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Adaptations of renewable energy policies to unstable macroeconomic situations—Case study: Wind power in Brazil

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Abstract

Despite the massive cost reduction in the last decade, wind power generation is generally still more expensive than conventional energy sources which benefit from the exclusion of externality costs in the price structure. Support policies for renewable energies guarantee the economic viability of this type of electrical power generation in many European countries. In Latin America, Brazil has become the pioneer state for renewable energy with the implementation of the PROINFA programme that supports, among other sources, wind power development of 1100 MW. This article presents an overview of the differences between the German and Brazilian wind power promotion policies with a special focus on how PROINFA can be adapted to the unstable macroeconomic situation of Brazil. The document specifically examines the adaptation of wind power promotion policies to large inflation and interest rates in Brazil.

Keywords: Brazil; Feed-in tariff; Renewable energies; Promotion policies; Wind park financing; Wind power

1. Introduction

Since the 1990s the development of a competitive renewable energy industry sector in Europe was triggered by the implementation of a varying set of renewable energy-friendly incentive (promotion) policies. The countries where feed-in systems were introduced, e.g. Spain and Germany, have experienced significant advances in the development of renewable electricity in comparison to countries with non-tariff-based promotion policies. Special tariffs for electricity generated by renewable energy sources are the main instrument of feed-in systems. These tariffs, typically above the market price for electricity form in combination with long-term power purchase agreements (PPA), the main instrument of feed-in systems and encourage investments in this industry sector. One important characteristic of the European feed-in systems consists of small expenditures for administration and control purposes. The beneficiaries of this advantage are at last the final consumers.

In countries such as China, India and Brazil, electricity demand is expected to increase considerably during the next decade. Brazil intends to meet the additional demand in part by renewable energy sources. After a major electrical energy crisis in the year 2001, the Brazilian Government initiated PROINFA: a support instrument principally based on the European feed-in

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Nomenclature

BC	basic compensation
BNDES	Banco Nacional de Desenvolvimento Econômico e Social (Brazilian Bank of Economic and Social Development)
CF	capacity factor
DIC	duration of initial compensation
EEG	Erneuerbare-Energien-Gesetz (renewable energies law)
I	inflation goal for the next 12 months
IC	initial compensation
IGP-M	Índice Geral de Preços do Mercado (General Market Price Index)
IPC-M	Indice de Preços ao Consumidor (Consumer Market Price Index)
IPCA	Índice Nacional de Preços ao Consumidor Amplo (National Broad Consumer Price Index)
NC	nominal capacity
PPA	power purchase agreement
PROINFA	Programa de Incentivo às fonts alternatives de energia elétrica (Incentive Programme for Alternative Sources of Electrical Energy)
R	risk premium
RE	reference energy
R$	real (Brazilian currency)
RY	reference yield
RYY	relative reference yield
TJLP	Taxa de Juros de Longo Prazo (long-term interest rate)
VE	Valor Econômico (economic value)

policies. PROINFA, modified by the current government in December 2003, is the first support scheme for grid-connected systems in Latin America and also the largest of all the promotion policies in the region with a scope of 3300 MW: 1100 MW small hydro power, 1100 MW biomass, 1100 MW wind power (Law No. 10438 of 2002; Law No. 10762 of 2003).

However the economic frameworks and energy policies of Brazil and EU countries differ fundamentally in many aspects. Some of these differences were considered in the policy design of PROINFA. In this paper the authors focus on the adaptations of the Brazilian PROINFA to the unstable macroeconomic situation in the country, specifically on the large interest and inflation rates in comparison to European standards. The paper demonstrates a comparison of the Brazilian and German promotion policies for wind power on that basis.

For purposes of this document the word ‘‘compensation’’ is used for the amount of money that is paid for the feed-in of electricity into the electrical grid; another expression that could be used is ‘‘feed-in tariff’’.

