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Framework conditions for the promotion of new renewable energies in Brazil: The case of grid-connected photovoltaics

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Abstract

Increasing concerns about climate change and the desire for security of supply have driven many countries to the development of their renewable energy potential. Brazil, one of the largest emerging economies, does not really share these concerns. With an energy mix based mainly on hydropower and with practically no energy imports, the country does not experience the same pressure to develop other energy sources. However, renewable energy is not always sustainable. Sustainability concerns can therefore drive the development of alternative renewable energy sources in Brazil, including grid-connected solar photovoltaics (PV). The high cost of PV and the efforts required for its successful integration in the electricity grid still pose obstacles for its diffusion in the market. This implies a need for structured policy intervention. This paper identifies a series of framework conditions, either drivers or barriers, which could promote or hinder the introduction of a support policy for the integration of solar PV in the Brazilian energy mix, and discusses their implications.

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List of Abbreviations

Abbreviation	**Description**
ABINEE	Associação Brasileira da Indústria Elétrica e Eletrônica/Brazilian Association of Power Sector Equipment
ABRACE	Associação Brasileira de Grandes Consumidores Industriais de Energia e de Consumidores Livres/Brazilian Association of Major Power Consumers and Free Consumers
ABRADEE	Associação Brasileira de Distribuidores de Energia Elétrica/Brazilian Association of Electric Power Distribution Companies
ABRAGE	Associação Brasileira das Empresas Geradoras de Energia Elétrica
ACL	Ambiente de Contratação Livre/Free Contracting Environment
ACR	Ambiente de Contratação Regulada/Regulated Contracting Environment
ANEEL	Agência Nacional de Energia Elétrica/Brazilian Electricity Regulatory Agency
BA	Federal state of Bahia
BNDES	Banco Nacional do Desenvolvimento Econômico e Social/Brazilian Development Bank
CB-Solar	Centro Brasileiro para Desenvolvimento da Energia Solar Fotovoltaica
CCEE	Câmara de Comercialização de Energia Elétrica/Electric Power Commercialization Chamber
CE	Federal state of Ceará
CEPEL	Centro de Pesquisa de Energia Elétrica/Electric Energy Research Center
CNPE	Conselho Nacional de Política Energética/National Energy Policy Council
COFINS	Contribuição para o Financiamento da Seguridade Social/ Contribution for Social Security Financing
COP15	The 15th Conference of the Parties to the UNFCCC
DEMA	Departamento de Engenharia de Materiais
DF	Distrito Federal (Brasília)
EPE	Empresa de Pesquisa Energética
FIT	Feed-in tariff/ Feed-in law
FNMC	Fundo Nacional sobre Mudança do Clima/National Climate Change Fund
GT-GDSF	Grupo de Trabalho em Geração Distribuída com Sistemas Fotovoltaicos
ICMS	Imposto Sobre Circulação de Mercadorias e Serviços/Value Added Tax
IEA	International Energy Agency
IEE	Instituto de Eletrotécnica e Energia
II	Imposto de Importação/Import Duty
IPI	Imposto sobre Produtos Industrializados/Excise Tax
LPT	Programa Nacional de Universalização do Acesso e Uso da Energia Elétrica Luz para Todos/National Program for Universal Access and Use of Electric Power
MCT	Ministério da Ciência e Tecnologia/Ministry of Science and Technology

MDIC	Ministério do Desenvolvimento, Indústria e Comércio Exterior/Ministry of Development, Industry and Foreign Trade
MME	Ministério de Minas e Energia/Ministry of Mines and Energy
ONS	Operador Nacional do Sistema Elétrico/Electric System National Operator
PDE	Decennial Plan for Energy Expansion/Plano Decenal de Expansão de Energia
PIS	Contribuição ao Programa de Integração Social/Contribution to the Social Integration Plan
PNE 2030	Plano Nacional de Energia 2030/National Energy Plan 2030
PNMC	Plano Nacional sobre Mudança do Clima/Brazilian National Plan on Climate Change
PNMC	Política Nacional de Mudanças Climáticas/ National Policy on Climate Change
PR	Progress Ratio
PRODEEM	Programa para o Desenvolvimento da Energia nos Estados e Municípios/Program for Energy Development of States and Municipalities
PRODIST	Procedimentos de Distribuição de Energia Elétrica no Sistema Elétrico Nacional
PROINFA	Programa de Incentivo às Fontes Alternativas de Energia Elétrica/Incentive Program for Alternative Sources of Electric Energy
PUCRS	Pontificia Universidade Católica do Rio Grande do Sul
PV	Photovoltaic
RE	Renewable Energy
REN21	Renewable Energy Policy Network for the 21st Century
RGR	Reserva Global de Reversão/Global Reversal Reserve
RO	Federal state of Rondônia
SCE	Sistema de Compensação de Energia
SIN	Sistema Elétrico Nacional
SP	Federal state of São Paulo
SPE	Secretaria de Planejamento e Desenvolvimento Energético/Division of Energy Planning and Development
TUSD	Tarifas de Uso do Sistema de Distribuição
TUST	Tarifas de Uso do Sistema de Transmissão
UFRGS	Universidade Federal do Rio Grande do Sul
UFSC	Universidade Federal de Santa Catarina
UNCTAD	United Nations Conference on Trade and Development
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICAMP	Universidade Estadual de Campinas
USP	Universidade de São Paulo

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1. Introduction

1.1. Research topic and objectives

The research in this paper has been carried out against the central background notion that contemporary society needs to move away from the exploitation of conventional and finite energy resources, towards the use of renewable energy (RE)[1]. In recent years, developed countries like Germany and Spain have placed themselves at the forefront of this transformation by introducing successful policies for the promotion of renewables. These support policies are considered to be a driving force behind the increasing shares of renewable energy worldwide (REN21, 2011), with feed-in laws[2] being considered the most effective mechanism of promotion in terms of the induced introduction rate and technological and market development (Bechberger et al., 2003; Kissel, 2008).

Developing countries and emerging economies differ in regard to their political and economic framework and also in the structure of electricity generation as compared to Europe, but the energy sources and technologies that they choose to develop now will affect their future living conditions, and will have a global impact (Geller et al., 2004). This means that they are placed to play a key role in advancing renewable energy.

In Brazil, renewables provide nearly 50% of the primary energy supply and over 75% of the electricity generation. However, these shares are provided almost exclusively by large hydropower and biomass, with wind and solar energy playing next to no role (EPE, 2010). These two "new renewable energy sources", as Goldemberg et al. (2004) call them, could play a more important role for Brazil in a future where stronger environmental restrictions will impede building further large hydropower plants and the increasing distance between remaining possible locations for these new plants and the urban centers they are meant to supply will lead to higher costs of electricity (Rüther & Zilles, 2010).

The need for diversification of the electricity generation does not pose a problem per se. Nevertheless, the risks to the environment and the security of supply caused by large hydro can lead to a scenario in which the lack of alternative renewable energy systems negatively impacts the development of the country. Therefore, the context and the reasons for which the lack of diversification might arise as a problem will be considered carefully.

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[1] The terms renewable energy, renewables and RE will be used interchangeably throughout the paper.

[2] The terms feed-in law and feed-in tariff (FIT) will be used interchangeably throughout the paper.

