market failures. Promotion strategies for RES-E are necessary to enable RES-E deployment, to achieve a critical mass and a steep learning curve. This will bring RES-E investment and generation costs down. Ultimately, it will enable RES-E technologies to reach grid parity (when RES-E becomes cost-competitive with conventional electricity), and consequently promotion strategies to make them competitive with gray electricity will become unnecessary.

3.1.1 Description of Existing Promotion Strategies

Different promotion strategies have been applied in Europe to promote renewable energy sources, and all have led to varying results and degrees of success. The table below depicts the main promotion strategies that have been adopted in Europe so far.

Table 3-1: Classification of Renewable Energy Sources promotion strategies. Source: Haas et al. (2001).

		Direct		Indirect
		Price-driven	**Quantity-driven**	
Regulatory	Investment focussed	• Investment incentives • Tax incentives	• Tendering system	• Environmental taxes
	Generation based	• Feed-in tariffs • Rate-based incentives	• Tendering system • Quota obligation based on TGCs	
Voluntary	Investment focussed	• Shareholder programmes • Contribution programmes		• Voluntary agreements
	Generation based	• Green tariffs		

While regulatory policies are mandatory, voluntary policies are based on the consumer's willingness to pay higher rates for electricity of renewable sources (Resch et al., 2009).

Investment-focused policies aim to increase the installed capacity of RES-e, not considering how much electricity is actually generated afterwards with this capacity. These policies provide financial support through, for example, grants or soft loans paid per unit of capacity installed. On the contrary, generation-based policies support the generation of RES-e and therefore the financial support is paid per unit of RES-e generated.

Direct policies aim to increase deployment of RES-e in a direct manner, either supporting the increase of RES-e capacity installed or of RES-e generated, while indirect policies tend to do it in an indirect manner, i.e. by punishing pollution, setting a carbon tax or removing subsidies to nuclear and fossil-fuel electricity (Haas et al., 2001).

All promotion strategies are an intervention in the electricity market and therefore an artificial market is created. The difference is whether the strategy will artificially fix the price or the quantity of the RES-e. Price-driven strategies set the price to be paid for RES-e whereas quantity-driven strategies set the quantity of RES-e to be either installed or generated.

In the next section, the promotion strategies listed in table 3-1 above will be described in more detail.

3.1.1.1 Regulatory Promotion Strategies

3.1.1.1.1 Direct promotion strategies

Price-driven promotion strategies

3.1.1.1.1.1.1 Investment focused promotion strategies

Investment incentives offer financial support per unit of RES-e capacity installed, i.e. a certain amount is paid by the government to the investors per kW of RES-e installed. The amount of incentive paid may vary depending on the technology of RES-e being deployed.

Tax Incentives offer tax rebates for investors in RES-e capacity, i.e. an exemption on import, VAT or income taxes when investing in RES-e capacity. The incentives may vary depending on the technology of RES-e being deployed (not all tax rebates or exemptions have to be the same for all types of RES-e technologies).

3.1.1.1.1.1.2 Generation based promotion strategies

Feed-in Tariffs (FITs) fix the price that each generator of RES-e is entitled to be paid per unit of RES-e generated and fed into the grid, which is normally guaranteed for a period long enough to enable the costs of the investment to be fully amortized (typically 15 to 20 years). A similar version of the FIT is the Feed-in Premium (FIP). Generators receive a fix "premium" per unit of RES-e generated and fed into the grid, in addition to the electricity market price. While the "premium" is fixed for a certain amount of time, the market electricity market price will probably vary and therefore this option offers less security to investors. Both FITs and FIPs are normally technology-specific.

Given the importance of this promotion strategy and the many available design options (reason for which it has turned out to be the most successful promotion strategy for RES-e in Europe), it will be further described later on in this work.

Rate-based Incentives were used in the early 1990s in Germany and Switzerland and obliged utilities to pay photovoltaic electricity generators for (almost) the full production costs (Haas et al., 2001). The difference with FITs and FIPs is that FITs and FIPs are not specifically cost-oriented (Haas et al., 2001), in addition to the fact that FITs and FIPs are more refined in their design and certainly effective, which probably explains why these models have prevailed.

3.1.1.1.2 Quantity-driven promotion strategies

3.1.1.1.2.1.1 Investment focused promotion strategies

In quantity-driven tendering systems, a set capacity to be installed is announced by the government and contracts are awarded to the most convenient bids by means of up-front investment grants per unit of capacity installed.

3.1.1.1.2.1.2 Generation based promotion strategies

In generation-based tendering systems the government awards RES-e purchase contracts to the bidders who offer the lowest price per unit of RES-e generated while meeting all requirements of the tender. These contracts have a fixed duration.

In systems with Quota Obligations based on Tradable Green Certificates (TGCs), governments oblige a certain actor (the generator, the distributor or the consumer) in the electricity supply chain to purchase a certain amount of RES-e. RES-e producers receive TGCs for each unit of RES-e generated, which they can sell in the market to those who need TGCs to meet the quota obligation. A TGCs market is created, and depending on the demand and supply of the certificates, their price is fixed. Therefore RES-e producers have high uncertainty respect to the profitability of their investments, since this depends on the revenues obtained from the sale of the TGCs. Since in many countries where quota obligations have been established, no penalties have been defined for not meeting the quota, or these have not been high enough to incentive quota fulfillment, this strategy has proved ineffective.

3.1.1.1.3 Indirect promotion strategies

Environmental taxes have the indirect aim to foster the deployment of renewable energy sources by punishing polluting technologies. Examples of such strategies are taxes on carbon or any other environmentally dangerous materials, taxes on electricity from fossil or conventional sources, or via the reduction or cancellation of subsidies given to the fossil and/or nuclear industries.

3.1.1.2 Voluntary Promotion Strategies

3.1.1.2.1 Direct promotion strategies

3.1.1.2.2 Price-driven promotion strategies

3.1.1.2.2.1.1 Investment focused promotion strategies

In shareholder programmes, the general public is invited to participate in RES-e investment projects by purchasing shares of the investment. This strategy has been used in Germany under the name of "citizen initiatives", in which citizens have been able to purchase shares of photovoltaic plants equivalent to a certain amount of capacity, i.e. one share being equal to 100 Watts of installed PV capacity.

In contribution programmes, the general public gives contributions or donations to a RES fund, with which certain RES-e investment projects are promoted. This strategy has been used in Germany to promote investments in photovoltaics in schools and other public buildings.

3.1.1.2.2.1.2 Generation based promotion strategies

Green tariffs are very popular in Austria, Germany, Switzerland and the USA. The public has the choice to purchase "green" electricity (RES-e) from their elected electricity retailer, for which a "green tariff" (higher than the "grey" electricity tariff) is paid. These surcharges are transferred to the RES-e producer, to cover the higher generation costs. Utilities that have no green electricity in their portfolios may nevertheless offer "green tariffs", with the promise that the surcharges paid by the customers will be devoted to a fund for future investments in RES-e plants.

3.1.1.2.3 Indirect promotion strategies

Voluntary agreements consist of ways of indirectly promoting RES-e. It has been the case in Denmark, Germany, France, Netherlands and Sweden, where certain industry groups (energy companies and/or energy intensive industries) pledged for example to reduce their "grey" electricity consumption or the industry's specific CO_2 emissions within a certain timeframe.

3.1.1.3 Other promotion strategies used in the world

Renewable Portfolio Standards are like quota systems without TGCs. The utilities are obliged to integrate a certain quota of RES-e capacity in their portfolios, by a given date. In general quota systems, the utilities, the distributors, or the consumers are obliged to sell/purchase a certain amount of RES-e. The most successful of these strategies are mandatory and have strict penalties for non-compliance (Mendonça, et al. 2010).

Net metering allows private producers of RES-e to get a credit (normally equivalent to the price of conventional electricity) for each unit of electricity fed into the grid. This is made possible by means of an electricity meter able to measure how much electricity is taken from and fed into the grid.

System benefit charges are carried out in way of a tax on each kWh of electricity generated. The collection from this tax is allocated to a fund used to support desirable renewable energy projects which would otherwise not be implemented (Mendonça, et al. 2010).

R&D expenditures are made by governments of different countries in and out of the European Union in order to fund investigation on major energy topics like energy efficiency, scientific energy research, low carbon energy supply, development of new energy generation technologies, and others. The major disadvantage of this type of support is that it depends mostly on the governments' budgets, making it very susceptible to instabilities and uncertainty in case of financial or economic crises.

3.2 Analysis of Wind Power Promotion Strategies applied in Germany

Germany has been one of the pioneers in the wind industry. Thanks to the successful promotion strategies applied by its government for over twenty years, it is placed third in the world ranking of wind power installed capacity, with 27981 MW as of 30 June 2011.

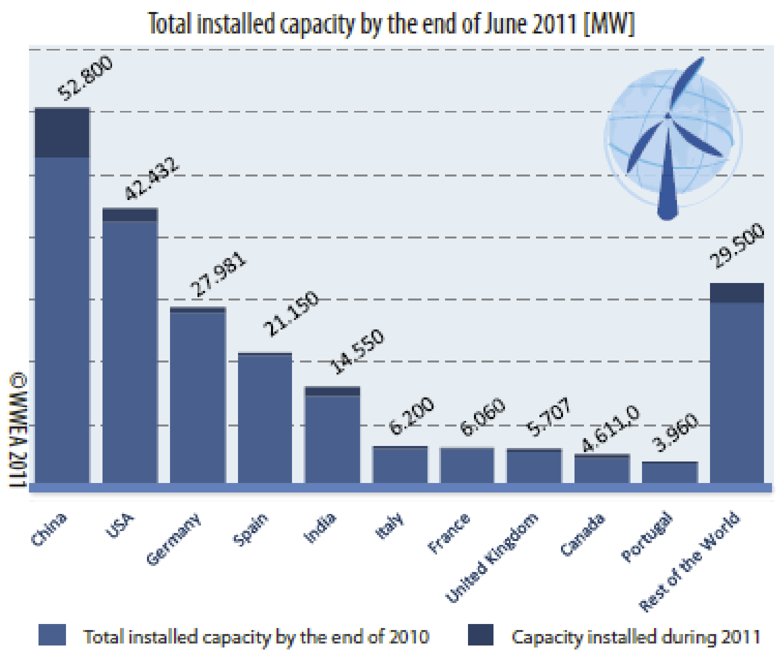


Figure 3.1: World total installed wind power capacity per 30 June 2011. Source: WWEA, 2011 (http://wwindea.org/home/index.php?option=com_content&task=view&id=317&Itemid=43).

3.2.1 Basic Introduction to Germany

The Federal Republic of Germany (hereafter Germany) is a central-European country with border to Denmark, Poland, Czech Republic, Austria, Switzerland, France, Luxembourg, Belgium and the Netherlands, as can be seen in the depiction below. It has access to both the North Sea and the Baltic Sea.

Figure 3.2: Map of Germany and neighboring countries. Source: Economist Intelligence Unit, Country Report July 2011 (http://www.eiu.com/).

With an area of 356.970 km^2, It is home to 81,8 million inhabitants (German Federal Statistical Office - DESTATIS, 2010). Of its surface, 55% is agricultural land and 29% is forest land (Economist Intelligence Unit, 2011).

Germany is the biggest economy of Europe with a GDP of US $3.317,4 billion (as of July 2011), but in GDP per capita (purchase power standard per inhabitant) it lies in place 8 within EU 27, as can be seen from the graph below.

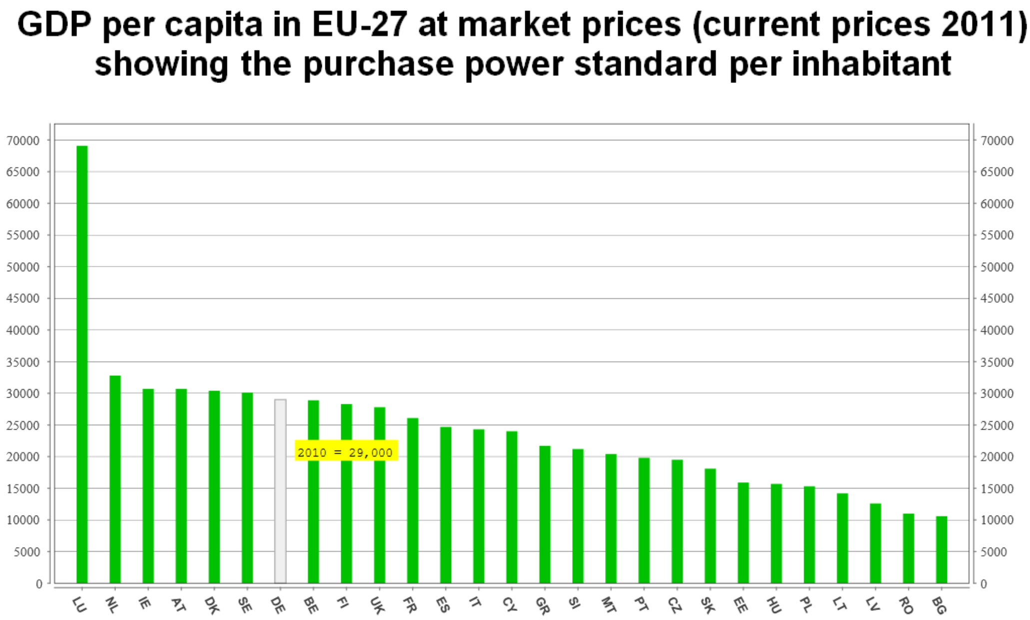


Figure 3.3: GDP per capita in EU-27 at market prices (current prices 2011) showing the purchase power standard per inhabitant of Germany (white bar). Source: Eurostat data and software (see link in footnote [4]).

The composition of the gross value added by sector can be seen in the following graph:

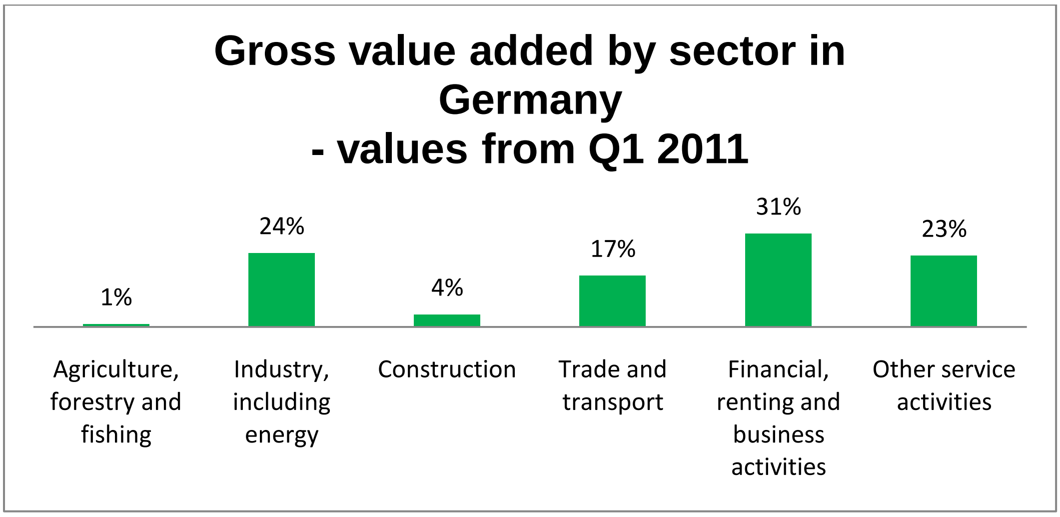


Figure 3.4: Gross value added by sector in Germany – values from Q1 2011. Source: German Federal Statistical Office - DESTATIS, 2011 (see link in footnote [5]).

[4] Source of figure 3.3:
http://epp.eurostat.ec.europa.eu/tgm/graph.do?tab=graph&plugin=1&pcode=tec00001&language=en&toolbox=sort

[5] Source of figure 3.4:
http://www.destatis.de/jetspeed/portal/cms/Sites/destatis/Internet/EN/Content/Statistics/TimeSeries/EconomicIndicators/NationalAccounts/Content100/vgr210a,templateId=renderPrint.psml

Being trade, transport, industry (including energy) and construction key value generators in Germany (together these represent 45% of the gross value added), it can be easily deducted that energy generation plays a key role in the country's economy. However, energy intensity (units of energy per unit of GDP) is relatively low compared to the world average: 0,16 toe/000 2000 US $ of GDP versus 0,31 toe/000 2000 US $ of GDP (source: Key World Energy Satistics 2011, IEA). Since 1990 energy intensity in Germany has decreased 38% (Umwelt Bundesamt, 2011) and it is expected to continue this trend until 2020, since both energy prices and energy efficiency are expected to rise (EIU, 2011) while reducing energy demand.

3.2.1.1Basics of the German Energy Market

According to the German Environment Ministry, from 1990 to 2010, total primary energy consumption in Germany fell slightly from 14906 PJ to 14057 PJ, thanks partly to higher efficiency in fossil-fueled power plants. While renewable energies had the strongest growth, all other energy carriers took the opposite trend. Consumption of coal (both hard and lignite) and mineral oil fell from 10724 PJ to 8012 PJ. Consequently, this had a positive impact in the carbon emissions.

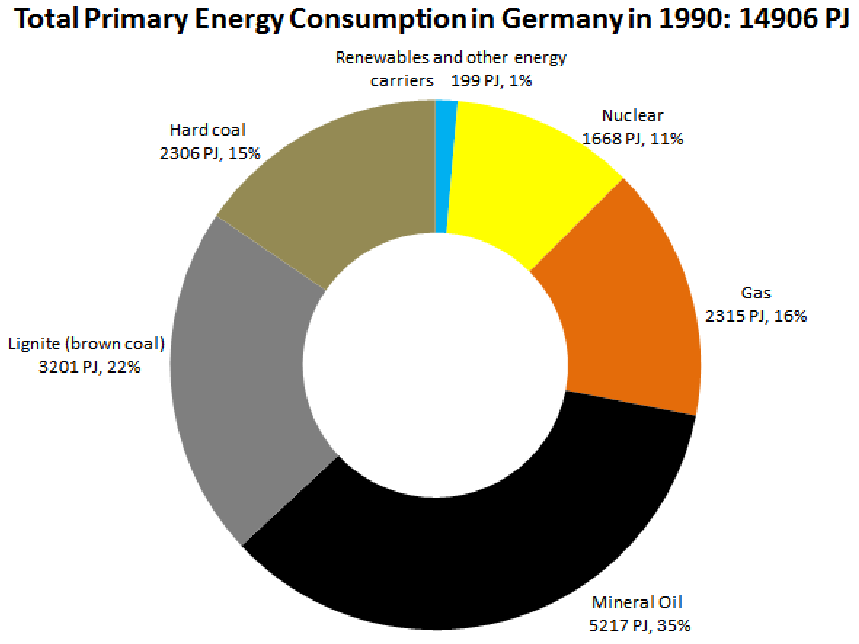


Figure 3.5: Total Primary Energy Consumption in Germany in 1990. Calculations made on the basis of efficiency of each technology. Other energy carriers were counted together with Renewables up to 1999 and afterwards became a separate category. Source: Arbeitsgemeinschaft Energiebilanzen, Energiebilanzen des Bundesrepublik Deutschland 1990-2009 (http://www.ag-energiebilanzen.de).