2. Comparison of compensation for the feed-in of wind electricity in Germany and Brazil

2.1. Wind power compensation in Germany

The German Renewable Energies Law of the year 2000 (EEG, 2000) established exclusive feed-in tariffs for electrical energy generated by wind power plants to be paid during a period of 20 years. A new law, brought into force in August of 2004 (EEG, 2004), did not change the duration of the PPA, but the basic compensation (*BC*) for on-shore wind power was fixed at 53.9 €/MWh for the year 2005 (see Fig. 1). In addition, a supplementary initial compensation (*IC*) of 31.4 €/MWh has been introduced for new on-shore wind power plants.

The duration of *IC (DIC)* depends on the relative reference yield (*RRY*) of the power plant: The smaller the *RRY*, the longer the *IC* is paid (Table 1). The *RRY* of a wind power plant is the yield in relation to the calculated amount of electricity (reference yield (*RY*)), which the same wind power plant would generate at a reference location. For both yields 5 years of operation are taken into account. The reference location is a place with the following dispositions: a Rayleigh-distribution of wind speeds with an average of 5.5 m/s at a height of 30 m above ground, a logarithmical height profile and a

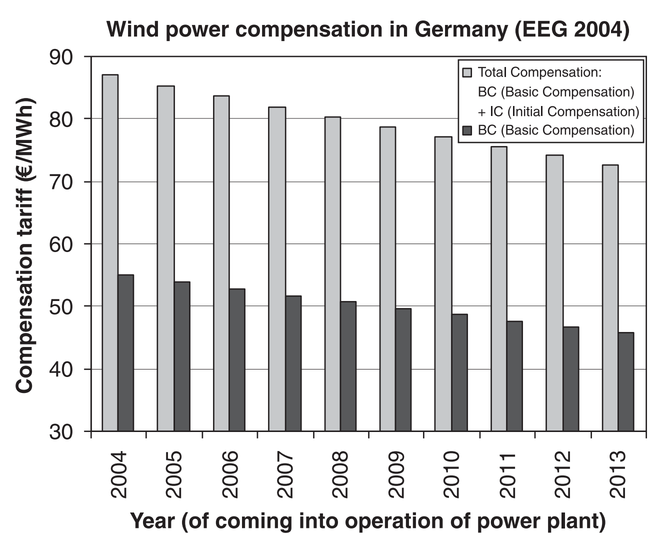

Fig. 1. Nominal feed-in tariffs for wind power electricity in Germany, depending on year of wind park inauguration (EEG, 2004, p. 1922) (own elaboration).

Table 1
Relation between *RRY* and duration of *IC* payment (*DIC*) in Germany fixed by EEG (2004, p. 1922) (own elaboration)

Relative reference yield (*RRY*) (in %)	⩾150	149.25	148.5	147.75	147	144	141	138	etc.
Duration of *IC* (*DIC*) (in months)	60	62	64	66	68	76	84	92	—

rugosity length of 0.1 m. The performance characteristic of the power plant (electrical output power as a function of wind speed) considered for the *RY* is based on measurements. Further details concerning the definition of *RRY* of a wind power plant are given in EEG (2004, p. 1929).

The *DIC* can be calculated using the following linear function:

$$DIC\text{ (in month)} = 60 + ((150 - RRY)/0.75) \times 2 \quad (RRY \leqslant 150).$$

The use of a variable *DIC* intends to guarantee the economic viability also for wind power plants at less favourable locations, it helps to compensate the elevated interests on capital in the first years after the initial investment, and it reduces the investor's risk. The purchase value of the generated wind electricity is influenced by two effects during the 20 years of PPA:

1. The actual value is reduced by the inflation rate.
2. After suspension of the *IC* the compensation drops immediately to the *BC*.

These effects are shown in Section 3.

The *German Renewable Energies Law* (EEG, 2004), which regulates feed-in tariffs for several years, is considered to be a stable framework. The relevant feed-in tariff for new wind power plants depends on the year when the power plant comes into operation for the first time. This value decreases by 2% annually in addition to inflation losses, triggering productivity improvements and cost reduction efforts of the manufacturers and operators.