This research paper seeks to explore the framework conditions for a support policy promoting renewable energy sources in Brazil. This will be carried out by means of a case study of grid-connected photovoltaics (PV). To date, the Brazilian government has not enacted such a policy. The objective of the paper is thus to analyze the conditions expected to influence its possible adoption. Therefore, the research question is: *Which are the relevant framework conditions for the introduction of a policy that promotes grid-connected photovoltaic energy in Brazil?*

The main focus of the paper is on demonstrating the existence of drivers, but, since not all conditions will be favorable, some of the barriers will also be highlighted. Various types of framework conditions will be analyzed, as well as the design options for potential support policy mechanisms.

1.2. History of the topic and methodological approach

Renewable energy support policies are the subject of an extensive body of international research. The diffusion of support policies in Europe and worldwide, with the feed-in tariff alone being in place in at least 61 countries and 26 states/provinces worldwide (REN21, 2011), has allowed for in-depth analyses from various perspectives.

A good overview of the spread of existing policies can be found in publications such as the "Global Status Report Renewables 2011" or in REN21's[3] previous reports. On the European level, the "Handbook of renewable energies in the European Union" by Danyel Reiche presents 15 case studies concerned with the support policies for renewable energy. Questions related to investment in renewable energy can be found for example in UNEP's[4] "Global Trends in Renewable Energy Investment 2011".

A number of publications are based on country case studies (Agnolucci, 2007; Foxon et al., 2005; Jacobsson & Lauber, 2006; Wüstenhagen & Bilharz, 2006). Some place their primary focus on highlighting the advantages and disadvantages of various instruments, such as feed-in tariffs versus quota systems (Menanteau et al., 2003; Ringel, 2006), while others describe the success determinants of existing renewable energy policies (Bechberger et al., 2003; Reiche & Bechberger, 2004). The literature review carried out for this paper only revealed a couple of publications concerned with the analysis of support policies in Latin American countries (Kissel et al., 2009; Costa et al., 2008) and even fewer advocating a potential policy (Rüther & Zilles,

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[3] REN21 stands for Renewable Energy Policy Network for the 21st Century.

[4] UNEP stands for United Nations Environment Programme.

2010). The innovative character of my research thus lies in detailing the drivers and barriers for adopting such a new policy in Brazil.

Regarding the methodology, for analyzing the framework for the adoption of a support policy in Brazil, the choice fell on Jänicke's environmental policy analysis model (2003), which categorizes determinants of general environmental policy into structural and situational factors. It offers a good approach for looking into framework conditions for a specific kind of policy, in this case the one for promoting renewable energy. For purposes of tangibility, the model has been merged with the external and internal framework conditions that influence the success of renewable energy according to Bechberger et al. (2003). For each of the conditions, a hypothesis was made and tested for validity. An extensive description of the framework conditions is given in Chapter 4.

In most South American countries renewable electricity generation is based on hydropower (IEA, 2009). Therefore, the risks these countries are exposed to due to insufficient diversity of generation sources are similar. This research paper thus also seeks to provide a basis for regional policymakers who are looking into changing their electricity generation structure by promoting other renewable energy sources, such as wind and photovoltaic.

In Brazil, solar energy has been successfully used for heating (solar thermal) and for supplying energy in remote, off-grid areas. The Brazilian solar thermal market comprises about 200 companies along the value chain and has an annual value of about R$500 million (US$ 278 million) (ABRAVA, 2012). Despite the relative strength of this market in comparison to the PV market, the focus of this paper is on the generation of electrical energy and not on the use of solar thermal energy for heating. Furthermore, the decision to look into grid-connected PV and exclude the systems in remote areas is justified by the existence of a well-developed Brazilian grid, which makes the integration of solar PV relevant in the context of future growth.

The paper is based on a comprehensive literature and data review. Sources of information that were used include topical books, journal articles, reports, statistics, legislation, relevant websites and newspaper and magazine articles. Furthermore, significant information was gathered through qualitative interviews with German and Brazilian experts and through informal conversations and correspondence.

1.3. Outline of the paper

This paper consists of six chapters. Following the introduction, Chapter 2 will give an overview of the theoretical approach chosen, and provide a few figures on renewable energy development in Brazil and worldwide as background information. Furthermore, the hypotheses to be tested will also be described in this chapter. Chapter 3 comprises a description of the problem setting. Chapter 4 and 5 will provide an analysis of the structural and situational framework conditions. Chapters 6 and 7 are dedicated to the description of the relevant stakeholders and the instruments they can employ. The paper concludes with a discussion of the framework conditions and their influence.

2. Theoretical approach

2.1. The extended environmental policy analysis model

The topic of this research paper is the question of which framework conditions allow for a successful introduction of a policy promoting grid-connected photovoltaic energy. This energy resource stands for all the so-called "new renewable energies" (Goldemberg et al., 2004) as opposed to traditional renewables[5], such as hydropower, which Brazil already deploys. The framework conditions refer to the contextual setting in the country, the variables of which influence the development of RE in Brazil. This chapter focuses on describing the most relevant ones, according to Jänicke's environmental policy analysis model (2003) and the classification made by Bechberger et al. (2003).

Both classifications emerged from empirical studies based mainly on European cases, so the hypotheses of this paper will have to be adapted to bear in mind the different reality of an emerging economy. Furthermore, both approaches are to be understood as a systematization of the main aspects and not as a complete inventory of all existing conditions. There is a multitude of existing framework conditions and aspects of a specific country that, due to their complexity, cannot be taken into account in the context of this research, such as its culture or customs.

The choice of the model is based on the dynamic interaction of the framework conditions with each other rather than on its dynamics over time. Therefore, its limits are set by the fact that, by lacking a time component, it is static. These limits will be compensated for in the following chapters, by including an analysis of the development of some determinants over time.

The extended environmental policy analysis model proposed as a theoretical framework is illustrated as follows:

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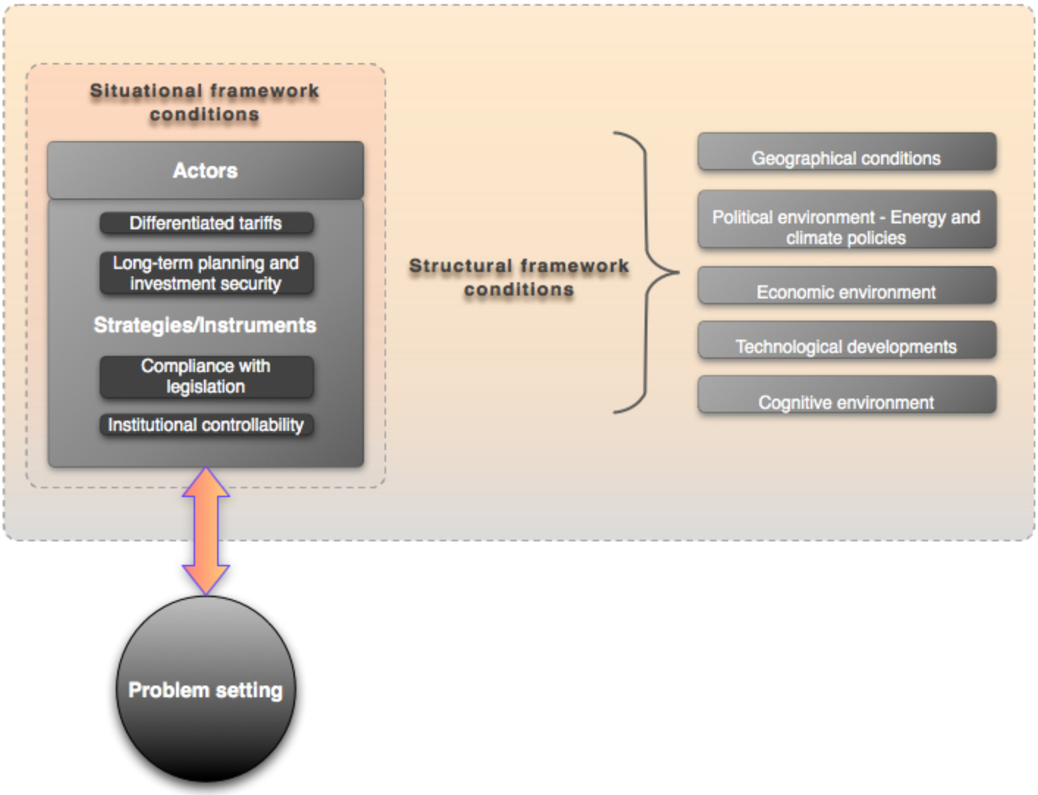
[5] The term traditional will be used in association with hydropower throughout the paper.