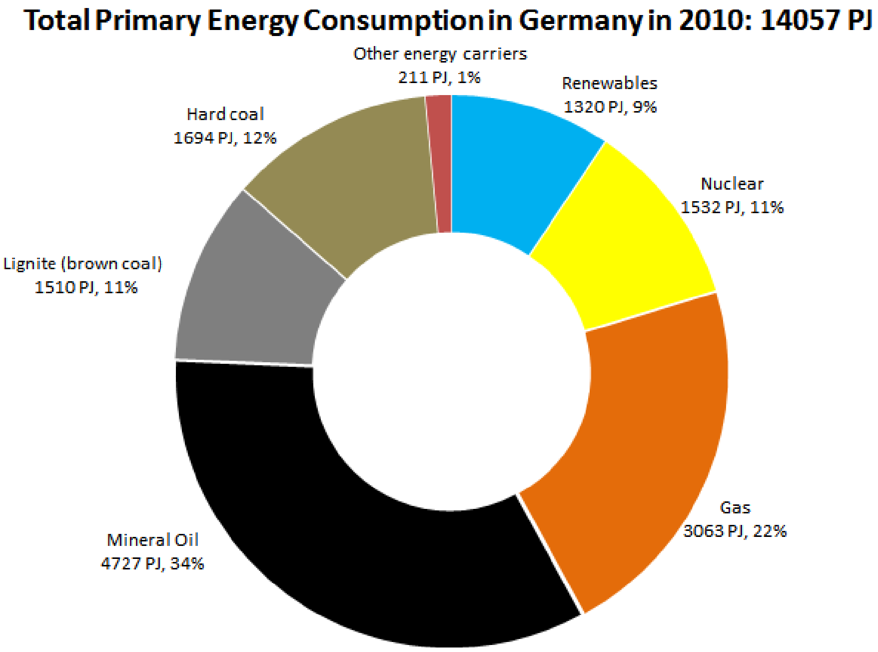


Figure 3.6: Total Primary Energy Consumption in Germany in 2010. Calculations made on the basis of efficiency of each technology. Other energy carriers were counted together with Renewables up to 1999 and afterwards became a separate category. Source: Arbeitsgemeinschaft Energiebilanzen, Energiebilanzen des Bundesrepublik Deutschland 2010, status as of February 2011 (http://www.ag-energiebilanzen.de).

Due to the economic downturn in 2009, the total primary energy consumption in 2009 was 4.9% lower than in 2010 since especially the energy-intensive industry was most affected by the recession.

3.2.1.2Basics of the German Electricity Market

According to the International Energy Agency (Key World Energy Statistics 2011), Germany was the seventh gross producer of electricity in the world in 2010, with 586 TWh, what represented 2,9% of the world's electricity production. Its electricity consumption represented 3,1% of the world's total. Additionally, Germany was the sixth world producer of nuclear electricity, with 23% of its total domestic electricity generation in 2009 and with 22% in 2010.

Being Germany among the world top ten producers of electricity from coal/peat, reaching fourth place with 291 TWh in 2008, it is not surprising to know that total CO_2 emissions in Germany in 2008 were 803,86 Mt of CO_2, what is equivalent to 2,74% of the world's total emissions. Per capita CO_2 emissions are 9,79 tons per year, 2,2 times the world average. Last but not least, electricity consumption per capita is approximately 7.148 kWh per year, 2,5 times the world average.

The chart below depicts Germany's gross electricity consumption in 2010 (preliminary figures), which amounted 603 TWh. It is striking that "green" electricity (electricity produced from renewables) reached 17%, and this can be attributed to the determination of the German government to make the country's electricity system more sustainable.

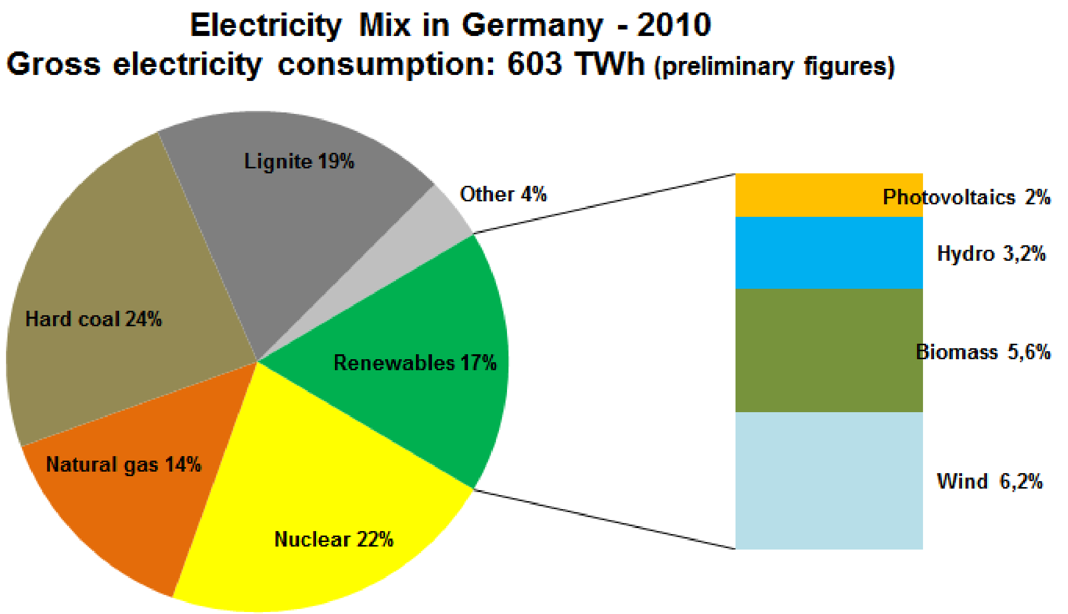


Figure 3.7: Germany's 2010 gross electricity consumption by origin. Source: Agentur für Erneuerbare Energien, (http://www.unendlich-viel-energie.de/uploads/media/AEE_Strommix-Deutschland-2010_feb11.jpg).

3.2.1.3Wind Power Potentials in Germany

The Wind Energy Report Germany 2010 published by Fraunhofer Institut für Windenergie und Energiesystemtechnik (Fraunhofer IWES) (2011) estimates a total onshore and offshore wind power potential for Germany of 85 GW.

The figure below depicts areas of Germany with an average mean long term wind speed of at least 6,5 m/s at 60m hub height. Most of the potential is concentrated in the Northern region of the country, what is consistent with the current regional distribution of the installed wind parks in Germany. The offshore potential is focused on the North and Baltic Seas, where already three wind parks are either commissioned or in process of installation.

Given the high urban settlement density of Germany and the vast protected areas (forests and others), which impose restrictions and/or bans on land use, approximately 7,9% of the inland surface of the country is utilizable for wind power generation (Fraunhofer IWES, 2011).

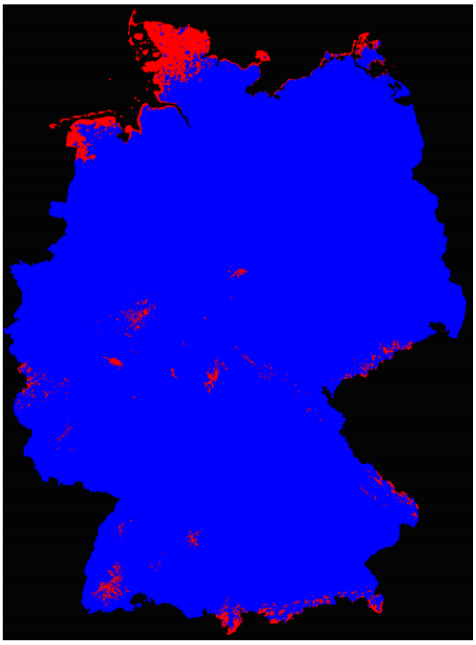


Figure 3.8: Locations in Germany with average mean long term wind speed of at least 6,5 m/s at 60m hub height. Source: Forschungsbericht zur Vorbereitung des EEG-Erfahrungsberichts gemäß § 20 EEG, 3. Zwischenbericht, BMU, 2008 (http://www.erneuerbare-energien.de/files/pdfs/allgemein/application/pdf/eeg_forschungsbericht_ergaenzung.pdf).

Wind speeds tend to be higher in winter months than in summer months in Germany.

3.2.2 Major German Energy Policy Issues

The reader may have already realized that Germany's strong economy needs massive amounts of energy and electricity in order to perform. Given the limited domestic resources, the Government has long ago embarked in the development of a strong energy policy, with the aim to make the country resilient to external supply and price volatilities.

Nevertheless there is still strong dependency on Russia, since most of the gas is imported from that country. Likewise, Russia is the most important oil supplier, followed by United Kingdom, Norway, Libya, and Kazakhstan. Together these five countries provide 77% of the oil supply of Germany (Bundesamt für Wirtschaft und Ausfuhrkontrolle, 2010), while only 3% of the domestic consumption is of domestic origin.

In view of the strong public reaction triggered by the Fukushima-Daiichi nuclear accident (in Japan), in June 2011 the German government coalition decided to phase out nuclear energy by 2022 and to replace the lost capacity with renewable sources, especially wind power (EIU, 2011).

As well, environmental considerations play a central role. Germany is expected to continuing the reduction of its CO_2 emissions, to about 72% of the 1990 levels by 2020 (EIU, 2011).

3.2.3 Main German Wind Electricity Promotion Strategies

A brief historical review and analysis of the promotion strategies for wind power in Germany will be carried out in this section. While the different strategies will be enumerated in chronological order, many of them were applied contemporaneously. This review is based mainly on the information available in the International Energy Agency (IEA) Global Renewable Energy Policies and Measures database (see website in footnote[6]), as well as on the structure provided by Mendonça et al. (2010) in the book “Powering the Green Economy – The feed-in tariff handbook”.

3.2.3.1 The “100 MW Programme” and “250 MW Programme” (1989 to 2006)

Funded by the Federal Ministry for Economics & Technology, the first German promotion strategy for RES-E from wind was initiated in 1989 as the “100 MW Programme” and was later extended to the “250 MW Programme”.

The programme had the purpose to support the construction and operation of promising new and innovative wind turbine technologies and designs, and not

[6] http://www.iea.org/textbase/pm/index.html

simply to support the commercial deployment of already-fully-commercial technologies. In support of this goal, from the beginning of the programme, a "Scientific Measurement and Evaluation Programme" (WMEP) was part of the support scheme. As such, all turbines that receive financial support were monitored for 10 years to assess technical performance (Langniss, 2006), which enabled the collection of valuable operational data from more than 1500 plants over 10 years. All participating operators were required to submit written reports about their operational results (i.e. wind speed, meteorological conditions to which the wind turbines were exposed, reliability of the turbines, occurring faults, and costs for the provision of electricity).

The programme offered support to the piloting and demonstration of new wind turbines and wind turbine designs, with a focus on German companies. However, Danish and Dutch companies were also eligible and in fact had a share of 34% of the installed capacity (Langniss, 2006).

Grants were awarded for the installation and operation of wind turbines at suitable sites, as follows:

- Investment subsidies of €102 per kW, up to a ceiling of 60% of the total investment to a maximum of €46.000, or €51.300 for facilities larger than 1 MW.
- Operation-based subsidies of € 0,041 until 1991 and € 0,031 after 1991 (due to the introduction of the Electricity Feed-in Law) for every kWh fed into the public grid for a period of 10 years. This pay was in addition to the remuneration from the utilities for the electricity sold.

The programme ran until 2006 with a total expenditure of €161 million (Langniss, 2006), of which 88% were operation-based subsidies and 12% investment grants. The cost of the "Scientific Measurement and Evaluation Programme" was additional €27 million. A total capacity of 362 MW was installed, distributed in 1560 wind turbines.

By helping local wind turbine manufacturers move from R&D to full commercialization stage, the programme successfully contributed to building national capabilities in the German wind turbine manufacturing industry (Langniss, 2006), nowadays at the leading edge.

According to figures of 2009 (Bundesverband Windenergie, 2011) German manufacturers and suppliers contributed to nearly 30% of the total world turnover of €22.1 billion, employing close to 100000 people. In 2010 three German companies (Enercon, Siemens and Nordex) were among the top 10 wind turbine manufacturers in the world (Research and Markets, 2011).

3.2.3.2 ERP-Environment and Energy Saving Programme

Between 1990 and 2008, the "Deutsche Ausgleichsbank" (today KfW Bankengruppe) offered low-interest loans for private companies, freelancers and public-private partnerships who take eligible measures to save energy or who plan to use renewable energies 2003. Credit terms varied between 10 and 20 years with a repayment-free initial phase of two to five years. Interest rates were slightly below market level. The wind power sector profited from this programme, being the main beneficiary of the €10.7 billion in support extended from 1990 to 2005.

3.2.3.3 Electricity Feed-In Law of 1991 ("Stromeinspeisungsgesetz") (1991 to 2000, amended in 1998)

In spite of its simplicity, many attribute the German wind industry boom to the success of this law. The 1991 Electricity Feed-In Law guaranteed grid access for RES-E and obliged utilities operating the grid to pay a feed-in premium for the electricity. But only plants with capacity lower than 5 MW were eligible, what was blocking many RES-E projects to be developed. The incurred costs of this law were borne by the electricity consumers in the regions where the RES-E was generated, and not equally by all, and this caused serious electricity price disparities within the country. The duration of the remuneration period was not fixed and therefore investors were lacking the security necessary for implementing the RES-E projects.

The feed-in premiums for wind power were 90% of the average electricity price paid by the end customers in the previous year. As a result of the electricity market liberalization and the phasing out of the coal levy, the feed-in premiums decreased after 1996. In 1998 the law was amended and a cap was introduced, to limit the amount of RES-E that electricity suppliers had to remunerate according to the law.

The shortcomings mentioned above had to be overcome in order to enable the German wind power industry to continue growing. According to Trittin (2000), due to several reasons this law had to be replaced. First, the green electricity output had exceeded the cap set for remuneration entitlement. In order to keep up the momentum gathered by the German wind industry, it was necessary to extend the remunerations to more RES-E plants. Second, it was necessary to re-design and level out the cost distribution between the regions and to provide RES-E generators with more investment security. Lastly, changes were necessary in order to comply with EU Directives.

3.2.3.4 Renewable Energy Sources Act („Erneuerbare-Energien-Gesetz“) (2000)

One of the first feed-in tariff schemes in Europe with solid design, the 2000 Renewable Energy Sources Act proved successful by enabling an increase in wind power capacity in Germany of approximately 10 GW in its first four years, and by increasing the RES-E generation from 13,6 TWh to 34,9 TWh in the same period (BMU, 2004).

In addition to the introduction of the improvements mentioned in the previous paragraph, several key design elements made this Act so successful. These will be analyzed next.

3.2.3.4.1 Eligible technologies

Eligible technologies for support were precisely defined. Moreover, a basket of eligible technologies were included: hydrodynamic power, wind energy, solar radiation energy, geothermal energy, gas from sanitary landfills, sewage treatment plants, mines, and biomass. This supported the diversification of the capacity to be deployed, by enabling economies of scale and thus giving a boost to those technologies with originally higher generation costs, bringing their costs down.

3.2.3.4.2 Eligible plants

Eligible plants were clearly determined in terms of size, time of commissioning, territory, and ownership. For instance, plants owned at least 25% by the Federal

Republic of Germany or one of Germany's federal states were left out, as well as biomass plants with over 20 MW, or hydroelectric plants of over 5 MW installed electrical capacity.

3.2.3.4.3 Tariff calculation methodology

The tariff calculation was made based on the "cost-covering remuneration" (Mendonça et al., 2010), therefore by making economically interesting for investors both technologies with high and low market shares, which is especially important for the latter, as these require economies of scale to reduce their high unit costs and to enable these to reach grid parity.

3.2.3.4.4 Technology-specific tariffs

Additionally, technology-specific tariffs were set. Onshore wind energy had a tariff of of €0,091 for the first five years starting from the date of commissioning, and afterwards €0,0619. But, if during these 5 years the achieved yield of the installation was less than 150% of a defined reference yield, then the 5-year period is extended by two months for every 0,75% which the yield of the installation stays below 150%. Offshore wind energy installations (at least three nautical miles seawards from the baselines used to demarcate territorial waters) obtain €0,091 for nine years. These differentiations not only tend to reduce windfall profits for those installations with better wind conditions and therefore higher outputs and revenues, but as well aim to foster installations in areas with poorer wind conditions. Lastly, the law intends to support investors deal with the presently higher investment costs of offshore wind projects.

3.2.3.4.5 Tariff degression

The Act foresees an automatic tariff degression of 1.5% annually, for new installations commissioned, meaning that the later a RES-E installation begins operations, the lower the payment compensation. This way the legislator found a simple way to ensure the feed-in tariffs would be adjusted to the technological learning curves, given that the industry had enormous improvement potential. Likewise, the idea was to give investors an incentive to speed-up their investments and begin operations rapidly.

3.2.3.4.6 Duration of the payments

The duration of the payments was set in 20 years after the year of commissioning (except for hydroelectric plants), which is considered a very reasonable period for amortization of renewable energy investments.

3.2.3.4.7 Financing mechanism

A financing mechanism was established in the law, and, contrary to the Electricity Feed-In Law of 1991 (whereby the incurred costs were borne by the electricity consumers in the regions where the RES-E was generated, creating disparities within the country), it introduced a fair nation-wide cost-sharing scheme. The additional costs were to be covered equally by all electricity consumers and the Transmission System Operators (TSOs) were mandated to make the necessary settlements among each other in order to equalize the RES-E volumes purchased by each of them and throughout the whole electricity value chain. This scheme ensured that each electricity customer was going to share the burden equally.

3.2.3.4.8 Purchase and compensation payment obligation

The purchase obligation is, after the long-term payment of the feed-in tariff, the most important ingredient of a feed-in tariff scheme, since it assures investment security (Mendonça, et al. 2010). The Act specifies that the grid operator geographically closest to the RES-E plant is obliged to purchase the entire amount of electricity offered by the RES-E generator and is as well obliged to pay the compensation as stipulated in the Act. In addition, the Act specifies that any subsequent grid operator upstream is also obliged to purchase the RES-E and pay the compensation. Consequently the Act assures that the RES-E generator is going to be protected from the monopolistic or oligopolistic attitudes that other bigger players (typically generating and sometimes also dispatching “gray” electricity) in the market may have, which would put “green” electricity at a disadvantageous competitive position.