Example: A wind power plant that starts operation in 2005 receives a *BC* of 53.9 €/MWh for 20 years. At least during the first 5 years the supplementary *IC* will be paid, summing up a total nominal feed-in tariff of 85.3 €/MWh in this period (Fig. 3).

BC and *IC* are paid by the (final) consumers of electricity. A nation-wide equalization scheme is supposed to avoid a discrimination of single consumers and consumer groups: grid operators are obliged to allow connection of wind power and other renewable energy plants to their grid, to purchase electricity available from these installations and to compensate the suppliers of this electricity in accordance with the actual feed-in tariff (*BC* and *IC*). The grid operator for upstream transmission is obliged to purchase, and pay compensation for the amount of renewable energy purchased by the grid operator. Every year the transmission-grid operators shall survey the amount of renewable energy purchased and its relative share of the total amount of electricity delivered to the consumers. If transmission-grid operators have purchased amounts of energy that are larger than the average share, they shall be entitled to sell energy to other transmission-grid operators for the relevant feed-in tariff, until these other grid operators have purchased the volume of renewable energy that is equal to the average share. So every consumer has to contribute with the same share to the additional costs, considering that all transmission-grid operators transfer the costs to the final consumers (EEG, 2004).

In the year 2004 an additional 2020 MW of wind power capacity was installed in Germany (total wind power capacity: 16,628.8 MW). Brazil, with a current wind capacity of 28 MW, is expected to start a dynamic development and substantial increase in the years 2006–2007 with the PROINFA program to be implemented (ANEEL, 2004; WWEA, 2005, p. 3).

2.2. Wind power compensation in Brazil

Within the first phase of the Brazilian Incentive Programme for Alternative Sources of Electrical Energy (PROINFA) ending on 31/12/2006, the support is limited to a maximum capacity of 1100 MW of wind power plants. The latest development indicates that the share of wind power at PROINFA is going to be increased from 1100 MW to almost 1400 MW. Due to an insufficient number of proposals for biomass power projects under the program (1100 MW in capacity), the remaining capacity of about 300 MW which has not been utilized will be transferred to the wind power share of the program; therefore it is expected that a total of 1400 MW of wind power capacity is going to be installed in Brazil in the next years.

For the second phase no regulations have been set up yet, but probably an electricity auction will be established. PROINFA does not feature a *BC* for wind electricity generation such as in the German EEG. The compensation (VE: Valor Econômico: Economic Value) depends on a capacity factor (*CF*) calculated for each wind power plant (MME, 2004). *CF* is calculated by the following function:

$$CF = [RE \times (1 - LG/100) - LC]/(NC \times 8760).$$

Table 2
Relation between CF and VE in Brazil fixed by Ministry of Mining and Energy (MME, 2004) (own elaboration)

CF = capacity factor	0.419347 (CF_{max})	0.4	0.38	0.36	0.34	0.324041 (CF_{min})
VE = Valor Econômico (R$/MWh)	180.18 (VE_{min})	185.09	190.16	195.23	200.3	204.35 (VE_{max})

RE (reference energy) is a multiplication between nominal capacity (NC) and the measured availability factor of the power plant. CF is a division between reference energy (RE) of the power plant, reduced by energy losses (LG[1], LC[2]), and the NC of the power plant multiplied by 8760 (number of hours per year). The CF remains in the interval between 0 and 1. CFs above 0.40 indicate a power plant in a good wind location.