Figure 1 The extended environmental policy analysis model



Source: Own adaptation of Jänicke (2003) and Bechberger et al. (2003)

The central idea of the model is to be able to portray factors that influence success. A large number of articles on renewables focus on the choice of the instrument and compare different models leaving aside the framework conditions and the specific design aspects of the instrument. However, the outcome in terms of installed capacity in various European countries has shown that it is not necessarily the choice of a policy, but also the framework surrounding its introduction and existence that is responsible for success (Bechberger et al., 2003).

In order to provide a better overview the factors have been classified according to their stability over time: the situational context comprises the conditions that can change easily, while the structural context refers to the relatively stable opportunities and barriers in the political and economic structures of a country (Jänicke, 2003). Seeing that the structural context of Jänicke (2003) and the external conditions identified by Bechberger et al. (2003) overlap, the two theories have been merged to offer an in depth description of the framework conditions, with the following five structural determinants emerging: geographical conditions, energy and climate policies, economic environment, technological development and cognitive environment.

The extended model also combines the different approaches of the articles, that is Jänicke's (2003) focus on the actors as proponents or opponents of environmental issues, with their strategies playing a secondary role, as outlines for taking action, and Bechberger et al.'s (2003) focus on the general and specific design conditions of the instrument, such as differentiated tariffs or compliance with legislation. It is important to note that, given different contexts over time, the proponents and opponents are not to be associated solely with drivers or barriers. For example, the state and its institutions should not be considered as a singular and coherent actor, since relevant ministries can be both for and against the introduction of a support policy for RE (Jänicke, 2003).

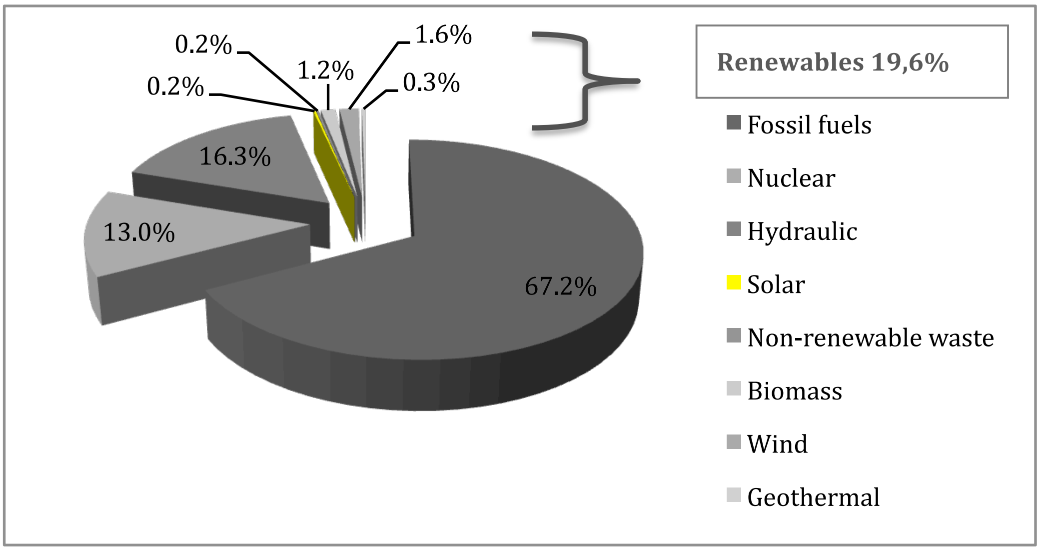
However, without the existence of a problem one would not need a policy. The setting of the problem, comprising its urgency and the available solutions, will be thus presented before the framework conditions.

Policy analyses are often employed as means of providing policy recommendations. In this case, too, the aim is to provide information for the relevant policymakers, so they can better understand the drivers and the barriers for establishing a policy for promoting grid-connected photovoltaic energy in Brazil.

2.2. The background of renewable energy development in Brazil and worldwide

According to the latest figures to be found in the “Global Status Report Renewables 2011” and the “Worldwide electricity production from renewable energy sources. Thirteenth Inventory – Edition 2011”, renewable energy continued to grow strongly in the last years. It currently supplies 16% of the global final energy consumption (REN21, 2011). As for electricity production, renewable energy currently contributes with 19.6%, as can be seen in Figure 2 (Observ’ER, 2011). The upward trend shown by RE worldwide is mainly due to the spread of support policies to more countries. By now, renewable power generation policies have been implemented in 96 countries (REN21, 2011).

Figure 2 Structure of the global electricity production in 2010

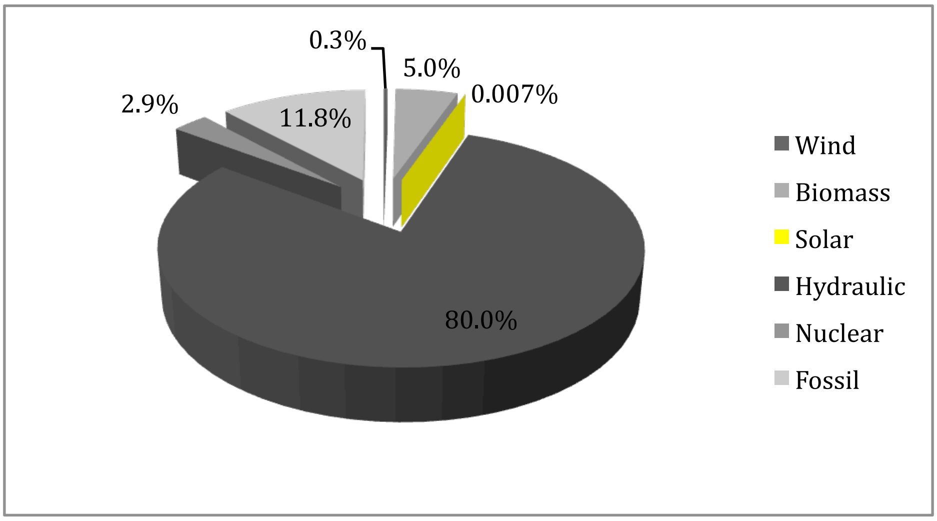


Source: Observ'ER, 2011, own representation

For industrialized nations, the reasons for adopting such policies are numerous: environmental concerns, concerns regarding the security of supply, the potential to create new industries and green jobs and many others. However, developing countries, which now represent more than half of the countries in the world with existing RE support policies (REN21, 2011), show different structural and economic conditions, which in turn lead to different political agendas for the deployment of renewable energy (Kissel et al., 2009).