3.2.3.4.9 Priority grid access

The Renewable Energy Sources Act enforces the grid operators to purchase RES-E and pay the stipulated compensation, with priority respect to conventional electricity. At the time the Act went into force the German electricity market had not been “unbundled” (referring to the ownership separation of electricity generation, transmission and distribution companies). The transmission system, the high voltage electricity grid which is typically a natural monopoly, was owned by companies which also owned distribution systems (low voltage grids) and/or which generated electricity. In order to ensure that no discriminatory practices were applied towards RES-E generators, the Act obliged the grid operators to purchase available RES-E as a priority. Moreover, it obliged the grid operators to make any necessary upgrades to the grid without delay in order to be able to receive the RES-E generated.

3.2.3.4.10 Cost-sharing methodology for grid connection

Grid connection costs in nuclear or coal power plants may be a negligible part of the investment. On the contrary, in RES-E projects these costs can account for a substantial share of the investment costs. Several studies attribute different estimates for wind power grid connection costs, which can vary from a few percentage points, up to more than 25% in cases of off-shore wind power (Weißensteiner et al., 2011). Therefore the profitability of a wind power project will vary significantly depending on the grid connection cost-sharing methodology.

The Act enforced that the costs associated with upgrading the grid exclusively in order to connect new installations, for accepting and transmitting energy fed into the grid for public power supply shall be borne by the grid operator whose grid will have to be upgraded. However, the costs associated with connecting the installations to the grid connecting point shall be borne by the installation operator (the RES-E investor). Referred to in the literature as “shallow” grid connection costs allocation, this cost-sharing methodology is beneficial to RES-E investors and evinces a commitment from the German government towards the deployment of RES-E investments in the country.

3.2.3.4.11 Progress reports

As a means of monitoring the progress of the feed-in tariff programme in terms of achieved market introduction and cost development of power, the Act determines that progress reports shall be prepared and submitted by the relevant Ministries. These reports are very adequate to analyze in addition the environmental benefits and costs of supporting renewable energies (Mendonça et al., 2010).

Furthermore, the Act determines that adjustments to the compensation amounts or their degression rates, or other adjustments as deemed necessary from the reports' results shall be made every two years. This way the legislators left the doors open to adjust the feed-in tariff programme to the ever-changing reality, keeping it updated with the industry's learning curves, market developments, ensuring it remains economic and efficient while it nevertheless guarantees investors a stable investment.

3.2.3.5 Renewable Energy Sources Act („Erneuerbare-Energien-Gesetz“) (2004)

The 2000 Renewable Energy Sources Act proved to be highly effective but further changes were required in order to maintain its effectiveness and efficiency, and to comply with the European Union Directive on the promotion of electricity from renewable energy sources of September 2001 (since in the 2000 Act not all renewable energies defined in the Directive were considered). Therefore, the law was amended and it entered into force on 1 August 2004. The main changes introduced -with focus on those related to wind power- will be analyzed next.

3.2.3.5.1 Setting higher targets

The 2004 amendment increased and specified the share of renewable energies in the total electricity supply to at least 12,5% by 2010 and to at least 20% by 2020. Previously, the Act mentioned its aim to double the share of RES in total energy consumption by the year 2010. With this change the German government strengthened its commitment towards renewable energies in the mid-term. Since the target was set to be “at least” 12,5% by 2010, it guaranteed the investors that it will not act as a cap and prevent further growth when the 12,5% share is reached.

3.2.3.5.2 Tariffs for wind power

Tariffs for onshore wind energy were reduced to €0,087 for the first five years starting from the date of commissioning, and afterwards €0,055, with the intention to reduce excessive incentives for installations at coastal sites, which tend to be very productive.

The Act determined that plants unable to achieve at least 60% of the defined reference yield were no longer eligible for feed-in tariff payment. The intention of the legislator was to not incentive investors to install wind power plants in poor wind sites, and to incentive more installations in good wind sites.

Offshore wind energy installations (at least three nautical miles seawards from the baselines used to demarcate territorial waters) obtain €0,091 per kWh for 12 years (previously nine years) if the plants are commissioned by 2010 (previously 2006). Citing the Act, "the 12-year period is to be extended for installations built at a greater distance from the shoreline and at greater depths: for every additional nautical mile beyond 12 nautical miles the period will be extended by 0,5 month and for every additional metre of depth by 1,7 months". The base rate which follows the initial rate was set to €0,0619 per kWh for the remaining months until 20 years are completed.

Furthermore, the Act excluded from feed-in tariff payment eligibility any offshore wind installations with construction licensed after 1 January 2005 to be built within the German Exclusive Economic Zone or in coastal waters, and in nature conservation or bird protection areas, with an obvious aim to protect environmentally sensitive and valuable areas.

3.2.3.5.3 Tariff degression

The Act increased the automatic tariff degression for onshore wind power to 2% annually, for new installations commissioned. For offshore wind power, the tariff degression was set to be 2% from 2008 onwards.

3.2.3.5.4 Payment obligation

The amended Act tied the obligation to pay the feed-in tariff to plants with a capacity of over 500 kW where the capacity is measured and recorded. The intention of the legislator was to promote better integration of RES-E technologies into the electricity system.

3.2.3.5.5 Additional tariff payment for repowering

The Act foresaw the extension of the payment of the initial (higher) tariff for an extra two months for each 0,6% of the reference yield which the plant's yield stays below the 150% of the reference yield, if the existing turbines are modernized or replaced and installed in the same administrative district, as long as the original turbines were commissioned before 31 December 1995 and the new power capacity triples the original.

3.2.3.6 Renewable Energy Sources Act („Erneuerbare-Energien-Gesetz“) (2009 - today)

The 2004 Act had to be amended in order to pave the way for reaching “an increase of the share of renewable energy sources in electricity supply to at least 30% by year 2020 and to continuously increase that share thereafter” (BMU, 2008).

3.2.3.6.1 Feed-in tariffs adjustment

In order to stimulate wind power installations the wind feed-in tariffs were increased. The initial remuneration for onshore wind was set in €0,092 per kWh (compared to €0,0787 per kWh if the 2004 Act had remained valid). The basic remuneration was set in €0,0502 per kWh (compared to €0,0497 per kWh if 2004 Act had remained valid). The 2009 initial remuneration for offshore wind was raised from €0,0874 per kWh to €0,13 per kWh. On top of the initial remuneration, a “sprinter bonus” of €0,02 per kWh was offered to offshore wind installations commissioned before 31 December 2015. The basic remuneration was brought down from €0,0595 per kWh to €0,035 per kWh.

3.2.3.6.2 Degression rate

The degression rate for onshore wind was reduced from 2% annually to 1% annually. For offshore wind, the degression rate was set in 5% annually from year 2015 onwards (compared to 2% annually in the 2004 Act).

3.2.3.6.3 Additional tariff payment for repowering

On top of the initial remuneration, a bonus of €0,005 per kWh was offered for onshore repowering meeting the following criteria: one or several turbines are completely replaced; turbines are located in the same or neighbouring administrative district, original turbines were first commissioned at least ten years ago; and the new capacity is at least twice, but not higher than five times the original level (Grotz, 2008).

3.2.3.6.4 Additional system service bonus

The 2009 Act authorized the regulation of requirements for wind power plants to improve the network integration, hazard beacons, navigation lights, voltage control, reactive power supply, frequency control and other system services previously only mandatory for conventional power plants. The Ordinance on System Services by Wind Energy Plants came into force in July 2009. Therefore, the 2009 Act foresaw a bonus payment for system service as follows: for turbines who come into service after 30 June 2010, €0,005 per kWh on top of the initial remuneration; for turbines commissioned after 1 January 2002 the bonus is €0,007 per kWh over five years if the required technical upgrade is made before 31 December 2010.

3.2.3.6.5 Other requirements

The 2009 Act imposed a new requirement that wind turbines with capacity over 100 kW need to be equipped for remote reduction of supply and monitoring of actual supply in case of grid overload. Old turbines (commissioned before 1 January 2009) were forced to comply from 1 January 2011.

Grid operators' obligations were expanded and now included not only the extension but as well the optimization and enhancement of the grid systems. Operators willing but unable to feed-in their RES-E can claim for the lost compensations if grid operators fail to comply.

Additionally, grid operators were entitled to exceptionally take technical control over installations with capacity over 100 kW to prevent grid overloads, for transitional periods. Those operators who were prevented to feed-in RES-E into the grid were given the possibility to request compensation.

3.2.3.6.6 Incentives for participating in the conventional energy market

As in the 2004 Act, operators of RES-E plants were given the possibility to sell electricity directly on the stock exchange or to other third parties, but had now the additional possibility to sell directly only a certain fixed percentage of their total output, which had to be informed in advance to the grid operator. For the remaining output the operators could still feed-in to the grid and claim the corresponding remuneration. The intention of the legislator was to “train” RES-E operators to perform in the electricity market, under standard market conditions.

3.3 Analysis of Wind Power Promotion Strategies Applied in Brazil

3.3.1 Basic Introduction to Brazil

The Federal Republic of Brazil (hereafter Brazil) is the largest south-American country with border to French Guiana, Suriname, Guyana, Venezuela, Colombia, Peru, Bolivia, Paraguay, Argentina and Uruguay, as can be seen in the depiction below. It has access to the Atlantic Ocean through a coastline of more than 7000 km, what provides the country with strong and consistent winds.

Figure 3.9: Map of Brazil and neighboring countries. Source: Economist Intelligence Unit, Country Report July 2011 (http://www.eiu.com/).

With an area of 8.547.400 km^2 (EIU, 2011), It is home to 190,755 million inhabitants (IBGE, 2010). Of its surface, 44% is suitable for agriculture (Economist Intelligence Unit, 2011).

Brazil is the biggest economy of Latin America and seventh-largest economy in US-dollar terms (EIU, 2011) with a GDP of US $853,82 billion (as of 2008, expressed in 2000 US $, IEA). The GDP per capita is US $4581 (as of 2008, expressed in 2000

US $, IEA), and this places Brazil in fourth place within Latin America and the Caribbean, behind Trinidad and Tobago, Uruguay and Chile.

The composition of the gross domestic product by sector can be seen in the following graph:

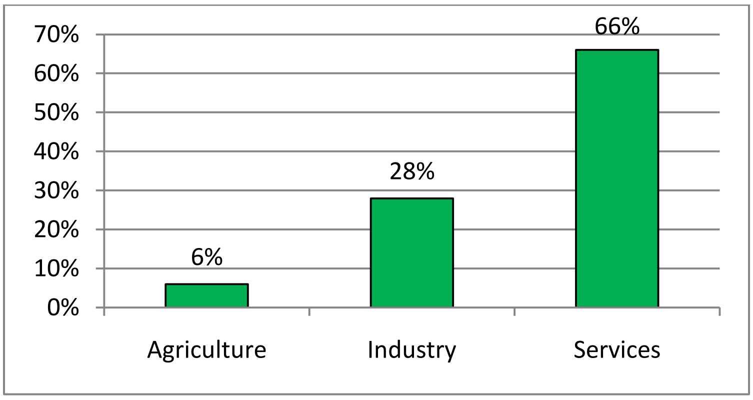


Figure 3.10: Gross domestic product by sector in Brazil – estimation for 2010. Source: CIA, 2011 (https://www.cia.gov/library/publications/the-world-factbook/fields/2012.html).

Brazil's industry includes iron and steel mining, machinery production, aircraft construction, vehicle parts and engines and petrochemicals, mainly energy-intensive sub-sectors. Industry was the largest energy consumer in 2010 with 38,18%, and with a 13% growth respect to 2009, owing to the recovery of the sector after the world crisis in 2008 and 2009. It is followed by transport with 30,72% of the final energy consumption in 2010, what represents a 10,8% increase respect to 2009 responding to the increase in vehicle sales in 2010.

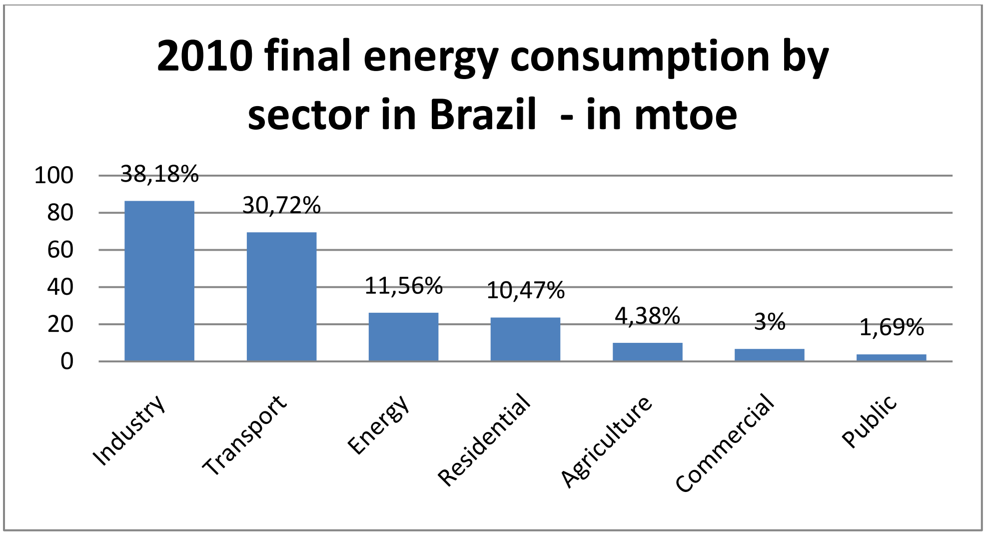


Figure 3.11: Final energy consumption by sector in Brazil in 2010 (preliminary figures). Source: Balanço Energético Nacional, Empresa de Pesquisa Energética, Ministerio de Minas e Energia (https://ben.epe.gov.br/).

Energy intensity (units of energy per unit of GDP) is lower compared to the world average (0,28 versus 0,31 toe/000 2000 US $ of GDP) (source: Key World Energy Satistics 2011, IEA). Energy intensity has slightly risen since 1990, from 0,124 toe/000 US $ to 0,13 toe/000 US $ (both expressed in 2010 US $; Balanço Energético Nacional).

3.3.1.1Basics of Brazil's Energy Market

According to the Brazilian Mining and Energy Ministry, from 1990 to 2010, total primary energy consumption in Brazil almost doubled from 5945 PJ to 11338 PJ, due mainly to a roughly 80% growth of the gross domestic product.

Below, the composition of the Total Primary Energy Supply (TPES) in Brazil in 2010 is depicted. Mineral oil and coal and their derivatives, and natural gas together represent more than 50%. Products from sugar cane have a 18% share and it is expected that these will increase their share, given that the stock of vehicles fuelled by sugar-cane ethanol will rise (EIU, 2011). Brazil is the second largest ethanol producer behind the USA

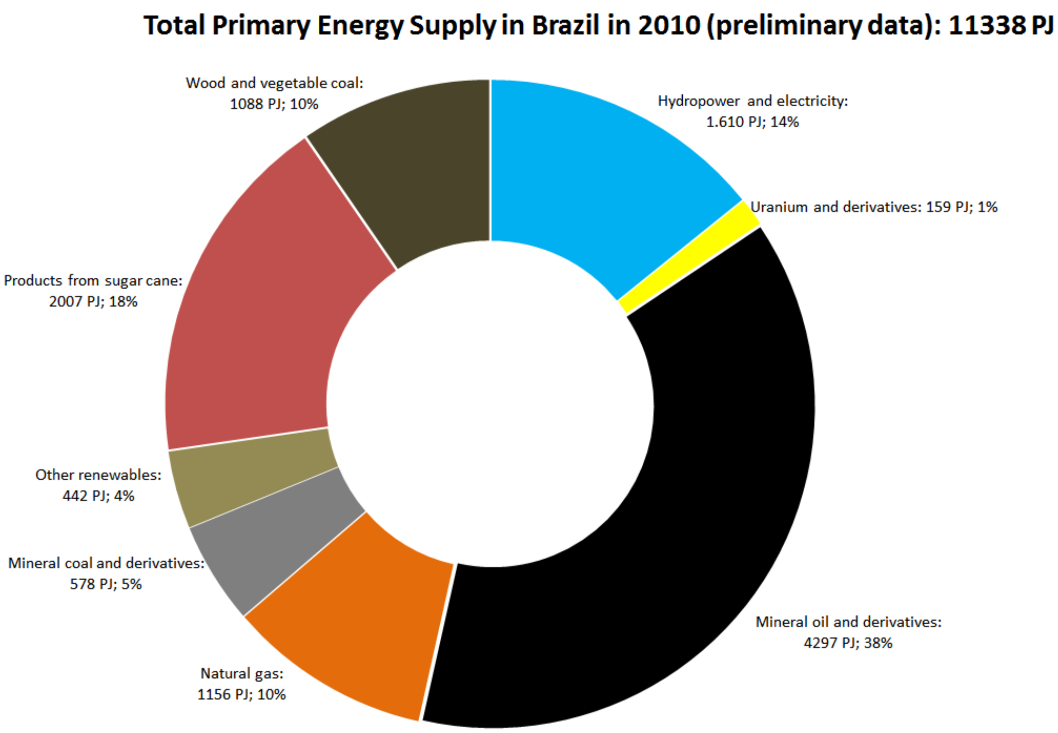


Figure 3.12: Total Primary Energy Supply in Brazil in 2010 (preliminary figures). Source: Balanço Energético Nacional, Empresa de Pesquisa Energética, Ministerio de Minas e Energia (https://ben.epe.gov.br/).

The figure below shows the evolution of the TPES composition in Brazil from 1970 to 2010. Although renewable energies (in green) have a high share, thanks to the leading role of hydroelectricity for power generation and to the widespread use of domestically produced ethanol as vehicle fuel, the rising trend of the share of non-renewable sources (in black) is evident.