Wind farms in less good location receive a greater compensation (VE: Economic Value) per energy unit than projects in favourable locations. Therefore, the larger the CF, the smaller the VE. The VE increases linearly from 180.18 R$/MWh (≈63.44 €/MWh)[3] ($VE_{min}$) for power plants with the maximum capacity factor (CF_{max}) of 0.419347 up to 204.35 R$/MWh (≈71.95 €/MWh)[3] ($VE_{max}$) for power plants characterized by minimum capacity factor (CF_{min}) of 0.324041 (see Table 2). CF_{min} and CF_{max} were fixed by the Brazilian Energy Ministry (Ministry of Mines & Energy—MME). The VE is calculated by the following linear function:

$$VE(\text{R\$}) = VE_{max} - [(VE_{max} - VE_{min})/(CF_{max} - CF_{min})] \times (CF - CF_{min}) \text{ (MME, 2004).}$$

The following is an example for the calculation of VE of a wind power plant with a CF of 0.38:

$$VE(\text{R\$}) = 204.35 - [(204.35 - 180.18)/(0.419347 - 0.324041)] \times (0.38 - 0.324041) \approx 190.15.$$

The VE of a wind power plant with a CF of 0.38 is about 190.15 R$/MWh (≈66.95 €/MWh)[3].

The VE is paid by the Brazilian energy entity '*Eletrobrás*', which is also responsible for the administration of PROINFA. '*Eletrobrás*' transfers the resulting expenditures to the consumers in proportion to their energy consumption, with the exception of a residential low-income subclass consuming less than 80 kWh/month (Law no. 10762 of 2003).

The CF of each wind farm will be revised periodically and VE adapted consequently, probably causing considerable alterations in compensation during the 20 years of PPA.

The differentiation of the VE that relates on the CF intends to make wind projects feasible at less favourable locations as well as to avoid an over-compensation of electricity generation at excellent wind locations. A 220 MW wind power installation limit for each federal state was implemented to prevent a concentration of most wind power generation capacity in a few states with favorable wind conditions, avoiding bottlenecks in the electrical grid. The best wind conditions can be found in the northeast of Brazil, but in this region the electrical transmission line infrastructure is not well developed.

Besides the periodical adaptations of CFs during the 20 years of PPA, the VEs suffer from the devaluation effect by inflation, which is the focus of the following section.

3. Adaptation of wind power compensation to inflation

In comparison to the German economy, the Brazilian economy is still in an unstable macroeconomic situation. Low interest rates and a small increase in prices as well as a low country risk characterize the German framework in comparison to extremely large interest rates, a relatively large inflation and an elevated country risk of the Brazilian economy. These differences have significant impact on long-term investments. The following sections examine the different characteristics of inflation in both countries and the resulting effects on the compensation of wind power electricity.

3.1. Repercussion of rise in prices to German wind power compensation

In the German EEG, feed-in tariffs are not readjusted during the 20 years of their payment. The nominal value of BC on the first day of PPA is the same as on the last day. The same happens to IC during the period of its payment. In the last 10 years the rise of the consumer price index in Germany has never surpassed 2% per year and stayed within the interval between 1% and 2% during the last 4 years (German Federal Bank, 2004; Federal Agency for Statistics, 2003). The effect of price increases is demonstrated in Fig. 2. After 20 years of operation, the actual value of the feed-in tariff will be about 82.0% of the nominal value considering a yearly devaluation of 1%, and about 67.3% for the case of a constant annual devaluation of 2% (Fig. 2).

In addition to the inflation effect, the compensation of wind electricity suffers an abrupt change of nominal

[1] LG: energy losses until grid connection.
[2] LC: losses of generated energy by consumption of wind power plant.
[3] Exchange rate at 8th of July 2005.

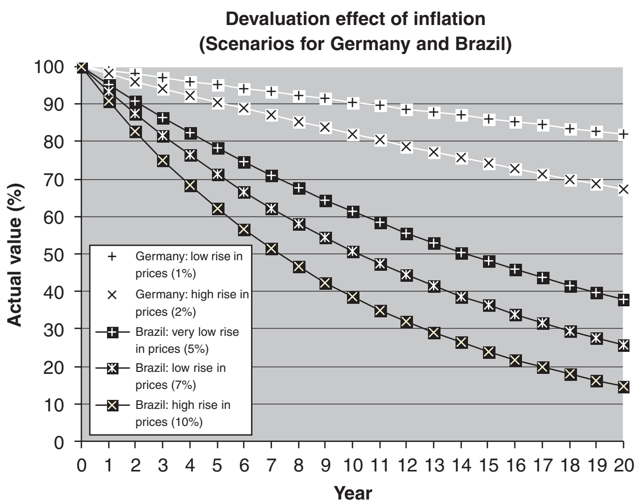

Fig. 2. Examples for devaluation effect of actual value according to German and Brazilian patterns of rise in prices (own elaboration).