The electricity generation in Brazil is already based on a renewable energy resource, i.e. hydropower, as can be seen in Figure 3, and it has been so for decades. Brazil is currently using 41.6% a year of its total economically exploitable hydroelectric capacity (Jannuzzi et al., 2010). The problem is that the remainder of this potential is mainly located in the environmentally sensitive Amazon region (Pereira Jr. et al., 2010; Salamoni, 2009). This makes future exploitation difficult, due to increasing environmental restrictions and the increased cost for the electricity coming from these new power plants. Besides, seeing that the electricity consumption in Brazil is forecasted to grow more than 3% a year until 2030 (Pereira Jr. et al., 2010), the diversification of the electricity supply appears as an appropriate solution.

Figure 3 Structure of the Brazilian electricity production in 2010



Source: Observ'ER, 2011

In this context, the promotion of new renewable energies, like wind and photovoltaic, can offer an attractive alternative to shape the electricity generation system (Rüther & Zilles, 2010). Besides, when it comes to integrating fluctuating energy sources, the existence of a large hydroelectric power supply is an advantage due to the complementarities in generation and regulation of power supply (Kissel et al., 2009).

To date, Brazil has a legal and regulatory framework for the promotion of some of the new renewable energy sources (Jannuzzi et al., 2010). Through the PROINFA[6] legislation, Brazil introduced a feed-in law to promote wind energy, small hydropower and biomass. In addition, these renewables have been addressed by public competitive bidding, a tendering system by which contracts to construct and operate specific projects or fixed quantities of RE capacity are awarded. Other sources, such as grid-connected PV, have not yet found the necessary political support, despite the existence of an inter-ministerial institutional effort that is underway to promote them (Jannuzzi et al., 2009).

Hence, photovoltaic energy is used in Brazil primarily in areas without access to the electric grid. Many of the existing systems have been installed through two programs which had as objective the expansion of rural electrification: PRODEEM[7], which came into existence in 1994 and ended in 2002, and "Luz para Todos" (LPT)[8]. The latter, established by Decree no. 4873/2003, and

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[6] PROINFA stands for O Programa de Incentivo às Fontes Alternativas de Energia Elétrica/Incentive Program for Alternative Sources of Electric Energy.

[7] PRODEEM stands for Programa para o Desenvolvimento da Energia nos Estados e Municípios/Program for Energy Development of States and Municipalities.

[8] LPT stands for Programa Nacional de Universalização do Acesso e Uso da Energia Elétrica Luz para Todos/National Program for Universal Access and Use of Electric Power.

amended by Decree no. 7656/2011, was even extended, to finish in 2014. It has provided electricity to more than 14.5 million people and has prioritized the use of PV energy for isolated systems (Jannuzzi et al., 2009; MME, 2011).

As regards grid-connected PV, their development started with research systems installed by universities, the same universities that are today's Brazilian excellence centers for PV. From 1995 to 2009, 38 systems with a total capacity of 174 kW were installed or expanded (América do Sol, 2011). In recent years, some of these systems were taken out of operation, but new and bigger projects were added (see Table 1).

Table 1 Grid-connected PV power plants in Brazil (Status as of March 2012)

Number	**Name of plant/Owner (Federal state)**	**Authorized capacity (in kW)**	**Installed capacity (in kW)**
1	Araras – RO/Fundação de Amparo à Pesquisa e Extensão Universitária (RO)	20.48	20.48
2	Tauá/MPX Tauá Energia Solar Ltda. (CE)	5000	1000
3	IEE/Instituto de Eletrotécnica e Energia (SP)	12.26	12.26
4	UFV IEE Car park/Instituto de Eletrotécnica e Energia (SP)	3	3
5	Italian Embassy in Brasília/Embaixada Italiana em Brasília (DF)	50	50
6	PV Beta Test Site/DuPont do Brasil S.A (SP)	1.70	1.70
7	Pituaçu Solar/Superintendência dos Desportos do Estado da Bahia (BA)	404.80	404.80
8	Aeroporto Campo de Marte/Empresa Brasileira de Infra-Estrutura Aeroportuária (SP)	2.12	2.12
	Total grid-connected PV		**1,494.36**

Source: ANEEL, 2012a, own representation

2.3. Determinants of a policy for grid-connected PV in Brazil

This paper assumes that the promotion of grid-connected PV in Brazil should be stimulated. The best way to do this is by introducing a support policy. After careful review of the literature[9] and of the expert contributions, the most suitable instrument appears to take the form of a regulatory price-based instrument. In the short-term, a net metering mechanism will be implemented, while for a long-term development of PV a FIT is being considered. The framework conditions influencing the introduction of these policies fall under one of the two categories – drivers or barriers. In this chapter both will be described, in general terms, together with their intended operationalization, after which hypotheses will be formulated as to how they influence the introduction of a support policy.

Structural framework conditions:

Geographic conditions: The geographic conditions of a country determine the availability of the existing resources – both of the one to be tapped and of other resources, as well as the competition among them. Regarding the availability of solar energy, the important factors to be considered are solar radiation and its characteristics (Bechberger et al., 2003). Regarding competition, the availability of alternative energy resources, in Brazils case strong winds, recently discovered oil deposits and a large hydropower potential, and the degree of their exploitation, influences the pressure to import energy and also the need to diversify the energy generation to include solar energy.

The geographic conditions as a determinant will be operationalized through the availability of the renewable resource, the availability of other resources and the extent to which they are used, as well as through the dependence on energy imports.

It is hypothesized that the geographic conditions contribute to the demand of photovoltaic energy and its future development in regard to the other available resources. If the renewable resource is not sufficiently available or if the country commands vast reserves of other energy resources and competition among them is strong, then photovoltaic energy will be less politically relevant.

Political environment – Energy and climate policies: The existence of overall energy and climate policies, the way they are formulated and their implementation are prominent political factors that influence the adoption of a support policy for photovoltaic energy (Bechberger et al., 2003). Furthermore, the existence of specific renewable energy goals is of significant importance: In association with the renewable energetic potential of a country, these can influence the priority

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[9] Kissel et al., 2009; Kissel, 2008; Rüther & Zilles, 2010, Salamoni, 2009

given to renewable energies, while their clear and continuous operationalization potentially influences the success of existing or further support policies. Regarding their formulation, the definition of what is considered to be renewable energies plays a central role in the Brazilian case, since the electricity generation system is already based on a renewable resource, i.e. hydropower.

The political determinant as a determinant will be operationalized through the existence of overall energy and climate policies and the existence and formulation of specific renewable energy goals.

It is hypothesized that the existence of overall political climate goals and specific goals for renewable energies facilitates the introduction of a support policy for photovoltaic energy. If the country has a strong climate policy and goals for renewable energies are set in the energy policy, then renewables have a high priority and better chances to develop.

Economic environment: Several economic factors can influence the introduction of a support policy for PV: the structure of the energy industry, the energy consumption, the investment capacity, the existing energy infrastructure, such as the size and reach of the power grid, or the stage of Brazil's economic development, given by its GDP per capita. But possibly the most significant factor are the energy costs of other energy sources, which directly influence the competitive context in which renewables develop (Laumanns, 2005). The conventional energy sources often profit from hidden subsidies and from negative externalities that are not factored into the price, and thus limit the competitive chances of renewables.