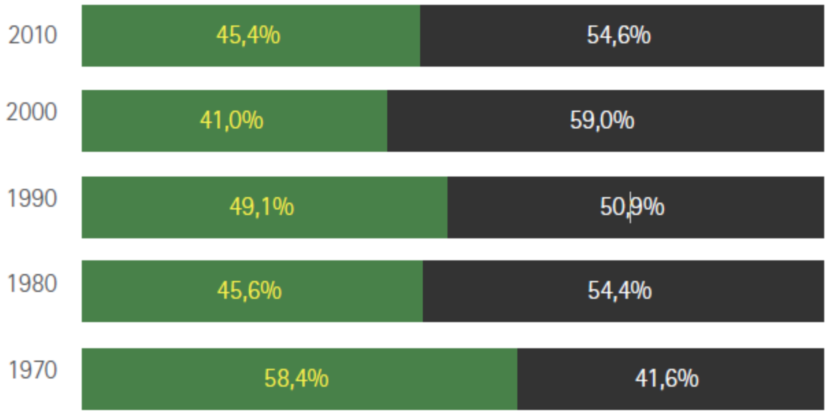


Figure 3.13: Evolution of renewable and non-renewable shares of Total Primary Energy Supply in Brazil from 1970 to 2010. Source: Balanço Energético Nacional, Empresa de Pesquisa Energética, Ministerio de Minas e Energia (https://ben.epe.gov.br/).

3.3.1.2Basics of Brazil's Electricity Market

According to the International Energy Agency (Key World Energy Statistics 2010), Brazil was the ninth gross producer of electricity in the world in 2009, with 466 TWh, what represented 2,3% of the world's electricity production. Its electricity consumption represented 2,31% of the world's total. Additionally, Brazil was the world's second largest net importer of electricity in 2009, with 40 TWh.

In 2009 Brazil was the world's second largest producer of hydro power (excluding pumped storage), with 391 TWh what is equivalent to 11,7% of the world's total hydroelectricity production. In 2010, hydropower generated 80% of the local electricity consumption.

CO_2 emissions in Brazil in 2009 were 337,8 Mt of CO_2, what is equivalent to 1,16% of the world's total emissions. Per capita CO_2 emissions are 1,74 tons per year, 59,44% lower than the world average.

Last but not least, electricity consumption per capita is approximately was 2.201 kWh in 2009, 19,38% lower than the world average. Electricity intensity has been nevertheless on the rise continuously since 1970 – it was then 491 kWh per capita and in 2010 it reached 2877 kWh per capita.

Figure 3.14 depicts Brazil's gross electricity consumption in 2010 (preliminary figures), which amounted 514,2 TWh. It is striking that hydroelectricity reached 80%, what partly explains the country's low CO_2 emissions. Nevertheless this heavy reliance on hydropower leaves the country vulnerable to below-average rainfall periods, what materialized a decade ago and forced electricity rationing to be put in place temporarily.

Natural gas is the second most important source of electricity generation. Gas from oil extraction will probably substitute current imports from Bolivia in the next years as Brazil starts exploiting its off-shore oil and gas deposits.

Playing a complementary role with the production of ethanol from sugar cane for vehicle fuels, electricity is generated from biomass, especially sugar cane bagasse and other biomass, thanks to the country's abundant vegetation.

Nuclear power is produced from two reactors, and a third is under construction. Brazil boasts approximately 5% of the world's uranium resources.

Despite its estimated wind power potential of 142,5 GW, wind power generation is still marginal but is definitely to grow in the next five years, as the 5,7 GW already contracted through power auctions become operational.

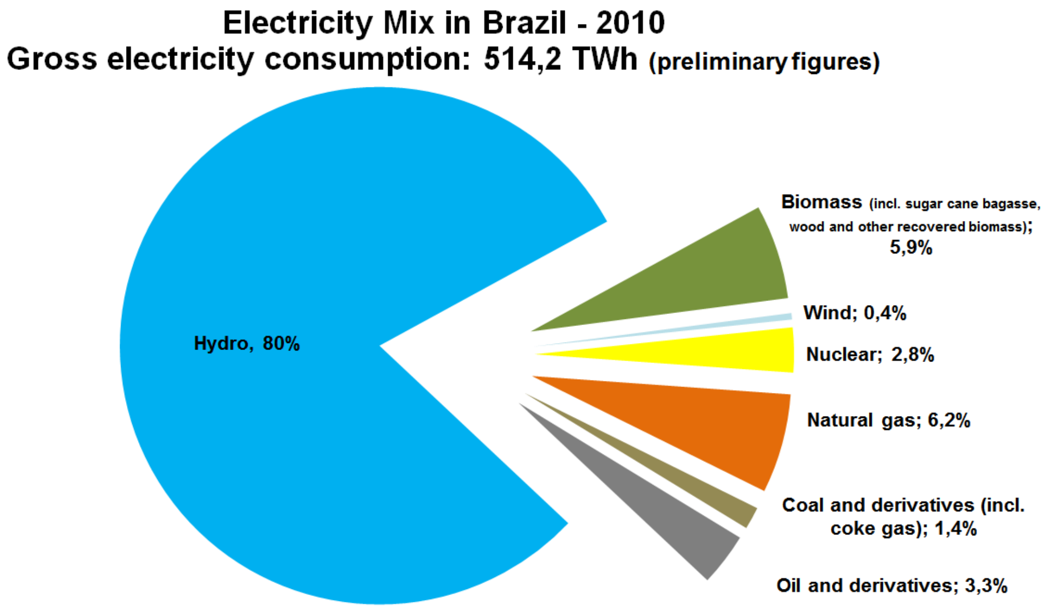


Figure 3.14: Brazil's 2010 gross electricity consumption by origin (preliminary data). Source: Balanço Energético Nacional, Empresa de Pesquisa Energética, Ministerio de Minas e Energia (https://ben.epe.gov.br/).

3.3.1.3Wind Power Potential in Brazil

The Atlas of Brazil's Wind Power Potential ("Atlas do Potencial Eólico Brasileiro") was published in 2001 by the Brazilian Ministry of Mines and Energy. According to it, the total onshore wind power potential of Brazil is 143,5 GW, considering a hub height of 50 metres, assuming a yearly average wind speed higher than 7 m/s and a mean density of 2 MW/km^2 of surface occupation. Water surfaces were excluded for this purpose.

On average 1899 full load hours are estimated with these parameters, what would result in a total yearly generation potential of 272,2 TWh for the entire country.

More than half of the potential is concentrated in the Northeastern region, with 75 GW and an estimated yearly generation of 144,3 TWh. Second best are the Southeast and South regions, which together accumulate 52,5 GW (some 36% of the potential). The coastal areas in these regions boast the best wind resources.

The depiction below illustrates the five regions of Brazil, their wind power potential and the mean annual wind speed at 50 metres hub hight.

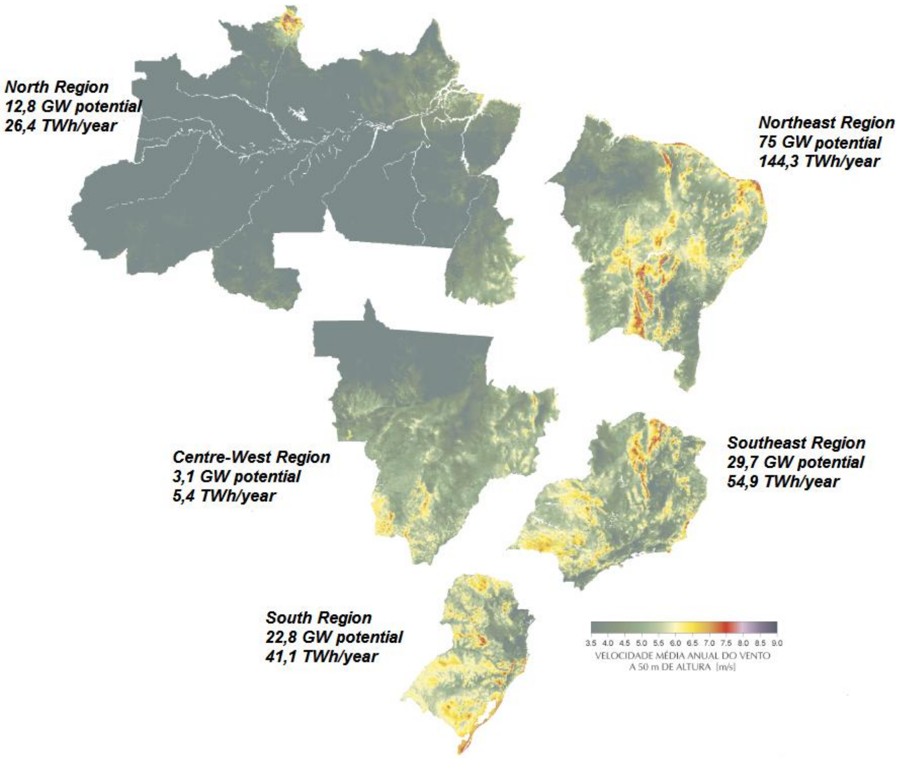


Figure 3.15: Wind power potential in Brazil per region. Source: Atlas do Potencial Eólico Brasileiro, Ministerio de Minas e Energia, 2001.

One important finding of the Atlas was that wind power is seasonally and geographically combinable to hydropower generation, so predominant in Brazil's electricity mix.

The strongest winds in Brazil are measured from June to November, when rainfall intensity tends to be the lowest, and vice-versa, the lowest winds are measured from December to May, when rainfall intensity and consequently hydroelectric generation, is high.

With regard to the geographical combinability between wind and hydropower in Brazil, the Atlas confirmed that the strongest wind power potentials are located close to demand areas (densely populated areas, like in the Northeast coastal region) and additionally at the ends of the grid and distant to the hydropower plants. As stated in the Atlas, this fact enables a smoother and easier integration of wind power into the grid.

For now, no official estimations have been made on Brazil's offshore wind power potential.

3.3.2 Major Brazilian Energy Policy Issues

Brazil boasts enviable energy resources, ranging from oil and gas reserves, a great hydropower resource, uranium deposits, strong winds (estimated average 1900 FLH, wind power potential 142 GW) 2009 the world's seventh largest energy consumer and

The Government nevertheless embarked approximately 30 years ago in the development of a local ethanol industry, taking advantage of the favourable conditions for the growth of sugar cane, with the aim to make the country resilient to external supply and price volatilities.

There is some dependency on Bolivia for gas supplies, which will be substituted soon by locally extracted gas from the recently discovered off-shore reserves. Likewise, Brazil produces crude oil but due to not enough refining capacity it needs to import refined products. Once Brazil starts exploiting recently discovered reserves, and if these fields end up being as big as estimated, the country may become oil self-sufficient and will very likely become gas self-sufficient.

In spite of the densely populated areas where the two Brazilian nuclear reactors are located, the Fukushima-Daiichi nuclear accident (in Japan) did not raise public concerns and the government even intends to expand its nuclear capacity by 3 GW (currently 2 GW) by 2030 (EIU, 2011). The alternative would be hydropower, which has also its controversial side as the capacity of projects in the pipeline and those in the planning stage account for 67 GW, and these also raise opposition and environmental concerns.

3.3.3 Main Wind Electricity Promotion Strategies applied in Brazil

A brief historical review and analysis of the promotion strategies for wind power in Brazil will be carried out in this section. While the different strategies will be enumerated in chronological order, many of them were applied contemporaneously.

This review is based mainly on the information available in the IEA Global Renewable Energy Policies and Measures database, the PROINFA website, and the information on Brazil available at the website of the Global Wind Energy Council (see websites in footnote[7]).

3.3.3.1 Programme of Incentives for Alternative Electricity Sources (Programa de Incentivo às Fontes Alternativas de Energia Elétrica, "PROINFA") (2002 to date)

3.3.3.1.1 PROINFA – First Phase (2002 to date)

The PROINFA was implemented by the Brazilian Ministry of Energy and Mining in 2002 with the objective to diversify Brazil's energy matrix. It aims to increase the share of new renewable energy sources in the country and particularly to increase the share of new renewable electricity to 10% of the consumption by 2020.

The programme was divided in two phases, the first of which established the installation of 1100 MW of biomass plants, 1100 MW of small hydropower plants (defined as such if capacity is lower than 30 MW) and 1100 MW of wind power plants. Subsequently and due to the large amount of proposals received, the wind power allocation was expanded to 1400 MW. The allocated projects had to be connected to the grid and be operational by 31 December 2006, but afterwards the deadlines were extended several times and now the programme runs until the end of 2011.

The winning projects are granted a power purchase agreement with Eletrobrás (the executing agent of PROINFA) for all electricity generated during 20 years from commencement of operations, at pre-set tariffs based on the "economic value" for each of the three RES-e sources and with a reference value floor of 50%, 70% and 90% of the rolling year national average supply tariff (for small hydro, biomass and wind power respectively).

[7] http://www.iea.org/textbase/pm/index.html
http://www.mme.gov.br/programas/proinfa
http://www.gwec.net

During the first phase wind power projects benefit from priority grid access and 50% reduction of grid tariffs.

It was established in the programme that all costs generated by the PROINFA programme (the administrative and financial costs, as well as the incentives paid per kWh of electricity generated) were to be funded equally by all classes of electricity end-use consumers, except for those in the lowest residential class (with monthly consumption lower or equal than 80 kWh).

With the objective of developing and strengthening a local renewable energy industry, one of the PROINFA eligibility criteria is that projects have to demonstrate at least a rate of 60% national construction costs.

Additionally, the National Social and Economic Development Bank ("Banco Nacional de Desenvolvimento Econômico e Social", "BNDES") offers special financing programmes for PROINFA eligible projects. Up to 70% of capital costs excluding site acquisition, imported goods and services) could be financed with the basic national interest rate plus 2% of basic spread and up to 1,5% of risk spread. Interests are not charged during construction and the amortization period is of 10 years. A guarantee may be requested for up to 50% of the financing supplied by BNDES. Another requirement is a debt service cover ratio of at least 1,3.

According to GWEC (2011), foreign suppliers became eligible for BNDES financing, based on their commitment to manufacture wind turbine generators in Brazil within a short timeframe. The initial goal is to reach a 60% nationalization rate. As a result, international companies like Enercon, IMPSA and Siemens have opened manufacturing plants in Brazil. Also, General Electric, Vestas and Alstom Wind are currently building factories in Brazil. Gamesa and Suzlon have announced their intention to follow suit in the short term.

In order to avoid geographic concentration of the projects, a regionalization criterion was set whereby each State has a maximum preliminary limit of 20% of total capacity for wind and biomass, and 15% for small hydropower projects, but exceptions may be considered if need be.

During the first phase of PROINFA 1429 MW of wind power were allocated. As of 31 December 2010, 900 MW are in operation (concentrated in 40 PROINFA projects), 394,1 MW are under construction (13 PROINFA projects) and expected to be connected to the grid by mid-2011. One project of 135 MW has not started construction yet.

Administrative barriers have delayed the implementation of PROINFA projects and therefore delayed commencement of operations, reason for what the programme's deadline was postponed several times. In particular, according to GWEC (2011) the following difficulties have been encountered:

- long lead times and excessive bureaucracy to obtain and renew the environmental permits and the "declaration of public utility" permit (necessary, among other things, to obtain land use rights);
- several obstacles for obtaining grid connection (especially in the central-western region);
- due to the 60% nationalization rate, the emerging local wind power industry could hardly keep up with the high demand of equipment, delaying deliveries and commissioning of wind power projects.

3.3.3.1.2 PROINFA – Second Phase (not commenced yet)

The second phase of PROINFA establishes that once the 3300 MW objective has been met (meaning capacity is fully operational), the programme will further aim to increase the share of RES-e generated by small hydro, biomass and wind power, to 10% of annual electricity consumption in 20 years.

As described by GWEC (2011), "the price paid for the RES-e generated in this second phase will be equal to that of competitive energy generation, defined as the weighted average cost of the generation through new hydro power plants with capacities greater than 30 MW, and natural gas power stations". The winning projects will be granted power purchase agreements with Eletrobrás for 20 years, "by means of annual scheduled purchases from each producer, so that new RE sources achieve a minimum annual increase in power output of 15% to be supplied to the consumer market".

"PROINFA RES-e generators will be required, before end of each year, to issue a number of Renewable Energy Certificates proportional to the amount of clean energy produced by the plant".

In order for projects to be eligible for the second phase, a rate of at least 90% of national construction costs will have to be demonstrated.

Moreover, in the second phase wind power projects benefit from priority grid access and 50% reduction of grid tariffs.

3.3.3.2 Wind Power Auctions (2009 to date)

PROINFA's first phase deadlines have been extended several times to compensate for the wide range of difficulties encountered by the wind power project developers, and for this and other reasons not all PROINFA's first phase wind power projects are in operation yet. Therefore, the conditions to implement the second phase of PROINFA have not been met so far. Consequently, the Government of Brazil decided in 2009 to further stimulate the growth of wind power capacity in the country by holding power auctions. Otherwise, the investment flows into wind power would have been interrupted until the second phase of PROINFA was launched, with negative consequences for the incipient local wind power industry and supply chain.

The objective of these power auctions is to secure the country's electricity supply, as opposed to PROINFA which aims to diversify Brazil's energy matrix.

The first auction ("LER-2009"), held in December 2009, was exclusively for wind power. Operation has to start at the latest on 1 January 2014 and the contracting period is 20 years. 1800 MW (divided in 71 projects) were contracted, at an average price of US $68,50 per MWh (expressed in US $ of year 2000) or R$148 (GWEC, 2011).

The second ("LFA-2010") and third ("LER-2010") auctions, both held in August 2010, were not exclusively for wind power – small hydro and biomass projects participated as well. The contracting period for the awarded 2047,8 MW is 20 years and operations have to start at the latest on 1 September 2013. The average prices were US $63,47 and US $58,26 for LFA-2010 and LER-2010 respectively (expressed in US $ of year 2000, or R$134 and R$123 respectively in current prices).

Two more auctions took place in August 2011 ("LER-2011" and "A-3 2011"), with 78 wind power projects contracted, totaling 1928,8 MW at an average bid price of

US $61,95 (for the “LER-2011”, current prices). It is remarkable that in the “A-3 2011” auction, wind power projects competed not only against other RES-e generation technologies like small hydro and biomass, but as well against natural gas projects.

All auctions have practically had so far the same rules and regulations, not considering if the technology is dispatchable or not, or, in case of RES-E technologies, if these have variable output or not. This seems unsuitable for wind power, for which specific regulations should be in place if the country seriously intends to promote its development.

Wind power projects continue to benefit from priority grid access and 50% reduction of grid tariffs.

No nationalization index is enforced for wind power contracted through the tenders, however the 60% index is still valid for projects applying for BNDES funding.

To the surprise of the Authorities, the bid prices have been approximately 50% lower than under PROINFA (GWEC, 2011) and reflected a continuous downward trend (in the local currency) in each of the subsequent auctions, reflecting the fast capture of the global wind power learning curve.

Due to the fierce competition and the low bid prices contracted in the auctions, it is foreseeable that, in order to compete in more favorable conditions in the coming auctions, wind power developing companies will group themselves in consortia in order to take advantage of synergies and lower finance costs, and to create economies of scale (GWEC, 2011). Since tendering systems tend to force prices down, only big players are able to keep up and still remain profitable. What remains to be seen is whether all projects will be able to operate profitably if the bid prices contracted get even lower.