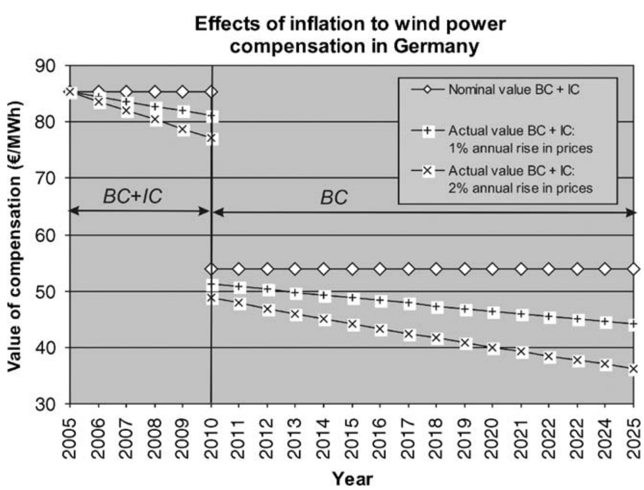

Fig. 3. Nominal and actual values of EEG wind power feed-in-tariff (tariff, 2005) for a wind power plant with an exemplary relative reference yield (*RRY*) of 150 and corresponding 60 month of *IC* payment (EEG, 2004) (own elaboration).

value after suspension of the *IC*, according to the German EEG (Fig. 3). Including this second effect, the actual value of the feed-in tariff after 20 years is about 51.8% and 42.5% of the value in the first year of compensation respective to annual devaluations of 1% and 2%.

3.2. Adaptations of wind power compensation to inflation in Brazil

Brazil has progressed considerably in the control of inflation since the set-up of the "Plano Real" in 1994. Nevertheless, the average increase in consumer prices has been between 9% and 10% annually during the last 10 years, falling slowly to 8–8.5% in average for the last 5 years (IPCA + IPC-M, Fig. 4). Without a readjustment of the feed-in tariffs for renewable energy, the inflation would cause a devaluation of the compensation of almost 50% in 10 years and more than 70% until the last year of PPA, with a supposed moderate inflation of 7% per year (Fig. 2).

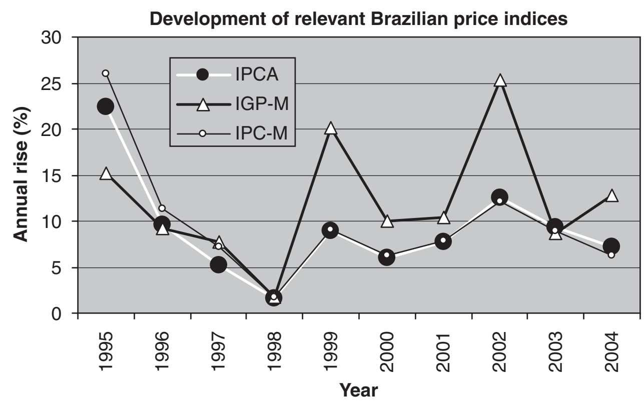

Fig. 4. Price index development of three relevant indices since *Plano Real* stability act (IBGE, 2005; FGV, 2005) (own elaboration).