The economic environment as a determinant will be operationalized through the existence of a competitive context.

It is hypothesized that favorable economic conditions are necessary for the development of photovoltaic energy in Brazil. Because of the "unfair" competitive environment created by distorted cost structures of traditional energy sources, this new renewable source has to be supported in order to enter the market.

Technological developments: The technological development of a renewable source is usually the factor limiting the introduction of a policy supporting it. This limitation is due to the stage of development and the high costs of the technology as compared to conventional ones (Bechberger et al., 2003). In the absence of a local manufacturing industry, the necessary technology has to be imported, which leads to even higher costs than the global average. Furthermore, renewables are fluctuating sources, so they require a development of the electricity network (both transmission and distribution lines), which in turn incurs costs.

Nevertheless, the costs of the technology can be lowered by constantly increasing its deployment (learning curve).

The technological development as a determinant will be operationalized through the existence of manufacturing capacities for grid-connected PV in Brazil and the favorable learning curve of photovoltaic energy as compared to other energy sources.

It is hypothesized that the learning curve and the existence of national manufacturing capacities influence the introduction of a support policy for a renewable energy source. A steep learning curve represents a significant decrease in manufacturing costs, which makes the technology attractive in the future. Having a national manufacturing industry that invests in research and development influences the competitiveness of the national components, thus also lowering costs and generating positive effects in other sectors of the economy.

<u>Cognitive environment:</u> The two main factors identified in the literature in regard to the cognitive environment are the availability of information about the renewable source and its approval among policymakers and the public (Bechberger et al., 2003). The first is determined by the existence of knowledge centers, which possess and spread the information, while the latter is mostly formed through an open debate and is influenced by the socio-economic reality of the country and the educational system (Laumanns, 2005). It is worth mentioning that the media plays an important role in creating and fostering this open debate, because of its reach and the capacity to educate the public.

The cognitive environment as a determinant will be operationalized through the existence of knowledge centers and the perception of grid-connected PV in the media.

It is hypothesized that a favorable and well-developed cognitive environment facilitates a more rapid introduction of a policy for the development of the renewable energy source. Both the availability of information and the acceptance of the topic contribute to prioritizing the introduction of a policy for photovoltaic energy.

<u>Situational framework conditions:</u>

The situational framework refers to the short-term variable chances or barriers that result from structure-changing events, such as a new government with a different agenda, media events that spark a public debate or a change in environmental regulations in important foreign markets (Jänicke, 2003). These changes determine the opening of so-called "policy windows", which are singular, passing periods of time when there is a greater likelihood of initiating policy change than usual (Michaels et al., 2006).

The situational context as a determinant will be operationalized through the existence of local and global events related to energy policy in a broad sense, which could influence the introduction of a support policy for grid-connected PV in Brazil.

It is hypothesized that the existence of structure-changing events per se is not sufficient for a successful placement of the issue on the political agenda. Rather the approach and actions of the actors are responsible for turning these events into chances for developing the renewable source.

Actors:

Energy policy can be influenced by a number of actors, such as political parties, state institutions, media, industry associations, research institutes or environmental groups. They can exert their influence from bringing an issue onto the political agenda to formulating a draft policy and changing the way it is implemented, i.e. in all phases of a policy cycle. These actors are determined both by their number, competence and organizational strength, and by the way they are configured. One of the main actors is the state with its relevant bodies, such as ministries and agencies. Nevertheless, the state as a singular actor in energy policy is a myth (Jänicke, 2003), since conflicting interests in different areas, such as environment and industry, have to be integrated to coexist. Furthermore, the relevant competencies are often divided among ministries and agencies, which follow their own agenda, sometimes in close co-operation with the private industry.

The actors as a determinant will be operationalized through the configurations of state and non-state actors, as well as the actors' relevance for the introduction of a policy.

It is hypothesized that the actors or the configurations of actors that are involved with the introduction of a support policy for grid-connected PV influence its chances to succeed. The effectiveness and efficiency of a support policy will likely be minimal, if it is introduced by the state institutions interested in the further development of traditional resources, or if these institutions co-operate closely with anti-renewable lobby groups.

Strategies and instruments:

The drive to support the development of a renewable energy source can be influenced by the choice and design of the instrument. There are various support policies for renewables – quota systems, public bidding, grants, tax rebates, but price mechanisms, such as net metering and feed-in tariffs, which are in place in many countries, are seen to be the preferred instruments for Brazil (Rüther & Zilles, 2010; ANEEL, 2011a). The selection of the instrument determines the way in which the goals will be achieved, while the design of the instrument determines the success of the policy. Bechberger et al. (2003) have identified a series of general aspects, which are essential for any instrument: differentiated tariffs, long-term planning and investment security, compliance with legislation and institutional controllability. Nevertheless, in Brazil's case, these aspects will have to be supplemented by country-specific ones.

The strategies and instruments as a determinant will be operationalized through the existence and design (general and specific aspects) of a support policy.

It is hypothesized that the design of the instrument is one of the most important determinants for introducing a support policy for grid-connected PV. A well-designed policy will achieve the goals, be cost-efficient, overcome the existing opposition and even gain public support. If the design is poor, the opposition will be strong and hinder the introduction.

3. Problem setting

A variety of environmental problems affect our world and our lives on a daily basis. Many have received a lot of attention from the public and have so entered our collective consciousness, such as the greenhouse effect, acid rain or air pollution. Looking beyond these problems to the broader context, one observes the high degree to which they are connected with our current energy supply systems, which are mainly based on conventional energy sources like coal, oil and gas, and whose negative consequences will be both serious and long lasting.

The Brazilian case, even if at first sight different, reflects elements of the above-mentioned context. Due to an abundant hydrological resource and decades of development of energy infrastructure, Brazil has an impressive hydroelectric capacity – 80% of total electricity supply (see Figure 3). Nevertheless, this generation structure can prove to be a problem: On one hand, the remainder of this potential is located in the Amazon region (Pereira Jr. et al., 2010; Salamoni, 2009), where its exploitation implies a multitude of social and environmental impacts, among them greenhouse gas emissions (Fearnside, 2004). On the other hand, the dependence on only one resource can lead to unforeseen energy shortages, like in 2001, when a combination between droughts, rising electricity demand and a long-term lack of investment in power generation caused Brazil to ration its energy in order to avoid power outages (Winrock, 2002). The diversification of the power supply to include new renewables, such as wind energy and grid-connected PV, would counteract some of the negative consequences of the current system. This means that for the purpose of this paper the lack of exploring alternatives, i.e. the lack of grid-connected PV, can be considered a problem.

According to Jänicke (2003), the success of environmental policy can be assessed only with regard to the structure of the problem to be solved. The structure refers to the urgency of a problem and whether possible solutions exist. Furthermore, it's not the scientific dimension or nature of the problem that determine this structure, but its social and political dimension. The first issue, of urgency, is about the manner and form in which the problem is recognized or whether it is recognized at all (Howlett & Ramesh, 2003). This politicization, as Jänicke (2003) calls it, is one of the three characteristics of the political dimension of a problem and determines the means with which the problem will be addressed by policymakers in the future. In Brazil, the lack of grid-connected PV has not been perceived as an urgent problem. The National Energy Plan (PNE) 2030[10], drawn up by the Brazilian Ministry of Mines and Energy (MME)[11], does not

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[10] PNE stands for Plano Nacional de Energia 2030.

consider, even marginally, the use of photovoltaic energy for satisfying the energy demand during the horizon of the study (Jannuzzi et al., 2009).