Lastly, it is clear that as long as the Brazilian electricity system continues to be conceived for big players, community wind power projects or project ownership by small investors and individuals will be out of the question.

Given that the best wind sites in Brazil are sparsely populated, the “NIMBY effect” is not an important issue in Brazil and there is almost no resistance against projects even though the local population has neither participation nor vested interests in wind power projects. NIMBY is an acronym that means “not in my back yard” and refers to the typical resistance and opposition that residents may feel towards, for instance, a wind park being erected close to their living areas due to the fear of losing quality of life (increase of traffic, noise, health hazards, etc.). It has been demonstrated in Germany that the inclusion of the local residents in the planning process of a wind park (be it by allowing them to purchase shares of the project, or by including them in the decision-making process) decreases this negative “NIMBY” effect, and moreover, it increases the positive perception of the local population towards the project. These aspects should be taken into consideration by wind power project developers in Brazil.

4 Analysis of Effectiveness and Efficiency of Wind Power Promotion Strategies

The degree of wind power deployment in Germany and Brazil will be assessed, and the cost of carried out promotion strategies in these countries will be calculated. The obtained results will be compared in terms of effectiveness and efficiency.

Additionally, the obtained results will be analyzed in order to identify potential for improvement and lessons learned.

4.1 Definition of Effective and Efficient Promotion Strategies

In the previous chapter the most widespread strategies applied so far to promote renewable energy sources have been listed and described. Each promotion strategy has led to different results and degrees of success in the different countries where these have been applied.

Even in Europe, huge differences have been observed within countries applying the same type of promotion strategy. As an example, France and Germany have both adopted feed-in tariffs but both countries have obtained very different results. While in Germany wind power installed capacity reached 27215 MW by the end of 2010, only 5660 MW have been installed in France in the same period. This signalizes that the design features of a promotion strategy design play a key role, but as well other factors affecting the RES-E investment environment can boost or prevent RES-E deployment.

As promotion strategies for RES-E are the key driver for RES-E deployment and RES-E generation, the purpose of this section is to explain the quantitative methods to assess how successful promotion strategies are.

In the literature two main criteria have been employed to assess RES-E promotion strategies, and these are the effectiveness and the efficiency.

4.1.1 Effectiveness of a Promotion Strategy

The effectiveness of a promotion strategy for RES-E is defined as the increase in RES-E deployment (Resch et al., 2009), or in RES-E generation (Ragwitz et al., 2007), in relation to the additional potential. Hence, an effective RES-E promotion strategy achieves a high RES-E deployment or RES-E generation in relation to the additional potential for a certain RES-E technology.

Two formulas will be used for the calculations in this work, and are represented as follows with two indicators:

Effectiveness of promotion strategy (simple) = kW/capita.year

$$\text{Effectiveness of promotion strategy (complex)} = \frac{\text{kW capacity added per year}}{\text{kW wind power potential}}$$

For simplification purposes the effectiveness in this work will be assessed with regard to the increase of wind power deployment (and not with regard to increase of wind power generation), but the increase in wind power generation will be verified as well for both countries.

It could be assumed that higher profits for investors are the reason for the higher effectiveness of the promotion strategies for wind power (higher wind power deployment). Therefore, the effectiveness results of Brazil and Germany will be plotted against the annuities (which will be calculated to represent the investors' profit) of an identical hypothetical wind power project in each of the countries, to prove if there is a correlation between higher profits and higher deployment.

The expected annuity or levelized profit (“A”) of a RES-E project indicates the expected specific discounted average return on every kWh produced, by taking into account income and expenditure over the entire lifetime of a technology (Ragwitz et al., 2007). Higher annuities represent higher profits for the investor.

$$A = \frac{i}{(1-(1+i)^{-n})} * \sum_{t=1}^{n} \frac{Revenue_t - Expenses_t}{(1+i)^t}$$

A= Levelized profit; i=Interest rate; t=Year;
n=Technical lifetime

Figure 4.1: Formula of the annuity or levelized profit, indicating the expected specific discounted average return on every kWh produced. Source: Ragwitz et al. (2007).

The parameters of the second part of the above formula are itemized as follows:

- $Revenue_t$ = (Remuneration paid for wind power)*kWh generated
- $Expenses_t$ = kWh*(country specific LRMC), being the LRMC the Long Run Marginal Cost of electricity, in US $ per kWh

The formula for wind power LRMC (in US $ per kWh) is: LRMC = $c_{fix} + c_{var}$

- c_{fix} is expressed as: (α)*(investment costs per kW)/Full Load Hours
- c_{var} equals the variable costs (namely operation and maintenance) per kWh.

For both countries the technical lifetime of the project lifetime of the project (“n”) will be 20 years and the interest rate will be 6,5%. Therefore, the α factor will be: $\frac{i*(1+i)^{20}}{(1+i)^{20})-1}$ and will result in 0,0908.

The full load hours (FLH) are the amount of hours per year where the wind turbine is operating at full rated power. For Brazil and Germany the average full load hours will be calculated. A sensitivity analysis will be carried out for the factors “i” (interest rate) and full load hours. The detailed calculations of the annuities and the sensitivity analysis for the hypothetical projects in Brazil and Germany will be found in section 4.2.3.

4.1.2 Efficiency of a Promotion Strategy

Promotion strategies for RES-E are not voluntarily adopted by the electricity consumers. On the contrary, the governments adopt them and their consequences are imposed on electricity consumers, who eventually bear the extra costs caused by the promotion strategy. Therefore, an efficient promotion strategy must minimize the overall additional costs for society over time (Resch et al., 2009). An efficient promotion strategy triggers RES-E generation while keeping the additional costs to society at a minimum.

One formula will be used for the calculation of efficiency in this work, and is represented as follows:

Efficiency indicator of promotion strategy = US $ cent of subsidy/kWh

The subsidy will be defined as the difference between the prices paid for wind power as defined in the promotion strategy, and the electricity spot price.

This efficiency formula will allow to assess the support levels in absolute terms and to compare both countries. It could be assumed that higher support levels are the reason for more RES-E deployment. Nevertheless, the example of Belgium and Italy can be cited, since the opposite was true in 2006: the highest support levels of EU-27 could not promote wind power deployment and these countries achieved in fact very low specific deployment levels.

In past sections an analysis of the promotion strategies applied in these countries was carried out. In further sections the applied promotion strategies applied in Brazil will be analyzed both in terms of effectiveness and efficiency. These will be compared with the results of the promotion strategies applied in Germany.

4.2 Analysis of Effectiveness of Wind Power Promotion Strategies in Germany and Brazil

The effectiveness of the promotion strategies implemented in Brazil and Germany will be analyzed in this sub-section. The intention is to assess the wind power deployment triggered by the respective promotion strategies.

Table 4-1: Effectiveness calculations for Germany and Brazil

	GERMANY EFFECTIVENESS (simple indicator)	GERMANY EFFECTIVENESS (complex indicator)	BRAZIL EFFECTIVENESS (simple indicator)	BRAZIL EFFECTIVENESS (complex indicator)
YEAR	kW/capita.year	(MW/year)/ (MW potential)	kW/capita.year	(MW/year)/ (MW potential)
2006	0,02659	3,40%	0,0011	0,15%
2007	0,01964	2,57%	0,0001	0,01%
2008	0,02002	2,68%	0,0005	0,07%
2009	0,02298	3,17%	0,0014	0,19%
2010	0,01823	2,57%	0,0017	0,23%
Average	0,02149	2,88%	0,0010	0,109%

The following table presents the data for Germany utilized to calculate the effectiveness. In subsequent paragraphs the sources, as well as the assumptions made, will be described.

Table 4-2: Basic data for Germany

GERMANY	ANNUAL CAPACITY DEPLOYED	CUMULATIVE WIND POWER DEPLOYED CAPACITY	WIND POWER ADDITIONAL POTENTIAL	POPULATION
YEAR	MW	MW	MW	inhabitants
2006	2.189	20.579	64.421	82.314.900
2007	1.615	22.194	62.806	82.217.800
2008	1.642	23.836	61.164	82.002.400
2009	1.880	25.716	59.284	81.802.300
2010	1.488	27.204	57.796	81.631.433
	27.204			

The cumulative wind power deployment data was obtained from the „Zeitreihen zur Entwicklung der erneuerbaren Energien in Deutschland, unter Verwendung von

Daten der Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat)", BMU, as of March 2011 (previous to 2006, 18390 MW had been deployed).

Annual capacity deployed was deducted from it. The source for the wind power potential for Germany was obtained from the "Wind Energy Report Germany 2010", published by the Fraunhofer IWES published in 2011. The 85000 MW potential are the total potential for the country including offshore.

Population data for Germany for 2006 to 2009 are actual data from "Statistisches Bundesamt Deutschland". The data for 2010 was projected assuming a linear decline.

The following table presents the data for Brazil utilized to calculate the effectiveness. In subsequent paragraphs the sources, as well as the assumptions made, will be described.

Table 4-3: Basic data for Brazil

BRAZIL	ANNUAL CAPACITY DEPLOYED	CUMULATIVE WIND POWER DEPLOYED CAPACITY	WIND POWER ADDITIONAL POTENTIAL	POPULATION
YEAR	MW	MW	MW	inhabitants
2006	208	237	143.263	182.083.566
2007	10	247	143.253	184.213.943
2008	94	341	143.159	186.369.247
2009	265	606	142.894	188.549.767
2010	325	931	142.569	190.755.799
	931			

The cumulative wind power deployment data was obtained from the GWEC Global Wind Report 2010. Annual capacity deployed was deducted from it. The source for the wind power potential for Brazil was obtained from the "Atlas do Potencial Eólico Brasileiro", published in 2001, assuming the calculated potential (143,5 GW) is for additional potential for 2001 onwards and knowing (GWEC) that only 29 MW had been installed before year 2006.

Population data for Brazil was obtained from the "Instituto Brasileiro de Geografia e Estatistica", Ministerio do Planejamento, Orçamento e Gestão. The data for 2006 to

2009 inclusive were projected based on the data for 2010 and on the yearly population growth of 1,17%.

The graph below depicts the cumulative capacity achieved in Germany and in Brazil, with relation to their respective additional potentials as of 31 December 2010. It is quite evident that while Germany has achieved considerable levels of deployment, amounting to a total of 27.204MW, what represents 47% of its additional potential as of 31 December 2010. Brazil, having an additional potential almost 2.5 times higher than Germany, has so far only achieved 931 MW of wind power deployment.

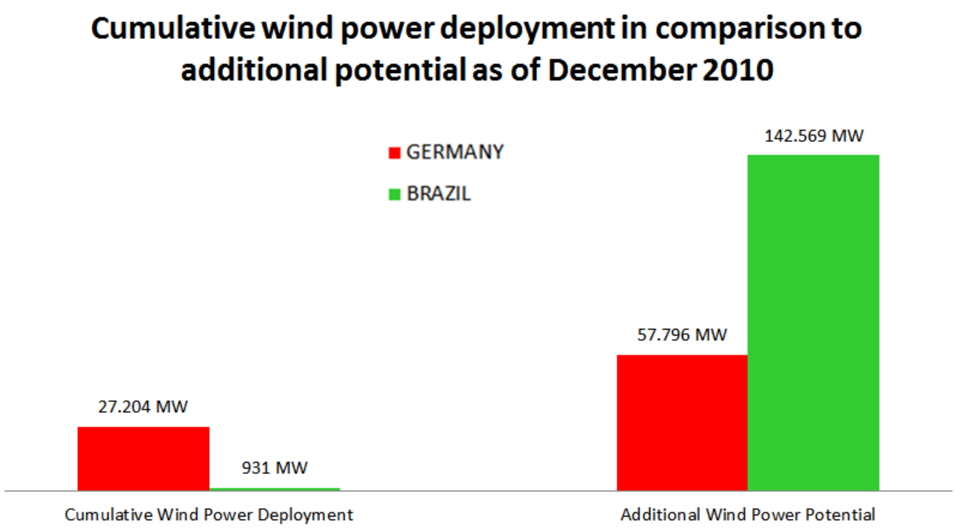
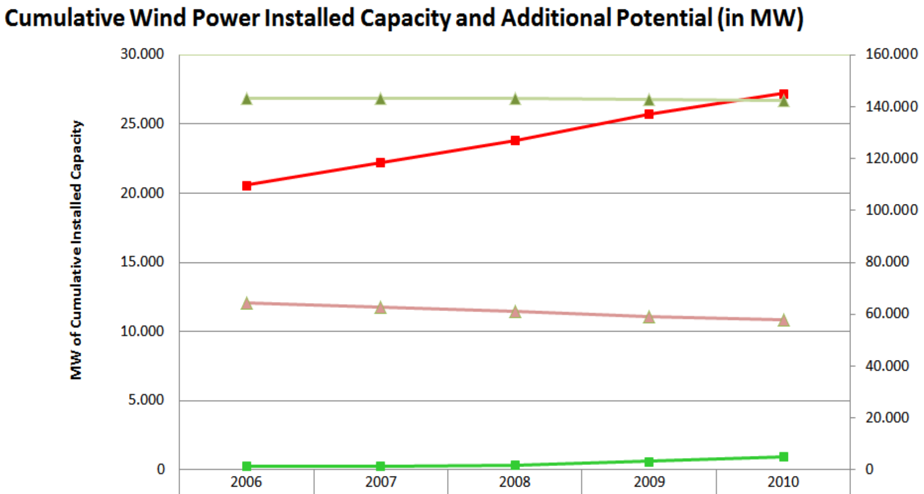


Figure 4.2: Cumulative wind power deployment (left) for Brazil and Germany in comparison to additional wind power potential (right), as of December 2010.

It has to be said, however, that Germany's first promotion strategy for wind power commenced more than 20 years ago and therefore has had more time to develop its wind power capacity. In Brazil the analogous process started within the last ten years, and it was as late as in 2006 when wind power deployment surpassed the 100-MW milestone.

The next chart shows the cumulative wind power installed capacity and the additional potential for Brazil and Germany, in green and red shades respectively, from 2006 to 2010. It has to be minded that the cumulative installed capacity (in the primary axis, to the left) and the additional potential (in the secondary axis, to the right) are in different scales, yet both in MW.

Both countries experienced continuous growth in wind power installation during the analyzed period. However while Brazil's additional potential of 142569 MW as of 31 December 2010 is rather similar to its original additional potential of 143263 MW five years before, the case of Germany is different. Germany has achieved 6675 MW of wind power installations within the analyzed 5-year period.



	2006	2007	2008	2009	2010
GERMANY	20.579	22.194	23.836	25.716	27.204
BRAZIL	237	247	341	606	931
ADDITIONAL POTENTIAL GERMANY	64.421	62.806	61.164	59.284	57.796
ADDITIONAL POTENTIAL BRAZIL	143.263	143.253	143.159	142.894	142.569

Figure 4.3: Cumulative annual wind power installed capacity for Brazil and Germany (primary axis) in comparison to annual additional wind power potential (secondary axis). The different scale in both axes has to be minded.

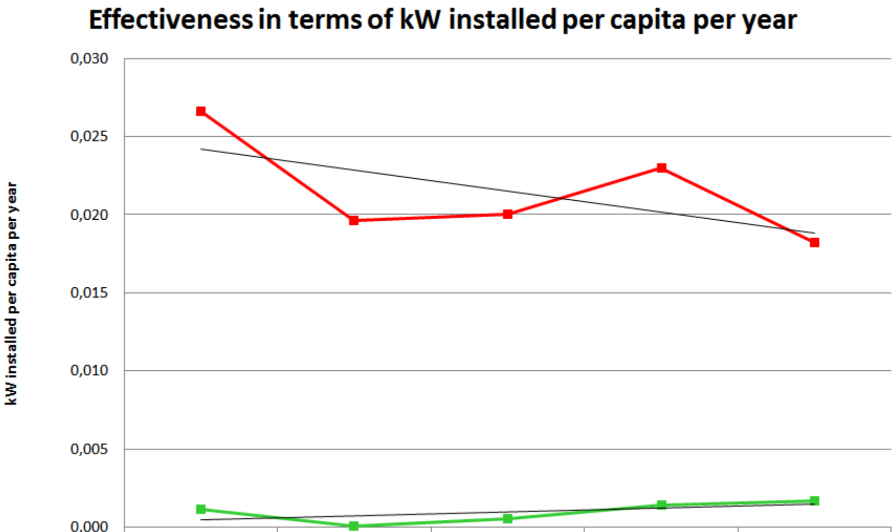
The analysis of the effectiveness in this work was undertaken through the analysis of two different indicators. In the next sections the "simple" and "complex" effectiveness indicators will be analyzed.

4.2.1 Effectiveness achieved with regard to kW installed per capita per year

In this section, the results of the analysis of the "simple" effectiveness indicator will be presented. First, the used indicator will be defined:

Effectiveness of promotion strategy ("simple" indicator) = kW installed/capita.year

The chart below depicts the development of the simple effectiveness indicator for Brazil (in green) and Germany (in red). While Germany shows a distinct downward trend in the five-year period 2006-2010, Brazil shows an incipient upward trend. This fact is not surprising given that in Germany the best wind sites have already been occupied with wind turbines while in Brazil the wind power movement is just starting and has not achieved yet the 1-GW milestone despite its almost 143 GW potential.



	2006	2007	2008	2009	2010
GERMANY	0,026593	0,019643	0,020024	0,022982	0,018228
BRAZIL	0,001142	0,000055	0,000504	0,001405	0,001704

Figure 4.4: Effectiveness in terms of kW of wind power installed per capita per year in Brazil and Germany from 2006 to 2010.

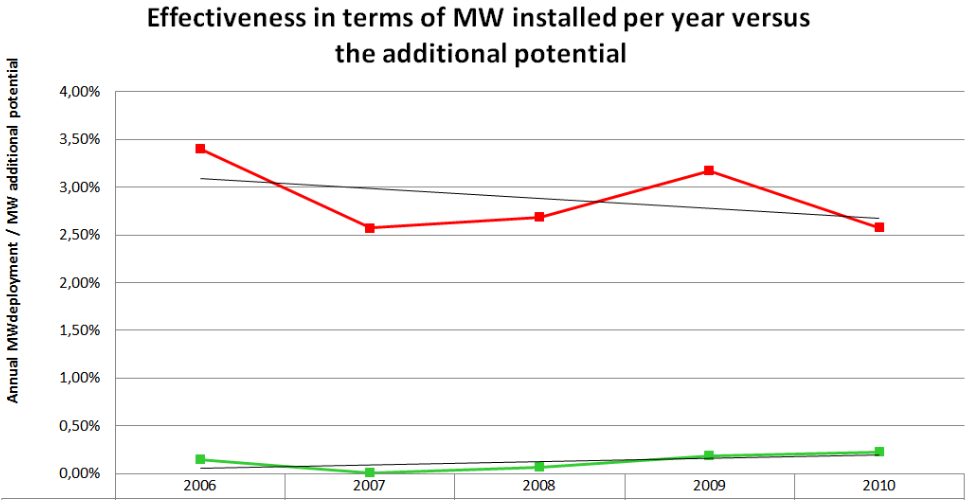
In terms of the “simple” effectiveness indicator itself, Germany’s effectiveness decreased from 0,0265 kW of wind power installed per capita per year to 0,0182 kW of wind power installed per capita per year in the 2006-2010 period. Brazil’s effectiveness varied between 0,00005 kW of wind power installed per capita (lowest value, in 2007) to 0,0017 kW of wind power installed per capita in year 2010. Brazil’s annual effectiveness indicators were at least one order of magnitude smaller than Germany’s annual effectiveness indicators during the same period.