3.2.1. Price indices as reference for readjustment

In Brazil readjustments of electricity tariffs to inflation are common. In new contracts the IPCA-Index, the National (Broad) Consumer Price Index (Índice Nacional de Preços ao Consumidor Amplo), is the relevant price index for readjustments (CanalEnergia, 2004), but PROINFA-tariffs will still be readjusted by the IGP-M, the General Market Price Index (Índice Geral de Preços do Mercado), the former index for these types of readjustments. IGP-M consists of three components: (1) Wholesale Trade Market Price Index (IPA-M) (60%), (2) Consumer Market Price Index (IPC-M) (30%) and (3) National Construction Cost Index (INCC-M) (10%) (FGV, 2005). It therefore differs from the consumer index IPCA. In Fig. 4 the two consumer price indices IPCA and IPC-M show a similar development, but IGP-M differs considerably.

Since 1997 the IGP-M has increased more than the consumer price indices, but long-term observation of CBIEE, the Brazilian Chamber of Investors in Electrical Energy (Câmara Brasileira de Investidores em Energia Elétrica), shows that the development of IGP-M and IPCA has not demonstrated considerable differences during the last 40 years (Machado, 2004).

3.2.2. Suitability of IGP-M and IPCA for readjustments

The "Financial Support Programme for investments in alternative sources of electrical energy in the scope of PROINFA" (Programa de apoio financeiro a investimentos em fontes alternativas de energia elétrica no âmbito do PROINFA) of BNDES (Brazilian Bank of Economic and Social Development) plays an important role in achieving economic viability for wind power projects. It offers loans with much smaller interest rates than those available on the free market in Brazil. Due to this programme BNDES used to be the most important financer of the Brazilian wind projects, but until March of 2005 only a single wind project had applied for the BNDES (BNDES, 2005c). The small demand caused some changes in the financing conditions of BNDES loans for PROINFA projects in April of 2005.

Depending on the nationalization quota, BNDES will cover up to 80% (before the change: 70%) of the investment costs. The loan amortization has to be finished after a period of 12 years (before: 10 years) (BNDES, 2005b).

BNDES applies the *TJLP*, the long-term interest rate (Taxa de Juros de Longo Prazo) to the loans for PROINFA projects as reference interest rate. The *TJLP* is much smaller than the interest rates of conventional financing institutions in Brazil, turning the BNDES into a fundamental institution for long-term investments in general. The *TJLP* is recalculated every 3 months by the following formula:

$$TJLP = I\,(\text{inflation goal for the next 12 months}) + R\,(\text{risk premium}).$$

The inflation goal (*I*) is fixed by the National Monetary Council (CNM—Conselho Monetário Nacional) using the broad consumer price index (IPCA) as reference. *R* is composed of the current interest rate on the international market and the consideration of the country risk in a middle and long term perspective (BNDES, 2005a).

Therefore, the debts to BNDES, the probably most important cost factor of wind projects in the first years, are directly related to IPCA in contrast to IGP-M, the relevant reference index for readjustments of the PROINFA tariffs. For the period from April to June of 2005 the *TJLP* has been fixed at 9.75% and BNDES charges 3.5% for this service, totaling annual financing costs of 13.25% (BNDES, 2005a, b). In comparison, the Brazilian base rate has been fixed at 19.75% on the 19th of May 2005 and is currently one of the largest in the world (Banco Central do Brasil, 2005). Adding bank profits and handling fees, Brazilian banks charge an interest rate in the vicinity of 30%. Consequently, loans from the free Brazilian finance sector will probably not play an important role in the financing of the wind projects due to the large interest rates. The remaining part of investment costs has to be financed by other development banks, foreign investors or private capital.

The Brazilian EcoEnergia Fund, which also considers PROINFA projects, focuses on small hydropower plants, which promise a larger return and fewer risks (EcoInvest, 2004).

3.2.3. Effects of readjustment to nominal values of compensation

The following scenario assumes that the yearly tariff readjustment by IGP-M is identical to the rise in the relevant prices for wind power projects, guaranteeing a stable actual value of wind power compensation during the period of the PPA.[4]

In Fig. 5, two examples for a possible readjustment of tariffs (7% and 10%) are visualized. The nominal value increases more than 250% in the moderate case and more than 1000% in the case of readjustment patterns of annually 10%.