Another characteristic used by Jänicke (2003) to describe the political dimension are the actors, determined by means of number and strength. In Brazil, due to the fact that energy generation is not mainly based on fossil fuels, the solar energy lobby did not exist either, until the creation of a dedicated group within the ABINEE[12] at the beginning of 2011, which has yet to prove its efficacy. As opposed to this, the traditional industry's lobby is relatively strong and closely connected to the state institutions (M. Baitz, personal communication, February 23, 2012).

The third and last characteristic referred to by Jänicke (2003) are the available options to solve the problem. Seeing that the problem is the lack of grid-connected PV in Brazil, the options at hand include both technological and political options, which are in turn connected to each other. Regarding the first option, the photovoltaic energy has seen an impressive development over the last years, which in turn has influenced the cost of its deployment. Considered a very expensive technology, the worldwide diffusion of the technology has helped lower the costs – in the last 5 years alone system prices in Europe have decreased by 50% (EPIA, 2011a), and projections of further decreases are in sight. This means that in the near future PV could be considered an appropriate and cost-effective technological solution for both developed and developing countries, such as Brazil. Regarding the political options, international experience has shown that public policy is responsible for the significant development of PV and the cost decreases associated with it (Jannuzzi et al., 2009). Governments play a fundamental role in establishing market conditions and they do so mainly by pointed and well-conceived legislation (Mallon, 2006). Considering this fact, the Brazilian government could introduce a support policy with the goal of increasing the use of grid-connected solar energy, adapted to the Brazilian situation, which would in turn make use of the available technological solutions.

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[11] MME stands for Ministério de Minas e Energia.

[12] ABINEE stands for Associação Brasileira da Indústria Elétrica e Eletrônica/Brazilian Association of Power Sector Equipment.

4. Structural context

4.1. Geographic conditions

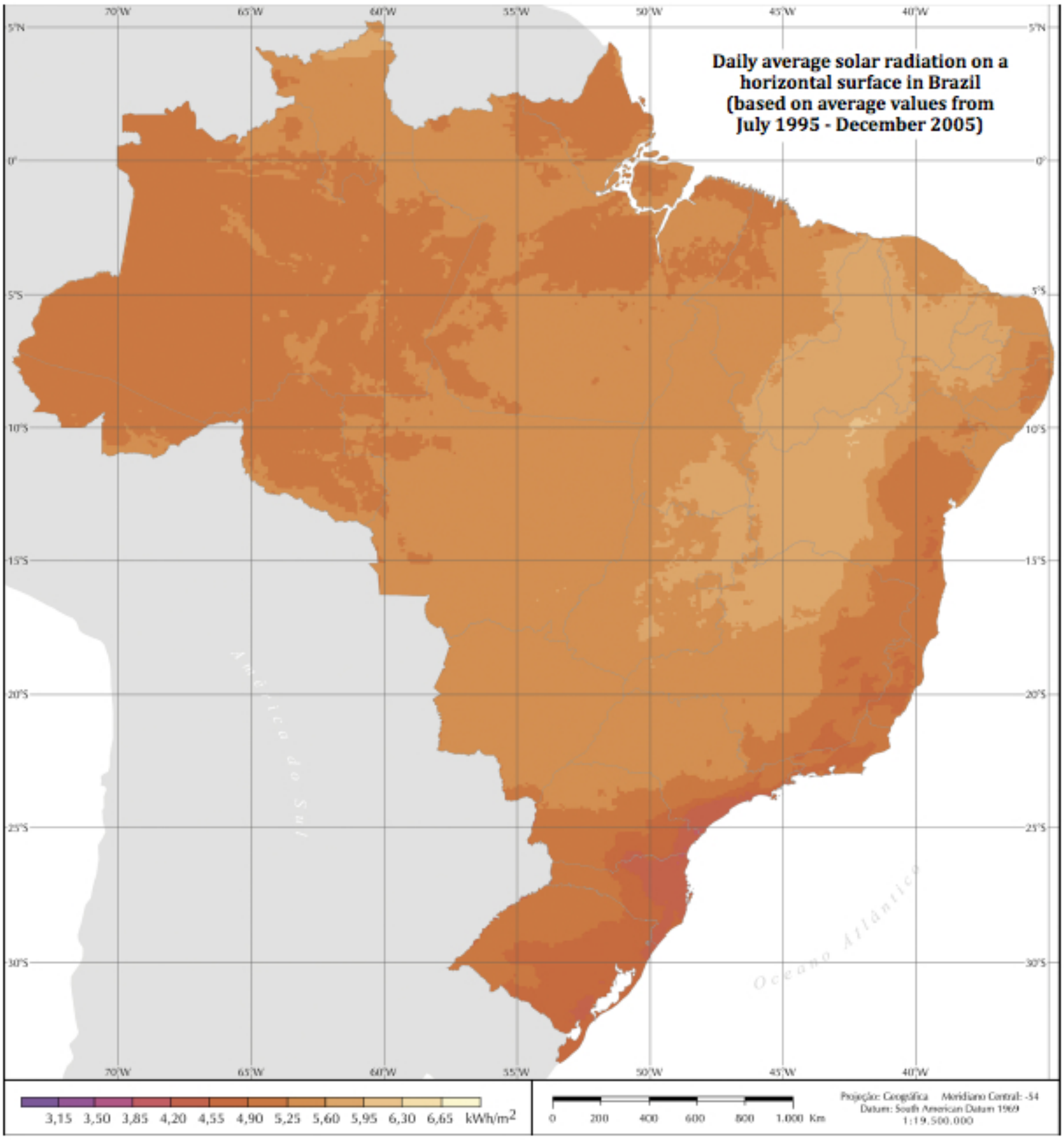
Brazil is the fifth largest country in the world in terms of both area (8,514,877 sq km) and population (205,716,890 inhabitants), with 87% of its population living in cities (CIA, 2012). The Brazilian economy is the eighth largest in the world, with an annual GDP growth rate in recent years of 3% - 6%, excluding the year 2009, when the GDP plummeted due to the global financial crisis (World Bank, 2012). Electricity consumption has also been growing, to reach 455.7 TWh in 2010, which means a growth of 7.8% as compared to the previous year. This demand was mainly satisfied by an increase in domestic electricity generation, which reached 502.9 TWh in 2010 – a 10% increase compared to 2009. The net imports dropped accordingly, from 7.9% in 2009 to 6.4% in 2010 (EPE, 2011).

Nevertheless, electricity consumption in Brazil is expected to rise sharply in coming years. According to BMI (2011), the electricity consumption is expected to increase from an estimated 459.63 TWh in 2010 to 766.32 TWh in 2020. Therefore, without an adequate increase in power capacity, the current power margin between capacity and demand will continue at its current low rate or even decline.