4.2.2 Effectiveness achieved with regard to annually added capacity versus additional potential

In this section, the results of the analysis of the "complex" effectiveness indicator will be presented. First, the indicator will be defined:

$$\text{Effectiveness of wind power promotion strategy ("complex" indicator)} = \frac{\text{MW wind power capacity added per year}}{\text{MW wind power additional potential}}$$

The chart below depicts the development of the complex effectiveness indicator for Brazil (in green) and Germany (in red). While Germany shows a distinct downward trend in the five-year period 2006-2010, Brazil shows again an incipient upward trend. This fact is not surprising given that in Germany the best wind sites have already been occupied with wind turbines while in Brazil the wind power movement is just starting and has not achieved yet the 1-GW milestone despite its almost 143 GW potential.



	2006	2007	2008	2009	2010
GERMANY	3,40%	2,57%	2,68%	3,17%	2,57%
BRAZIL	0,15%	0,01%	0,07%	0,19%	0,23%

Figure 4.5: Effectiveness in terms of MW of wind power installed per year in relation to the additional potential, in Brazil and Germany from 2006 to 2010.

4.2.3 Effectiveness Plotted Versus Annuity

As mentioned in 4.1.1, the 2010 effectiveness results of Brazil and Germany will be plotted against the annuity of an identical hypothetical wind power project (same type of turbines, same total installed power) in the respective countries to verify if the effectiveness of the promotion strategies can be attributed to the high profits paid to wind power investors. It will be assumed that the projects start being operational in 2010. The duration of each project is 20 years and the interest rate is 6,5%. For clarity purposes, the calculations will be made assuming that the output of the project is one MWh per year.

First, the annuities of the hypothetical wind power project projects in Brazil and Germany are calculated.

4.2.3.1 Annuity Calculation for Hypothetical Wind Power Project in Germany

Since in Germany the best wind sites have already been occupied by wind power projects, it is assumed that the hypothetical project will be installed in an area with 90% of the reference yield, so according to the Renewable Energy Act of 2009, the basic wind power feed-in tariff of €91,08 per MWh valid for 2010 (normally paid for 5 years only) will be paid for 18 years in total. After that, the feed-in tariff will be €49,698 per MWh. It is assumed that the project is eligible for the system service bonus of €5 per MWh during the 20 years.

First, the LRMC has to be calculated. The table below displays the calculation of the LRMC. The underlying assumptions will be explained thereafter.

Table 4-4: LRMC calculation for hypothetical project in Germany, in €.

Year	Investment Costs €/MW	Annual O&M variable costs €/MWh	Annual FLH	LRMC €/MWh	LRMC US $ of year 2000 /MWh
2010	€ 1.182.796	€ 13,77	1.344	€ 93,66	$106,47

The investment costs per MW are calculated from data in DEWI Market Status report per 31.12.2010 (http://www.dewi.de/dewi/index.php?id=47&L=1) and in „Zeitreihen zur Entwicklung der erneuerbaren Energien in Deutschland, unter

Verwendung von Daten der Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat)“. The FLH are calculated with data obtained from the latter. The variable costs per MWh are calculated with data from The Economics of Wind Energy (Krohn et al., 2009) and for simplification purposes it will be assumed that these remain constant during the entire project duration.

Having the LRMC, the annuity is calculated. The table below displays the calculation of the annuity. As mentioned in 3.2.1, the α factor is equal to 0,0908. The assumed exchange rate €-US $ is 1,4406 and to bring them to US $ of year 2000, figures are multiplied by 78,91% (http://data.bls.gov/cgi-bin/cpicalc.pl).

Table 4-5: Calculation of annuity for project in Germany – in US $ of year 2000:

A	B	C	D	E
	Discounted Cash flow	Nominal Cash flow	LRMC US $/MWh	Remuneration per MWh
	1+i = 1,065			
Year 2010 = 1	$2,59	$2,76	-$106,47	$109,22
2	$2,43	$2,76	-$106,47	$109,22
3	$2,28	$2,76	-$106,47	$109,22
4	$2,14	$2,76	-$106,47	$109,22
5	$2,01	$2,76	-$106,47	$109,22
6	$1,89	$2,76	-$106,47	$109,22
7	$1,77	$2,76	-$106,47	$109,22
8	$1,66	$2,76	-$106,47	$109,22
9	$1,56	$2,76	-$106,47	$109,22
10	$1,47	$2,76	-$106,47	$109,22
11	$1,38	$2,76	-$106,47	$109,22
12	$1,29	$2,76	-$106,47	$109,22
13	$1,22	$2,76	-$106,47	$109,22
14	$1,14	$2,76	-$106,47	$109,22
15	$1,07	$2,76	-$106,47	$109,22
16	$1,01	$2,76	-$106,47	$109,22
17	$0,94	$2,76	-$106,47	$109,22
18	$0,89	$2,76	-$106,47	$109,22
19	-$13,39	-$44,29	-$106,47	$62,18
20	-$12,57	-$44,29	-$106,47	$62,18
A =	$0,25			

An annuity of US $0,25 (expressed in US $ of year 2000) results as the sum of the 20 figures in column B multiplied by the α factor calculated in 4.1.1.

4.2.3.2 Annuity Calculation for Hypothetical Wind Power Project in Brazil

It is assumed that the project is awarded a wind power purchase agreement in the first wind power auction in 2010, "LFA-2010", where the auctioned price per MWh is US $63,47. The table below displays the calculation of the LRMC. The underlying assumptions will be explained thereafter.

Table 4-6: LRMC calculation for hypothetical project in Brazil – in US $.

Year	Investment Costs US $/MW	Annual O&M variable costs US $/MWh	Annual FLH	LRMC US $/MWh	LRMC US $ of year 2000 /MWh
2010	$1.120.000	$13,04	1.899	$66,57	$52,53

The investment costs per MW are calculated based on Nielsen (2011). The FLH are according to "Atlas do Potencial Eolico Brasileiro", 2001. The variable costs per MWh are based on own calculations. For simplification purposes it will be assumed that these remain constant during the entire project duration. Having the LRMC, the annuity is calculated. The table below displays the calculation of the annuity. As mentioned in 3.2.1, the α factor is equal to 0,0908. The assumed exchange rate €-US $ is 1,666 and to bring them to US $ of year 2000, figures are multiplied by 78,91% (http://data.bls.gov/cgi-bin/cpicalc.pl).

Table 4-7: Calculation of annuity for project in Brazil – in US $ of year 2000.

	Discounted Cash flow	Nominal Cash flow	LRMC US $/MWh	Remuneration
	1+i = 1,065		1	1
Year 2010 = 1	$10	$11	-$53	$63
2	$10	$11	-$53	$63
3	$9	$11	-$53	$63
4	$9	$11	-$53	$63
5	$8	$11	-$53	$63
6	$7	$11	-$53	$63
7	$7	$11	-$53	$63
8	$7	$11	-$53	$63
9	$6	$11	-$53	$63
10	$6	$11	-$53	$63
11	$5	$11	-$53	$63

12	$5	$11	-$53	$63
13	$5	$11	-$53	$63
14	$5	$11	-$53	$63
15	$4	$11	-$53	$63
16	$4	$11	-$53	$63
17	$4	$11	-$53	$63
18	$4	$11	-$53	$63
19	$3	$11	-$53	$63
20	$3	$11	-$53	$63
A =	$10,94			

An annuity of US $10,94 (expressed in US $ of year 2000) results as the sum of the 20 figures in column B multiplied by the α factor calculated in 4.1.1.

4.2.3.3Effectiveness of Wind Power Promotion Strategies versus Annuities

The result of the two annuity calculations above for Germany and Brazil are now plotted against the "complex" effectiveness indicator. The results can be seen in the graph below and are striking. While for Germany a relatively low annuity still enables a relatively high efficiency, the opposite is the case for Brazil.

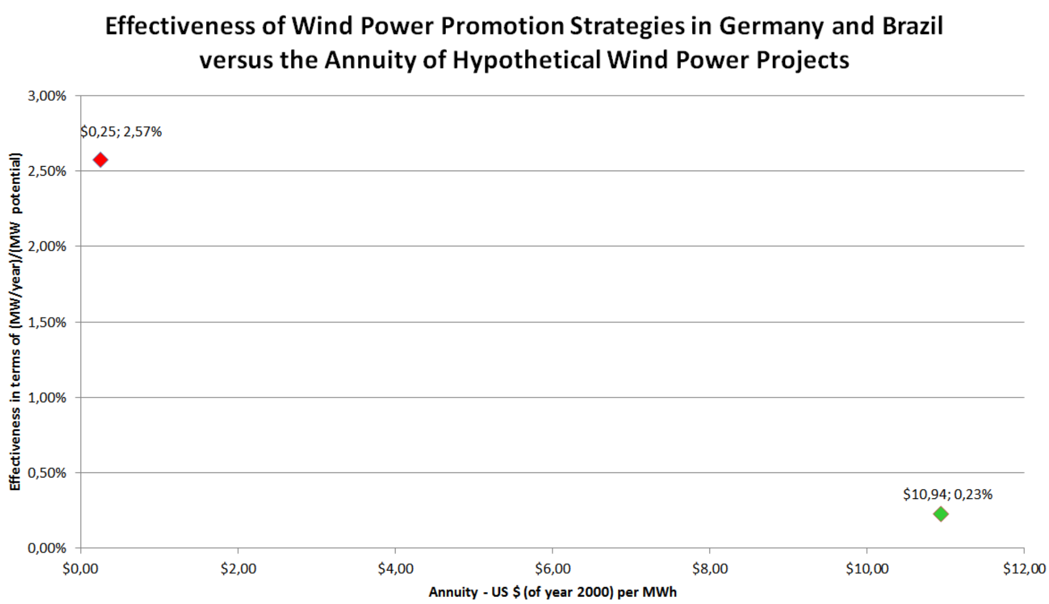
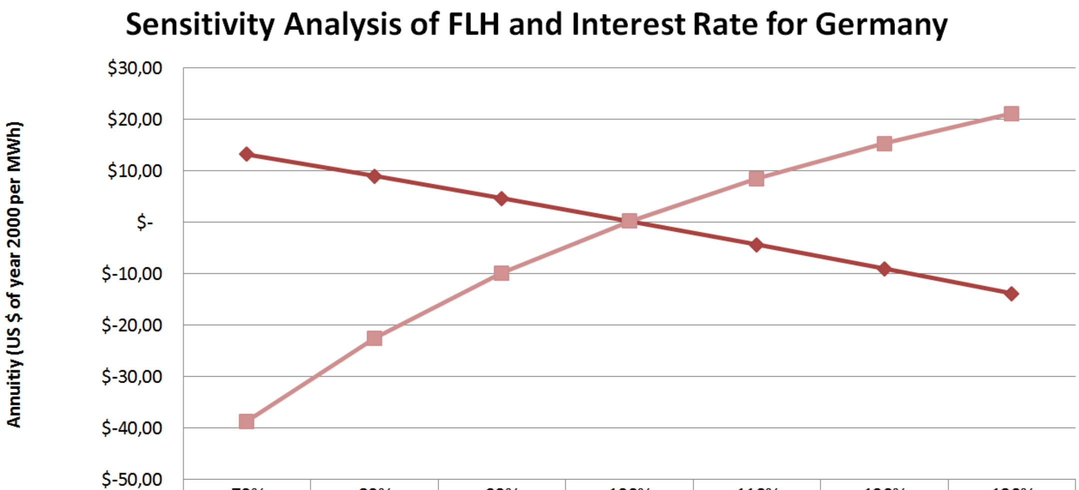


Figure 4.6: Effectiveness of wind power promotion strategies in Germany and Brazil against the annuity of a hypothetical wind power project in the respective countries, in 2010. The values for Germany and represented in red and those for Brazil are in green.

4.2.3.4Sensitivity Analysis of Annuity Calculation

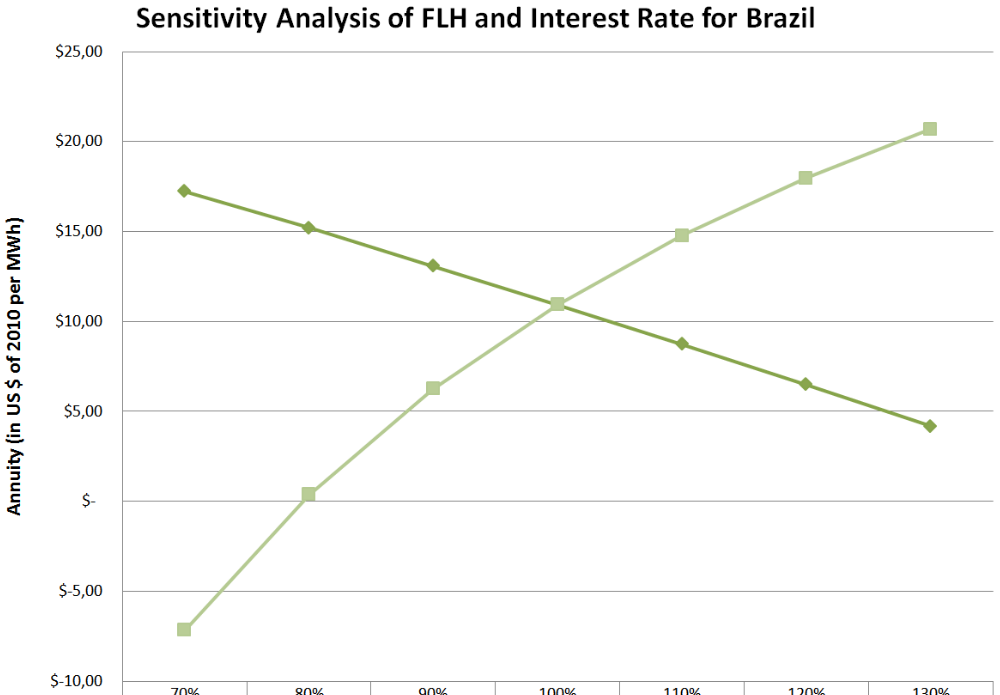
In this section a sensitivity analysis of the annuities calculated above is carried out for each country, with respect to the variables “interest rate” and “full load hours”. The former is reflected in the annuity calculation as well as in the LRMC calculation. The latter is actually not reflected directly in the annuity calculation but is a factor in the calculation of the LRMC of electricity and therefore has an indirect influence in the annuity calculation.

The two above-mentioned variables will vary for the analysis in ±10% increments between 70% and 130%. The results obtained for each country are depicted below.



	70%	80%	90%	100%	110%	120%	130%
Interest Rate	$13,26	$9,05	$4,71	$0,25	$-4,33	$-9,02	$-13,82
Full Load Hours	$-38,67	$-22,45	$-9,84	$0,25	$8,51	$15,39	$21,21

Figure 4.7: Sensitivity analysis for Germany



	70%	80%	90%	100%	110%	120%	130%
Interest Rate	$17,24	$15,20	$13,09	$10,94	$8,73	$6,48	$4,18
Full Load Hours	$-7,16	$0,38	$6,25	$10,94	$14,78	$17,98	$20,69

Figure 4.8: Sensitivity analysis for Brazil

The results for both countries are similar. Basically, for both countries the higher the interest rate, the lower the annuity obtained. And, the higher the full load hours, the higher the annuity obtained. However, the sensitivity towards both variables seems to be higher for Germany than for Brazil, due to the fact that the profit margin for the investor is lower in the former than in the latter.

Below the results of the sensitivity analysis of each variable will be depicted graphically in the plotting of the effectiveness versus the annuity. For Germany the results are depicted in shades of red and for Brazil in shades of green. First, the sensitivity of the annuities with respect to changes in the interest rate will be shown.

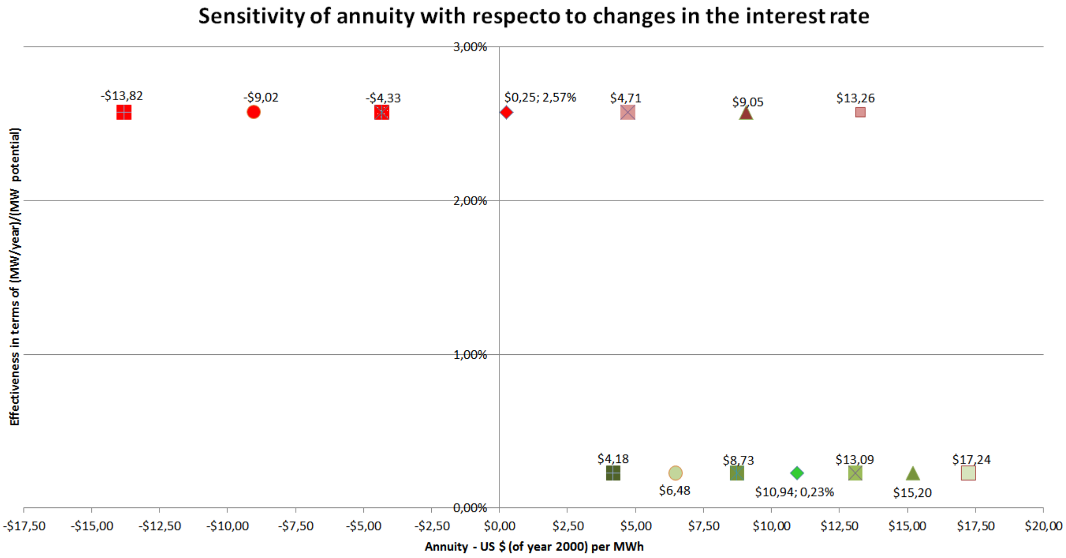


Figure 4.9: Sensitivity analysis of annuity value for Germany and Brazil, respect to interest rate.

In the graph below the sensitivity of the annuities with respect to changes in the full load hours will be shown.