It is important to point out the primary difference between the German wind power feed-in tariff and the Brazilian promotion policy: in PROINFA a mechanism was implemented with the goal to stabilize the actual value of the compensation during the entire running time of PPA, unlike in the German EEG where no readjustment of the tariffs to inflation is considered, but where an initial supplement (*IC*) is paid, increasing the income of the wind electricity producer considerably during the first years and supporting the decrease of the actual value of compensation caused by rise in prices over the time. In the following section the cost graphs of the projects show the importance of large compensations especially during the first years of operation.

4. Adaptation of compensation to cost structure of wind farms

The present cost structure data for wind power generation in Brazil is not representative, because of the small number of wind projects presently realized (total capacity: 28 MW; ANEEL, 2004). Most of the 47 PROINFA wind projects, totaling 1100 MW (1400 MW according to the most recent program shifts, see also Section 2.2), have not applied for the BNDES credits yet, and therefore in many cases it seems to be too early for a consolidated evaluation of the cost structure (BNDES, 2004, 2005c).

4.1. Comparison of cost structure of wind projects in Brazil and Germany

The present knowledge of total wind power costs in Brazil and Germany allows for a basic analysis of the cost distribution as a function of time (from the viability study of the projects until the end of PPA). Fig. 6 differentiates the relative costs (not considering capital repayment costs) and relative compensation for Brazil and Germany in a simplified way.

German compensation for instance suffers from an annual devaluation of 1.5% by inflation. The viability

[4]The actual value will not be totally adjusted, even if the readjustment stays congruent to the rise in relevant prices, since the readjustment is carried out once a year and not constantly.

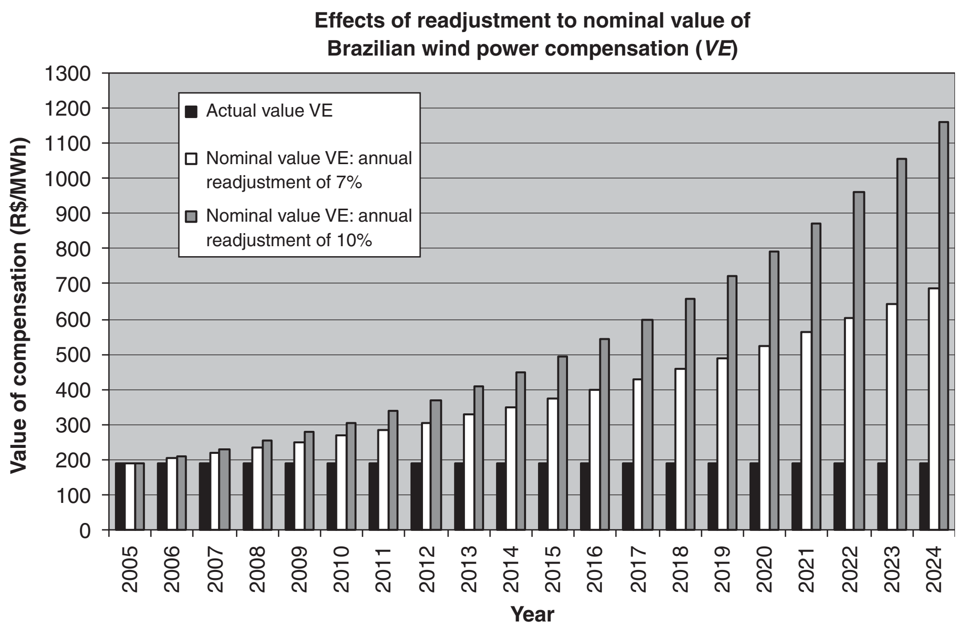

Fig. 5. Example for readjustment of *VE* for a wind power plant with $CF = 0.38$ and corresponding *VE* of 190.15R$/MWh [R$ 190.15 ≈ € 66.95 (€1.00 = R$ 2.84)] (own elaboration).