The renewable energy share in the Brazilian electricity market is high. Large hydropower has the highest share (about 80% in 2010), having registered an increase of 3.7% in 2010 as compared to the previous year (EPE, 2011). The potential for a further increase is present, since Brazil is only using 41.6% of its economically exploitable capacity of 811 TWh/year (Jannuzzi et al., 2009). Nevertheless, there are reasons that speak against a further expansion of hydropower capacity. On one hand, the remainder of the potential is mainly located in the Amazon region, which is environmentally sensitive (Pereira Jr. et al., 2010). On the other hand, the distance of the potential new plants from the main urban centers where the energy is consumed will result in high investments in transmission and distribution lines and hence in higher electricity prices (Salamoni, 2009). Furthermore, climate change projections tend to show a decrease in the total amount of rainfall and number of wet days in South America by 2030 (FBDS, n.d.). This might lead to crises in electrical power supply like the one Brazil experienced in 2001. Back then, the insufficient extension of the capacity of the power plants, combined with rainfall below average resulted in a power shortage that could only be solved by a rationing plan, with consequences for both the industry and the consumers. Further expansion of the already dominant hydropower source is thus questionable from a viewpoint of managing the risks of climate change.

In order to be able to avoid such crises, Brazil could make use of its solar potential, which is significant. According to the Brazilian Atlas of Solar Energy from 2006, the daily average solar radiation on a horizontal surface reaches from 3.0 to 6.5 kWh/m²/day, with a maximum value of 6.5 kWh/m²/day in the North of the state of Bahia and a minimum value of 4.25 kWh/m²/day in the state of Santa Catarina (see Figure 4). In comparison, the same values for the country with the highest penetration of PV, Germany, reach from 900 kWh/m²/year to 1,200 kWh/m²/year, which would result in daily values of 2.4 kWH/m²/day to 3.3 kWh/m²/day (DWD, 2011).

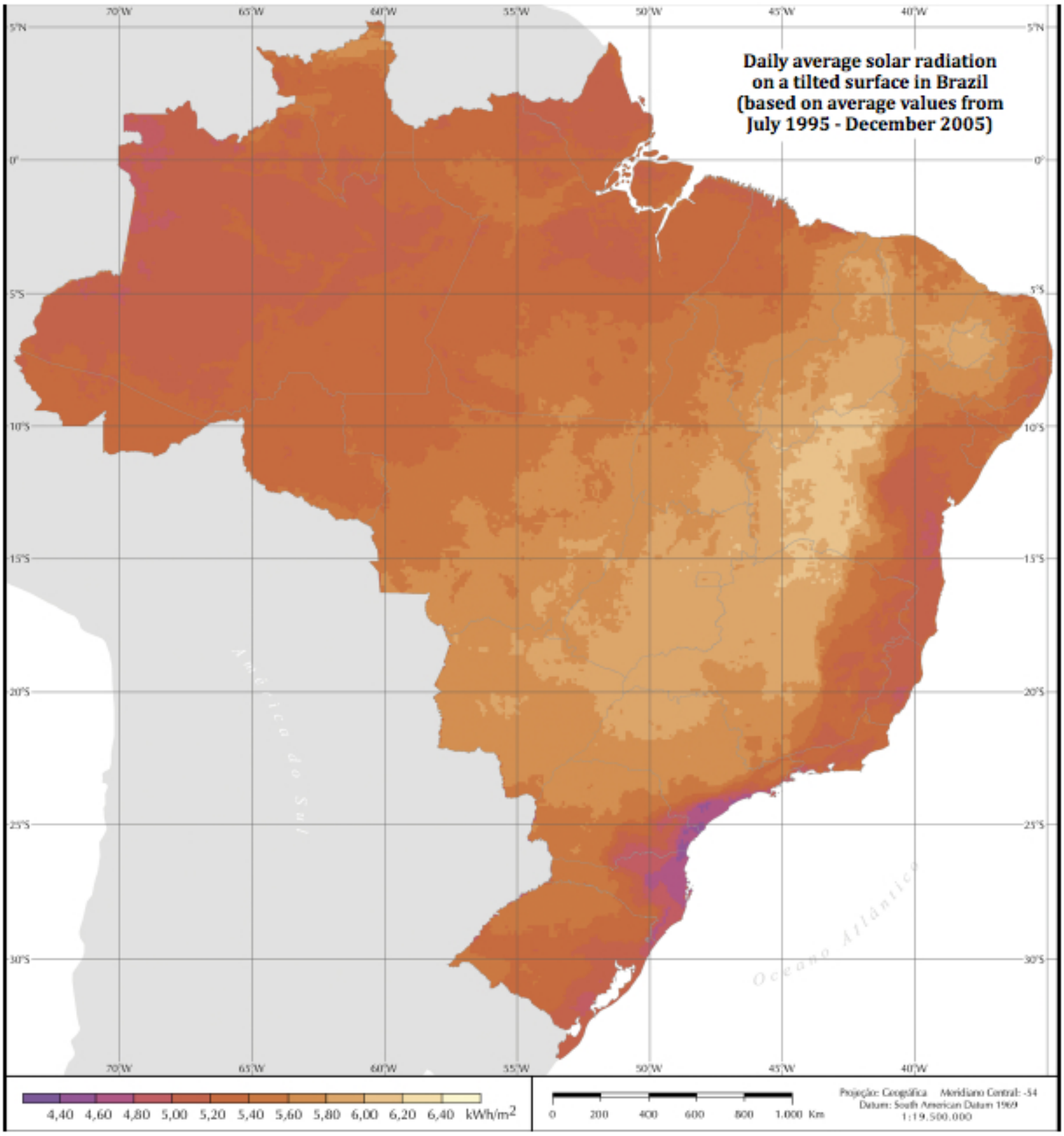
Figure 4 Daily average solar radiation on a horizontal surface in Brazil



Source: Pereira et al., 2006

Moreover, PV power plants are normally tilted to the sun to obtain the maximum yield. The Brazilian values are also optimal in this regard (see Figure 5).