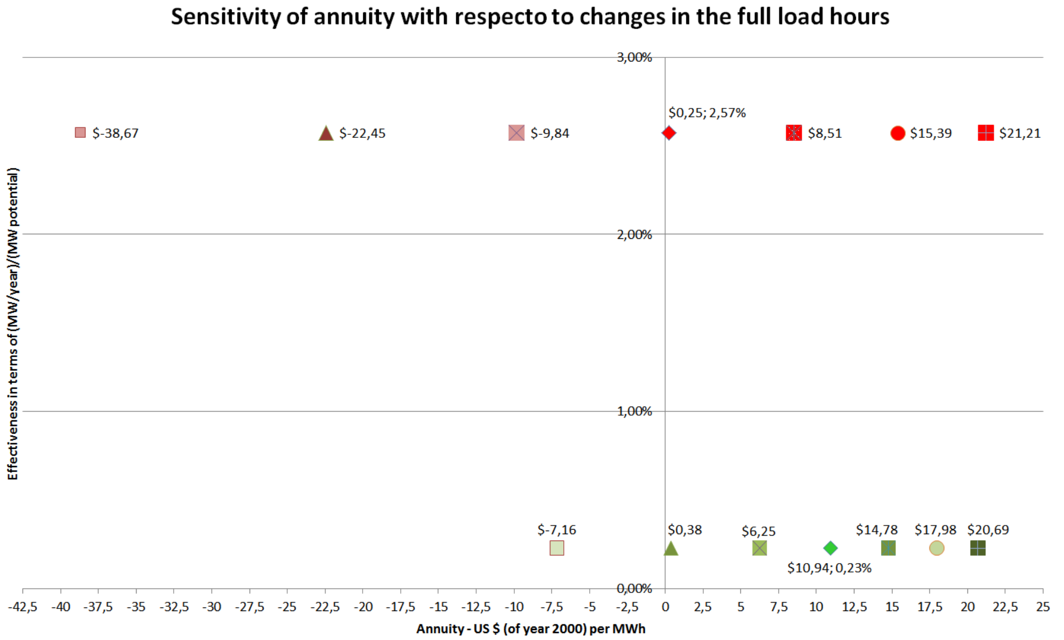


Figure 4.10: Sensitivity analysis of annuity value for Germany and Brazil, respect to interest rate.

Since the sensitivity analysis is made on the annuity values, the variations are seen along axis “x”, which represents the annuity. The effectiveness indicators as calculated in section 4.1.1 and 4.1.2 remain unchanged. It is observed again that towards both variables the sensitivity is higher for Germany than for Brazil, because the profit margin for the investor is lower in the former than in the latter.

4.2.4 Summary of Obtained Effectiveness Results

In this section the average effectiveness achieved by the respective wind power promotion strategies in both countries will be depicted and compared.

The next graph shows the average results obtained for both effectiveness indicators, depicted in bars, and the respective trends in 2010, depicted by a triangle. While both indicators for Germany show higher effectiveness than in Brazil, the trend in Germany is downward while the trend in Brazil is rising.

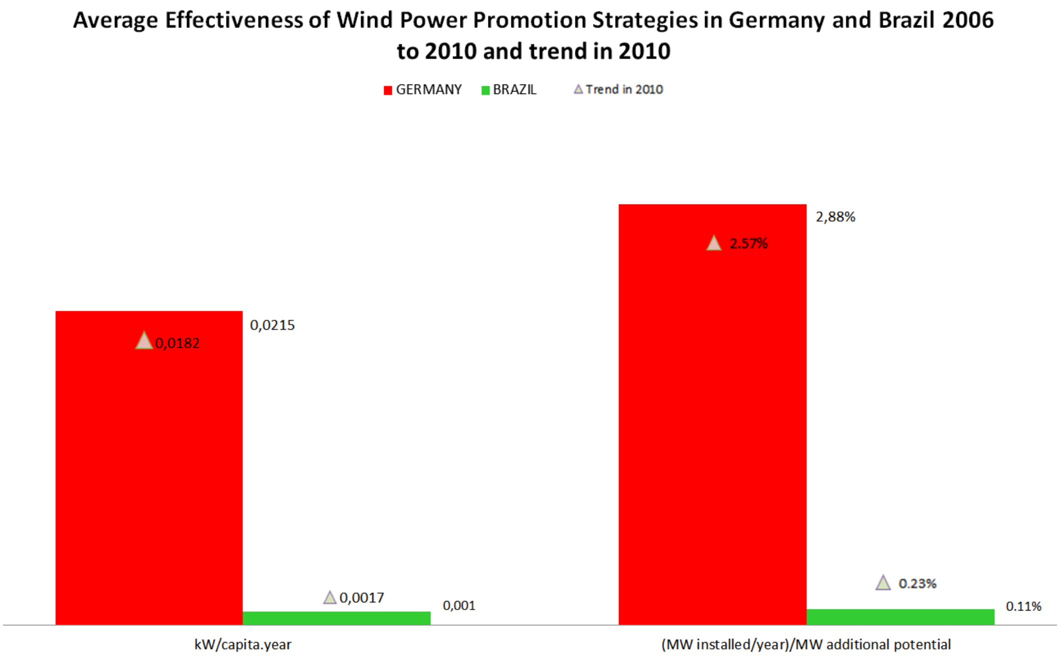


Figure 4.11: Average effectiveness of wind power promotion strategies in Brazil and Germany from 2006 to 2010 (depicted in bars), and trend in 2010 (depicted in triangles).

Germany has expanded its wind power capacity for twenty years already and the best wind sites with have either already been occupied by wind parks or cannot be used for this purpose, by reason of being natural conservation areas, natural parks, or of touristic or historic interest, etc. This explains the downward trend. Therefore the years ahead will likely change its main focus. Certainly new onshore wind parks will be erected, but probably not as many as in the past. Repowering, the replacement of older, less efficient and lower-powered installed wind turbines with newer, more efficient and higher-powered ones, will provide capacity increase opportunities. The German legislator has already recognized this potential and has consequently offered repowering bonuses for the feed-in tariffs since the 2004 Renewable Energy Act. Offshore wind power potential will be progressively tapped in the next years, once the learning curve for this technology is improved and the unit costs decrease, and as difficulties upon installation and grid connection and those related to maintenance are overcome.

With regard to Brazil, although wind power investments started in 2002, almost all of its 143 GW of wind power potential remain untapped in 2010. After a slow start with the PROINFA programme as far as effectiveness is concerned, wind power investments have picked up momentum with the power auctions, and as a result 5,7 GW are in the pipeline. The government will have to focus on improving the conditions for investors to continue installing wind power in the country in order to increase effectiveness of the current promotion strategies. How to increase their effectiveness is the main question, and possible solutions will be analyzed in chapter 5 of this work.

4.3 Analysis of Efficiency of Wind Power Policies in Germany and Brazil

The efficiency of the promotion strategies implemented in Brazil and Germany is analyzed in this sub-section. The intention is to assess the cost of the wind power promotion strategies, i.e. the level of remuneration per wind power generation unit in each country.

As can be seen in the table below, Germany's wind power subsidies are on average two times lower than those applied in Brazil. This can be explained by the maturity and refinement of the German feed-in tariff scheme, in place for more than a decade and which has been reasonably amended and enhanced several times to better adapt to the changing conditions. Brazil's subsidies seem rather high and it could be explained by the lack of experience of Brazil in design and implementation of a wind power promotion scheme.

Table 4-8: Efficiency calculations for Germany and Brazil

	EFFICIENCY = subsidy/MWh expressed in local currencies (current prices)		EFFICIENCY = subsidy/MWh expressed in US $ of year 2000	
YEAR	GERMANY	BRAZIL	GERMANY	BRAZIL
2006	€ 35,03	R$ 213,05	$39,56	$85,34
2007	€ 47,17	R$ 176,95	$46,27	$83,19
2008	€ 22,63	R$ 134,87	$24,66	$46,06
2009	€ 46,28	R$ 233,80	$46,92	$108,21
2010	€ 47,09	R$ 191,83	$38,97	$90,86
Average	€ 39,64	R$ 190,10	$39,28	$82,73

Additionally, it could be mentioned that feed-in tariffs have been proved by the literature to be the most economically efficient strategies to promote renewable energies. Ragwitz et al. (2007) and Resch et al. (2009) have illustrated this fact in several articles referenced along this work.

The PROINFA programme was the first wind power promotion strategy in Brazil and it definitely helped the country to start giving impulse to the wind power sector. But the change of strategy in 2009 towards power auctions evinces the learning effect from the country's own experience with hindsight to the developments at the international level, namely that wind power may be purchased at lower prices than those agreed under PROINFA.

The following table presents the data for Germany utilized to calculate the efficiency. In subsequent paragraphs the sources of the data will be described, as well as the assumptions made.

Table 4-9: Basic data for Germany

GERMANY	Wind Power Generation	Annual Expenditure Wind Electricity Feed-in Tariff	Average Wind Electricity Feed-in Tariff paid	Average Electricity Spot Price
YEAR	MWh	€	€ per MWh	€ per MWh
2006	30.710.000	€ 2.637.865.002,54	€ 85,90	€ 50,86
2007	39.713.000	€ 3.381.349.230,34	€ 85,14	€ 37,97
2008	40.574.000	€ 3.588.304.908,99	€ 88,44	€ 65,81
2009	38.640.000	€ 3.290.874.813,10	€ 85,17	€ 38,89
2010	36.500.000	€ 3.341.697.825,29	€ 91,55	€ 44,46

The wind power generation data was obtained from the „Zeitreihen zur Entwicklung der erneuerbaren Energien in Deutschland, unter Verwendung von Daten der Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat)“, BMU, as of March 2011. The figures on wind electricity annual expenditure were obtained from the annual reports on the actual feed-in tariff compensations published at the Information Platform of the German Transmission Grid Operators (“Informationsplatform der Deutschen Übertragungsnetzbetreiber, http://www.eeg-kwk.net/de/EEG_Jahresabrechnungen.htm).

Annual average wind electricity feed-in tariff paid was calculated with the two previous data sets.

The average electricity spot prices for Germany were obtained at the EEX website (courtesy of Haas, R.).

The following table presents the data for Brazil utilized to calculate the efficiency. In subsequent paragraphs the sources of the data will be described, as well as the assumptions made.

Table 4-10: Basic data for Brazil

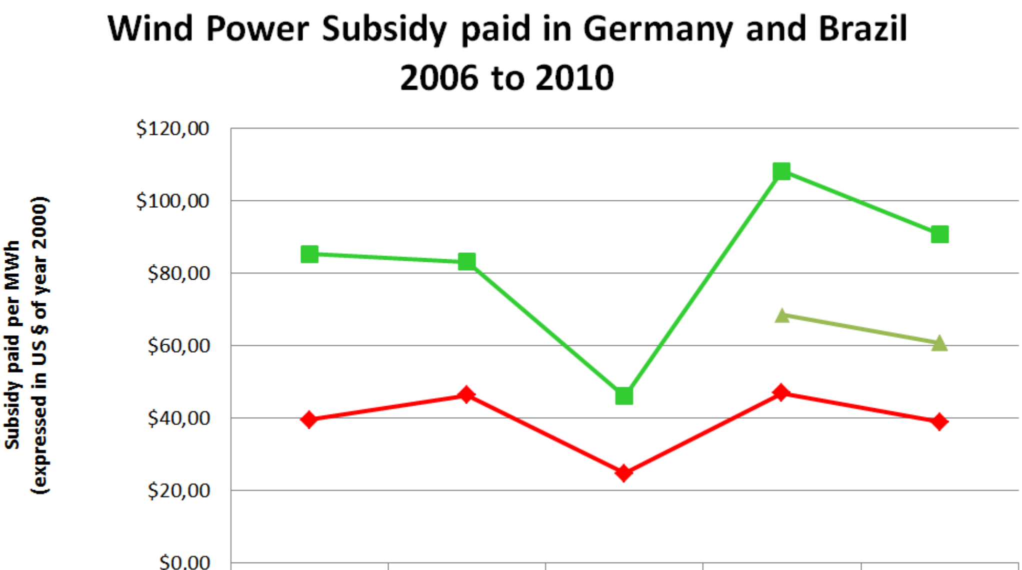
BRAZIL	Wind Power Generation	Annual Wind Electricity Remuneration	Average Wind Electricity Remuneration paid	Average Electricity Spot Price
YEAR	MWh	R$	R$/MWh	R$/MWh
2006	449.849	R$ 121.459.165	R$ 270	R$ 56,95
2007	469.028	R$ 126.637.458	R$ 270	R$ 93,05
2008	647.524	R$ 174.831.470	R$ 270	R$ 135,13
2009	1.150.732	R$ 310.697.569	R$ 270	R$ 36,20
2010	1.767.873	R$ 477.325.803	R$ 270	R$ 78,17

The wind power generation data was obtained based on the assumption of 1899 full load hours for Brazil (according to "Atlas do Potencial Eolico Brasileiro", 2001) and according to the wind power deployment figures mentioned in table 4-3.

The figures on annual wind electricity expenditure were calculated based on the wind power generation figures and the data available for the average wind electricity remuneration paid per MWh. According to the “Analysis of the regulatory framework for wind power generation in Brazil - Summary Report”, (GWEC, 2010), prices for power contracted in the auctions was 50% approximately of prices under PROINFA. Therefore, an average of R$270 is estimated as remuneration per MWh for wind power projects under PROINFA. Until 31 December 2010 only PROINFA wind power projects were operational in Brazil and are therefore receiving the corresponding remuneration.

The average electricity spot prices were obtained as the average of the weekly middle-value spot market prices available at the Chamber of Electric Energy Commerce ("Cámara de Comercializacão de Energia Elétrica", http://www.ccee.org.br/cceeinterdsm/v/index.jsp?vgnextoid=39aca5c1de88a010VgnVCM100000aa01a8c0RCRD).

The graph below depicts the different efficiency levels attained by the German FIT system and Brazil's PROINFA programme (presented in table 4-8 above). Additionally, the prices contracted in the 2009 and 2010 auctions in Brazil have been depicted in order to show the gradual alignment with more efficient systems.



	2006	2007	2008	2009	2010
GERMANY FIT	$39,56	$46,27	$24,66	$46,92	$38,97
BRAZIL PROINFA	$85,34	$83,19	$46,06	$108,21	$90,86
BRAZIL AUCTIONS	0	0	0	$68,50	$60,86

Figure 4.12: Efficiency indicator for wind power promotion strategies applied in Germany and Brazil. Source of data: see above paragraphs in this section. Brazil's auction data for 2010 is the average of the auctioned price during this year.

5 Conclusions

In the first chapter of this work a general introduction to the wind power sector was made, followed by an analysis the most widely applied renewable electricity promotion strategies of the last decades. Afterwards, the wind power promotion strategies applied in Germany and Brazil were analyzed qualitatively in chapter 3 and compared quantitatively by means of the effectiveness and efficiency indicators in chapter 4.

In this chapter, the last of this work, conclusions will be drawn from the results obtained in the previous chapters. The structure will be as follows: first, the conclusions will be drawn for each country on effectiveness, followed by the conclusions on efficiency. Finally, general conclusions and recommendations will conclude this work.

5.1 Conclusions on the Effectiveness of Wind Power Promotion Strategies

5.1.1 Conclusions on the Effectiveness of Wind Power Promotion Strategies applied in Germany

The review made in section 3.2.3 demonstrates that Germany has been implementing promotion strategies for RES-E, and especially for wind power, with continuity for more than 20 years now. Germany has provided investors the long-term stability they require in order to invest in wind power in the country, what leads to the achievement of a steady RES-E deployment. Great success can be attributed to the applied strategies by analyzing the development of accumulated wind power installed capacity and wind power generated in Germany.

As can be observed in the graph below, Germany has experienced an uninterrupted growth of cumulative installed capacity during the last 20 years, and as of 31 December 2010 it had the world's third largest installed wind power capacity of 27215 MW, behind China with 42287 MW and USA with 40180 MW (GWEC, 2010).

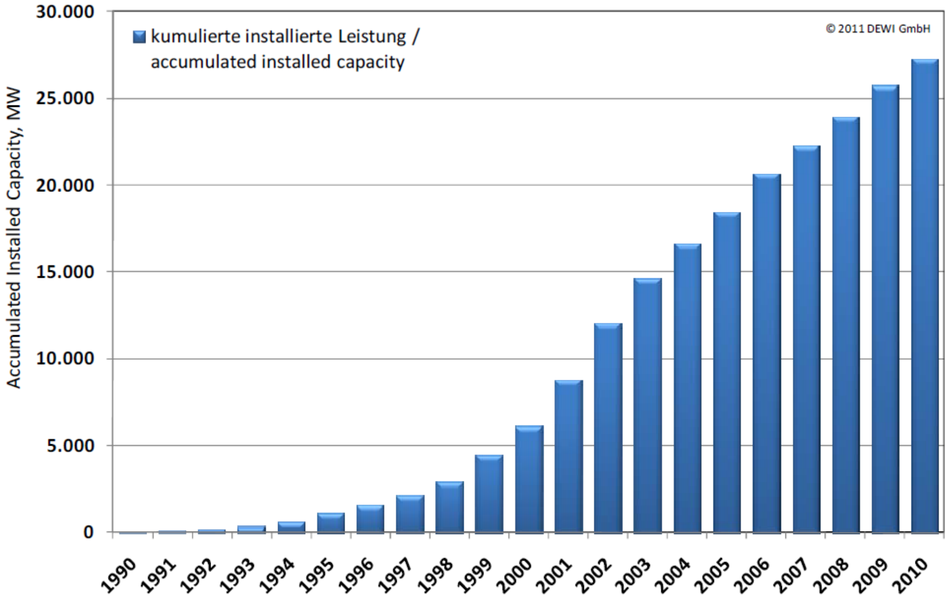


Figure 5.1: Development of accumulated wind installed capacity in Germany. Source: DEWI GmbH, 2010 (see footnote[8]).

As can be observed in the graph below, yearly installed wind capacity reached its peak during the first years of the "EEG" (years 2001 to 2003), and since then lower capacities have been installed. Though not at the same pace as before, partly because most of the best inland wind sites have already been occupied with wind parks, yearly capacity installations continue at good pace.