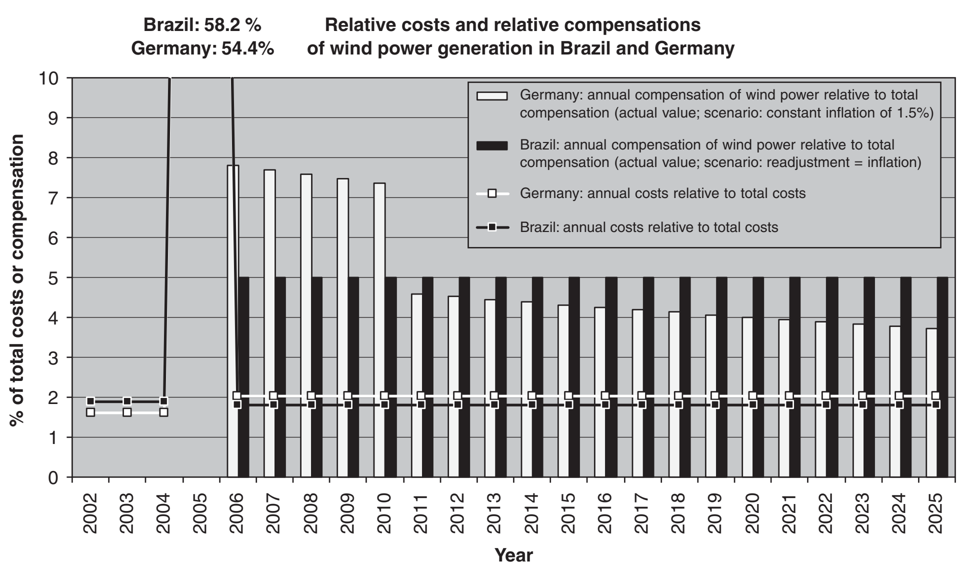

Fig. 6. Relative average costs (without capital cost repayment) and relative compensations in the different "life-cycles" of a wind power plant in Brazil and Germany as a function of time (Molly, 2003, 2004; EEG, 2004; MME, 2004) (own elaboration).

study and development of the wind farm projects are assumed to take 3 years with constant costs in this period. The construction and additional infrastructure set-up is expected for the fourth year. The beginning of operation is foreseen for the fifth year. The annual costs up from the fifth year are expected to remain stable during the whole running time of the PPA.[5]

In Germany 59.2% of the gross costs have to be raised in the first 4 years, contrasting to 63.9% in Brazil. From the fifth year onwards, the relative annual costs are 1.80% in Brazil and 2.04% in Germany in average (Fig. 6).

[5]O&M (Operation & Maintenance), as part of the annual costs, are less in the first 2 years of operation when the warranty of equipment is still valid (Molly, 2003, p. 37). The constant use of the equipment is

(*footnote continued*)
supposed to lead to a rise in O&M costs after a few years. These two effects are not considered in Fig. 6, where average annual costs are applied.

5. Conclusion

In comparing gross costs in both countries it is clear that relatively large investment costs lead to considerable capital costs repayment in the first years after the construction of wind farms. The German profile of tariff adaptation during the years for wind power grid-integration appears to be better adapted to reality than the Brazilian one (Fig. 6). The Brazilian framework, with large expected return rates of investments at high interest rates, shows the importance of an elevated compensation of wind power particularly during the loan amortization period. The applied adjustment of VEs to inflation is inaccurate most likely and presents an extra risk for investors in addition to the general high risk for investments in a new energy source—wind power—at least in Brazil.

Proposal: A higher *VE* level during the first years, concerning the high capital cost repayment in the period after the investment, would help diminishing the investor's risks and increase the profitability of the wind projects. When the capital repayments have been amortized, feed-in tariffs could be reduced considerably.

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