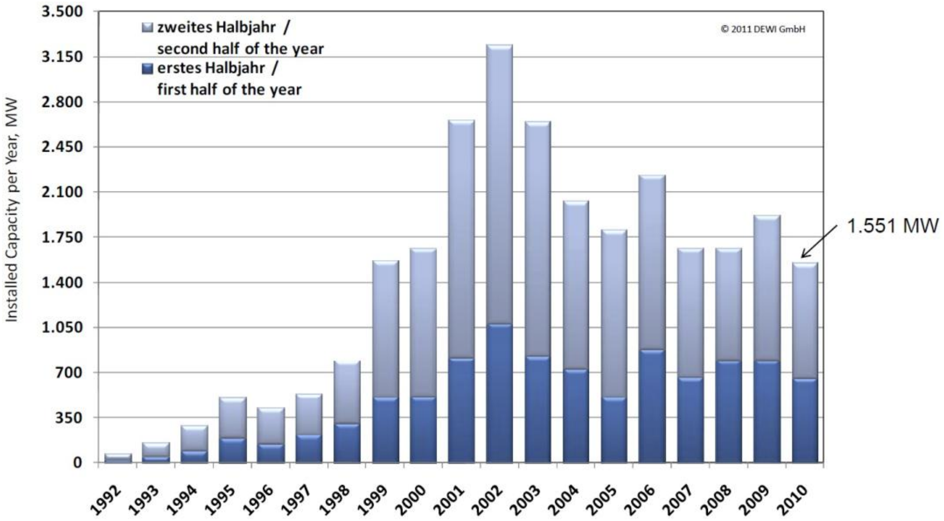


Figure 5.2: Installed wind capacity per year in Germany. Source: DEWI GmbH, 2010 (see footnote[9]).

[8] Source of figure 5.1:
http://www.dewi.de/dewi/index.php?id=66&L=1&tx_ttnews%5Btt_news%5D=114&cHash=95e3a930cdbca0dfdb7acb6542865780

[9] Source of figure 5.2:
http://www.dewi.de/dewi/index.php?id=66&L=1&tx_ttnews%5Btt_news%5D=114&cHash=95e3a930cdbca0dfdb7acb6542865780

The graph below displays the yearly wind power generation that received feed-in tariff compensations within the German Renewable Energy Sources Act ("Erneuerbare-Energie-Gesetz" or EEG). Since year 2000, when the EEG came into force, as much as 289 TWh have been generated from wind power. The rising trend of wind power generation in Germany is evident and this fact is as well a success that resulted from the promotion strategies implemented in the country.

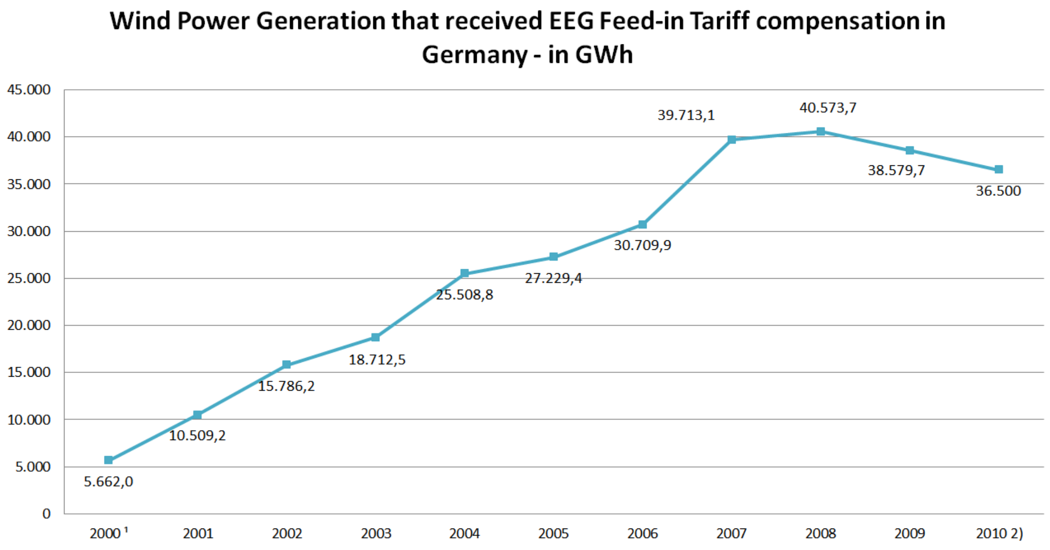


Figure 5.3: Wind power generation that received EEG Feed-in Tariff compensation in Germany. 1) 1 April to 31 December 2000. 2) Preliminary data for 2010. Source: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2011 (see footnote[10]).

It can therefore be concluded that the German RES-E promotion strategies have been highly effective in achieving wind power capacity deployment and wind electricity generation as well, and can hence be regarded as a success story within the European Union and a model for the rest of the world.

Recently published figures indicate that during the first six months of 2011 already 793 MW of wind power were installed in Germany (DEWI, 2011), which exceeds the capacity installed during the same period of 2010. It all suggests that the successful trend will continue and the promotion strategy will carry on bearing fruit.

[10] http://www.erneuerbare-energien.de/files/pdfs/allgemein/application/msexcel/ee_zeitreihe.xls

5.1.2 Conclusions on the Effectiveness of Wind Power Promotion Strategies applied in Brazil

With the commissioning of 931 MW as of 31 December 2010 and remaining 6275,6 MW in the pipeline until 2013, both the PROINFA programme and the auctions have given, undoubtedly, initial momentum to the wind power capacity development in Brazil.

As a positive consequence of the dynamic triggered by both the PROINFA programme and the auctions to the wind power sector in Brazil, the establishment of a local wind power industry has been gradually enabled. As of 31 December 2010, the Brazilian wind power industry has an overall production capacity of over 1 GW per year (GWEC, 2011). Still, the country has a great wind power resource that needs to be tapped and the planned capacity expansion of the local wind power industry that is foreseen for the short term will certainly contribute to this end. Otherwise this will act as a bottleneck what will hinder wind power deployment at the required rates to obtain high effectiveness.

The following graph depicts the scheduled wind power installations according to the deadlines of the above-mentioned PROINFA programme and for the respective auctions. As of 31 December 2010, 931 MW of wind power capacity have been installed in Brazil corresponding to the PROINFA projects. The remaining 499 MW should be installed by 31.12.2011. As of 2012 at the latest, the installation of the MW contracted through the auctions will have to take place in order for the project developers to benefit from the conditions agreed upon.

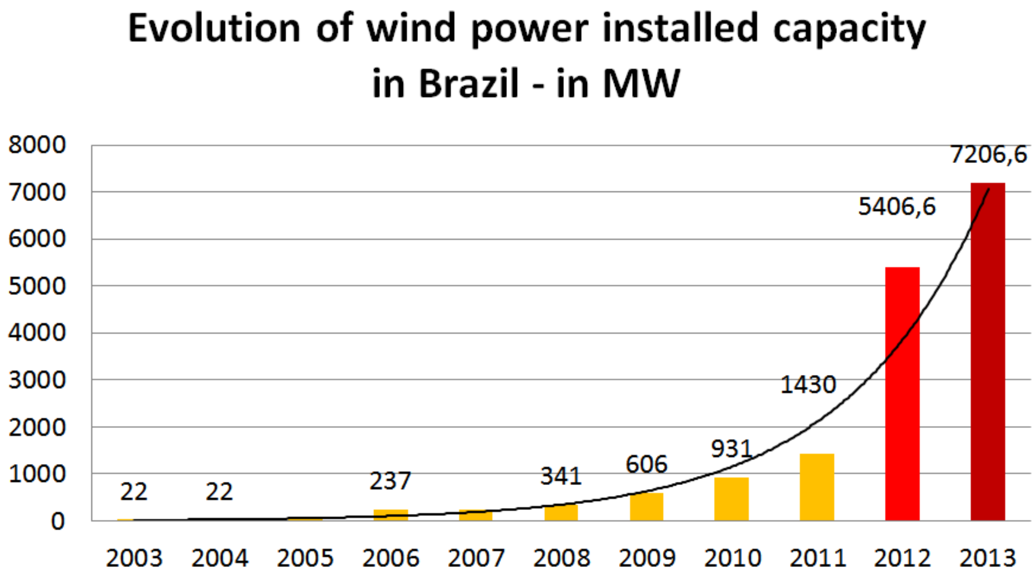


Figure 5.4: Evolution of wind power installed capacity in Brazil, according to PROINFA and 2009, 2010 and 2011 auctions' installation deadlines. Until 2011 inclusive: PROINFA. Year 2012: Auctions LFA2010, LER2010, LER2011, A3-2011. Year 2013: Auction LER2009.

Deployment within the PROINFA programme has been delayed due to several administrative barriers encountered by the investors, like difficulties obtaining environmental and land use permits, and grid connection. As well, the 60% nationalization rate created a bottleneck for the national wind power industry which was not able to supply at the required rate to meet the programme's deadlines. However, out of the 1400 MW of wind power foreseen for the first round of the programme, 931 were installed as of 31 December 2010 and it is foreseen that the remainder will be installed by end of 2011. These difficulties need to be overcome as soon as possible, or else the timely deployment of the 6275,6 MW will be endangered.

Therefore, it can be concluded that while effectiveness of the PROINFA's programme (first phase) in itself is relatively high in the sense that -although late- it will meet its targeted deployment. However, considering it from the perspective of the country's wind power potential (142,5 GW), and according to results obtained in section 4.2, it can be concluded that the effectiveness of the PROINFA programme in terms of wind power deployment is very low since its targets (1400 MW of wind power deployment in the first phase) were very modestly set for such a high wind power potential. This is confirmed by the success obtained by the auctions, which after only two years achieved the contracting of 5776 MW of wind power purchase agreements. Had the auctions not been launched, the country would have experienced a standstill of the wind power development sector. This would have been a negative signal for investors, who need a stable and certain business environment.

With regard to wind power generation, it can be concluded that the promotion strategies in place in Brazil not only encouraged wind power deployment but wind power generation as well, which has increased constantly since 2005, as can be seen in the graph below.

Of course the limited effectiveness achieved by the promotion strategy so far is a direct consequence of the type of promotion strategies implemented. The government of Brazil has chosen to arbitrarily set the maximum quantity of wind power to be deployed, unlike the FIT where the price is set by the government and quantity deployed is set by the investors. Respect to the wind power potentials of the country, the targets were set too low.

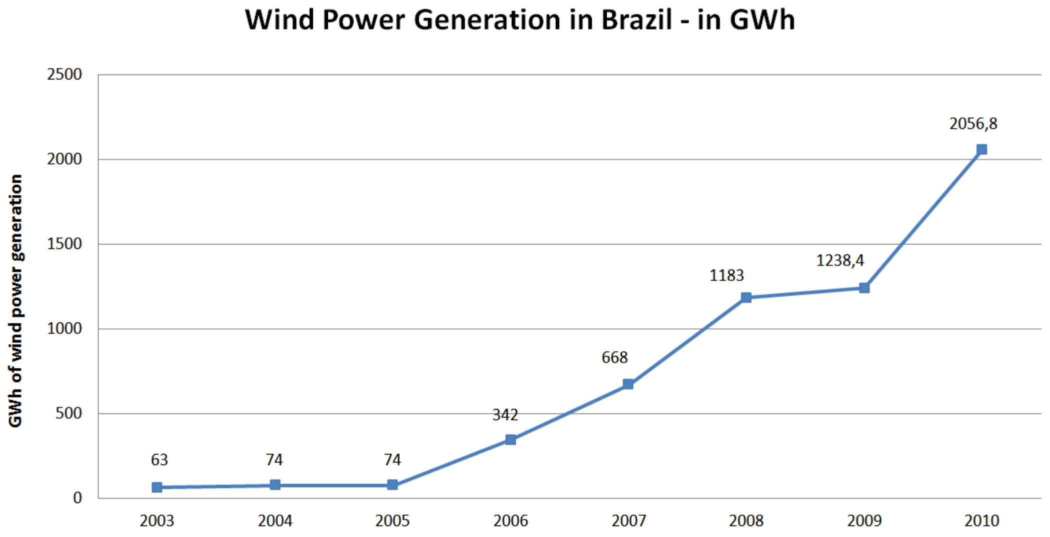


Figure 5.5: Annual wind power generation in Brazil, in GWh. Sources of data: Balanço Energético Nacional 2011, Balanço Energético Nacional 2010 (https://ben.epe.gov.br/).

In the case of PROINFA the price paid per MWh was set, and in the case of the auctions, an initial price was set but the market set the final contracted price. Both promotion strategies mean a "stop and go" for the investors. Until the intention of the government to invite for further tenders is made known, there is uncertainty with regard to the future of wind power deployment in the country. Therefore, as long as Brazil does not want to move into a feed-in tariff system, it would be recommended that at least tender schedules and their respective maximum contracted capacities are published for the short and medium term. Additionally, Brazil should revise its electricity plan for 2019 (target of 10% electricity from renewables) and increase the targets for wind power according to the power already contracted and to the high wind power potential. The investors require certainty on the continuity of wind power investments in the country; otherwise the local wind power industry will not possibly grow and increase production capacity. Given Brazil's strong condition as an exporting country to other countries in the Latin American region, the consolidation of a Brazilian wind power industry will probably benefit that region with products adapted to the market, shorter distances for delivery and servicing.

With regard to the relation between the effectiveness and the annuities paid, it has been clearly demonstrated in the previous chapter that in Brazil too high investors' profit have been paid, although, given the limitations set by the promotion strategies, the effectiveness has been low. The opposite is clearly demonstrated for Germany, which applied feed-in tariffs achieving high levels of effectiveness at low investors' profit.

5.1.3 Conclusions on the Efficiency of Wind Power Promotion Strategies applied in Germany

As depicted in figure 4.11, efficiency of the German promotion strategies have been much higher than Brazil's. This is owed primarily to the fact that the experience accumulated by Germany in the past 20 years has allowed for numerous adjustments of the feed-in tariffs. The "EEG" law has foreseen periodic degression of the tariffs as technical advances improve the technology and lower the costs, but it also has happened that the tariffs were increased when necessary, due to changing conditions. But also, the German FIT has differentiated payments according to the yield of each site compared to a reference yield. Therefore, the German promotion strategy has been properly fine-tuned several times and although the windiest inland locations have already been taken or are not available for wind power (protected areas, urban settlements, etc.), deployment of wind power has not been stopped.

5.1.4 Conclusions on the Efficiency of Wind Power Promotion Strategies applied in Brazil

The Brazilian efficiency started being much lower than that of the Germany feed-in tariff system and with the introduction of the auctions it has improved very quickly, as shown by figure 4.11. Still, the optimum efficiency has not been reached. As demonstrated in several articles of the literature and as confirmed by the results obtained in this work, the adoption of a correctly designed feed-in tariff system in Brazil would definitely further improve the efficiency in comparison to the wind power auctions.

In case auctions remain as the wind power promotion strategy, price differentiation could be performed in the auctions depending on the wind conditions at the sites. It does not seem reasonable that projects at excellent wind sites get the same payment than projects at more moderate wind sites.

5.2 General Conclusions and Recommendations

Comparing the German and Brazilian wind power promotion strategies is certainly not easy, given that both have an opposite rationale. The German FIT system intends to pay an attractive, yet not excessive, price per unit of electricity generated. The Brazilian auctions offer a maximum power to be contracted and the wind power price is pushed down with competition.

Another difference between the German FIT system and the Brazilian auctions is that the former promotes energy democracy in that it allows not only big players but also normal citizens to generate electricity. This seems unfeasible under the Brazilian promotion strategies, but a way to make them more democratic could be to launch support programmes for small wind power, for rural areas especially.

As has been demonstrated in the past sections, the German feed-in tariff system is far more effective and efficient than Brazil's promotion strategies. Even if Brazil does not intend to change its wind power policy from auctions to a feed-in tariff, some issues should be resolved to improve their effectiveness and efficiency. As was mentioned previously, administrative barriers have prevented projects to be implemented at the originally established schedules. Delays in project commissioning have occurred because of lengthy and tedious permitting processes, both for environmental and land use permits. This issue will pose a great risk to further deployment and the establishment of a “one-stop shop” could help, by concentrating and harmonizing the administrative permitting process in one governmental authority and therefore making it more transparent and less risky to investors.

Another issue to be taken care of by the government is the carry out of necessary adjustment to the grid, to cope with the expansion in wind power deployment and power in general. Relative to the grid, priority grid access rights and electricity feed-in rights have to be ensured in Brazil for wind power producers, no matter which promotion strategy is in place. This aspect has been one of Germany’s “EEG” key success factors, by underscoring the government’s commitment to wind power and which resulted in investors’ credibility and willingness to invest in the country, both in wind power production and in the wind power industry.

In order to level the playing field among conventional and renewable electricity sources, and especially between dispatchable and variable electricity generation technologies, exclusive auctions for wind power should be designed in Brazil. Given the country’s large wind power potential, and the necessary electricity generation capacity needs, it seems logical that wind power deserves deployment targets that do not compete with other sources (in at least one auction wind power competed with natural gas, small hydro and biomass).

The already estimated positive effects of wind power on the merit order, bringing electricity generation costs down (wind power displacing thermoelectricity, which represented 4,7% of the mix in 2010 – see figure 3.18), and the ideal seasonal combinability of wind power with large hydro, the backbone of electricity generation in Brazil, should convince the government of Brazil to commit to developing both the national wind power industry and the wind power generation.

To give further momentum to and to increase competitiveness of the incipient wind power industry, a special tax framework should be designed for wind power in

Brazil. This will strengthen the national industry, a key factor for the success of the wind power development.

Brazil undertook more than three decades ago a series of measures to boost the production and utilization of ethanol, as an indigenous source of energy. What for many was a crazy undertaking is today normal in the country and a model for the world. Gasoline is mandatorily mixed with ethanol and the majority of the cars and many motorcycles (mostly “made in Brazil”) have flexible engines that allow them to work on normal gasoline or on cheap ethanol. The same impetus that was given to the ethanol programme (which comprised the local production of the ethanol and the car engines to use it) should be now given to wind power.

It seems clear that the conditions are given for wind power to become a significant indigenous electricity generation source in Brazil, backed-up by a national wind power industry. An adequate promotion strategy, for instance a feed-in tariff, would make this happen sooner and at a lower cost to society.

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8 ANNEX

EXCHANGE RATES US Dollar - Euro
http://www.ecb.int/ecb/html/index.de.html
http://www.ecb.europa.eu/stats/exchange/eurofxref/html/eurofxref-graph-usd.en.html
1 € = x US $

31.12.2010	1,4406
31.12.2009	1,3917
31.12.2008	1,4721
31.12.2007	1,322
31.12.2006	1,18115
31.12.2005	1,3621
31.12.2004	1,263
31.12.2003	1,0487
31.12.2002	0,89255
31.12.2001	0,9364
31.12.2000	1,0068

EXCHANGE RATES US Dollar – Brazilian Real
1 US $ = x R$
http://www.oanda.com/lang/de/currency/historical-rates/

31.12.2010	1,666
31.12.2009	1,7343
31.12.2008	2,3417
31.12.2007	1,7666
31.12.2006	2,1325
31.12.2005	2,3279
31.12.2004	2,6565