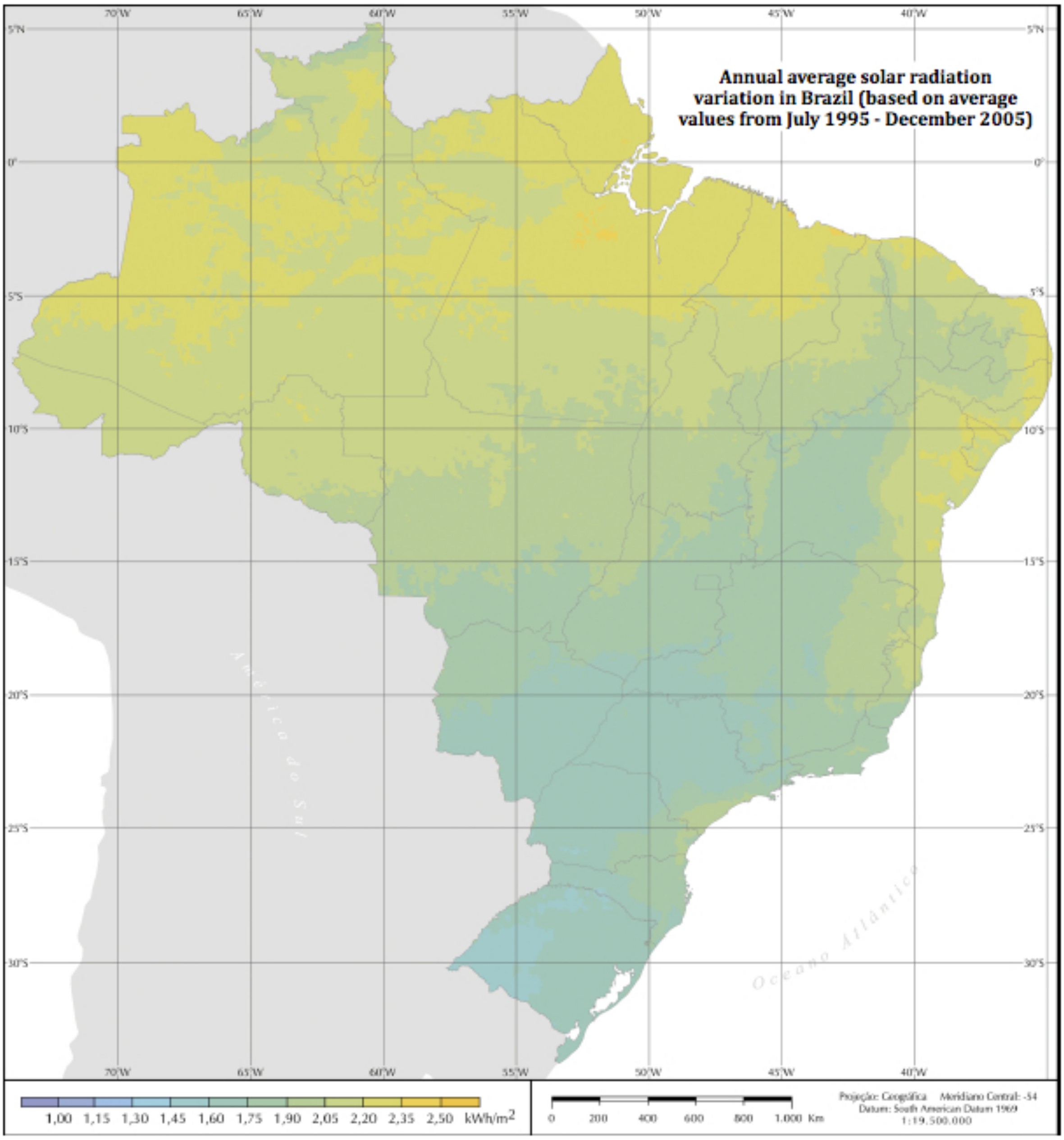
Figure 5 Daily average solar radiation on a tilted surface in Brazil



Source: Pereira et al., 2006

In addition, the annual variation of the solar radiation is minimal, which points to a continuous and stable electricity generation (see Figure 6). Locations in North and Central Brazil are most suitable for the installation of PV panels. Being close to the Equator, they show the least variation in the country.

Figure 6 Annual average solar radiation in Brazil



Source: Pereira et al., 2006

As opposed to the situation encountered in most European countries, PV is a perfect fit in sunny urban areas all throughout the developing world (Rüther & Zilles, 2010). Because of the coincidence of solar radiation with the demand curve, PV as decentralized generation can be a solution for commercial or industrial sectors with high midday demand or for urban areas, where the capacity of the network cannot be expanded to accommodate an increasing demand without causing high costs for network development (Salamoni, 2009). Furthermore, not only do solar radiation and daily demand curve coincide, but solar radiation also varies in accordance with the yearly peak load values. The bigger the peak load values in the summer in comparison to those in the wintertime, the more likely it is that they match the actual solar resource. Today, this is the typical picture of most capital cities in Brazil and experts assume that in the future this correspondence will only become more significant, mostly due to the increase in the use of air-conditioning caused by improved economic conditions (Rüther & Zilles, 2010).

Rapid development of PV energy could still be considered problematic for the stability of the network, as is currently the case in Germany. However, this risk is likely to be offset in Brazil by different starting conditions than those in most industrialized countries, whose electricity generation is mainly based on fossil fuels: The strong role of hydroelectricity in the Brazilian power sector is an advantage when integrating fluctuating renewable energy resources, due to complementarities in generation and regulation of power supply (Kissel et al., 2009; J. Kissel & D. Aßmann, personal communication, February 11, 2012).

As for other resources, Brazil is well endowed: With a deepwater oil field estimated to hold five to eight billion barrels of light crude oil, which was discovered in 2007 (The New York Times, 2008), it does not lack alternatives to hydropower. Nevertheless, since the technical and environmental challenges associated with extracting deepwater oil are big, and a project on such a scale has never been tried before, the first commercial quantities are not expected before 2015 (The New York Times, 2008). Furthermore, even if large hydropower is not sustainable, it is still renewable, so substituting it with a conventional resource would only mean a step backwards. Rather the use of other renewable resources, such as wind, are to be considered an alternative: With wind speeds from 4.8 to 7.5 m/s and a share of only 0.3% in the Brazilian energy mix, this resource still disposes of vast untapped potential.

There is though another important factor that speaks for the use of photovoltaic in Brazil: the existence of vast reserves of silicon, which is the raw material used for manufacturing solar panels. At current, Brazil is exporting metallurgical-grade silicon, which has a low added value. The existence of a PV industry in the country would stimulate the production of high-purity silicon (E.T. Serra, personal communication, February 23, 2012). The higher degree of purity would in turn increase the export added value by seven to ten times (MME, 2009). And even without the monetary gain due to exports of higher value, the abundance of the raw material locally could make the Brazilian PV industry competitive on the world market.

Conclusion: The hypothesis according to which the geographic conditions contribute to the demand of photovoltaic energy and its future development in regard to the other available resources has been validated. Brazil possesses a number of different resources, among which hydropower figures as one of the best developed and with a huge untapped potential. Since the dependence on imports is low, the competition between PV energy and other domestic resources is big. There is nevertheless a pressure in the long-term on developing this renewable resource, both from an environmental and from an economic point of view. On the environmental side, the risk of electricity shortages could increase due to changes in precipitation. Furthermore, the remainder of hydropower potential could become subject to stricter environmental restrictions and therefore not be exploited fully, so a diversification in electricity generation might be required. On the economic side, the existence of silicon reserves, which are currently exported as cheap raw material provides an important incentive for the creation of a local PV industry to stimulate the production of higher-quality silicon and boost exports, and to produce cheap and competitive solar panels.

4.2. Political environment – Energy and climate policies

One of the essential questions in regard to the energy and climate policies is what sources are considered to be "renewable energy". The International Energy Agency (IEA) (2003) sets down the following broad definition: *"Renewable Energy is energy that is derived from natural processes that are replenished constantly. In its various forms, it derives directly or indirectly from the sun, or from heat generated deep within the earth. Included in the definition is energy generated from solar, wind, biomass, geothermal, hydropower and ocean resources, and bio-fuels and hydrogen derived from renewable resources."* However, another term has emerged in recent years, i.e. "new renewable energy". This has occurred for several reasons: First, it identifies the latest wave of renewable technologies and second, it excludes technologies such as large hydroelectric dams, which have major local and environmental impacts and which can also cause significant CO_2 emissions (Mallon, 2006).

Even if Brazil does not have a definition for renewable energy in its legislative framework, it considers large hydropower as being a renewable and sustainable energy source, as most interviewed experts confirmed. This conviction, that Brazils energy mix is sustainable, has been identified as one of the main reasons for lacking the pressure needed to introduce a support policy for PV energy.

Regarding the importance of "new renewables" in Brazil, they have seen an unprecedented boost since the end of last decade. Brazil is signatory to the United Nations Framework Convention on Climate Change (UNFCCC) and to the Kyoto Protocol, but because it is a non-Annex 1 country under the Kyoto Protocol, it has no emission reduction goals to achieve. Even so, on November 25, 2009, two weeks before the COP 15[13] in Copenhagen, the Brazilian administration introduced the National Policy on Climate Change (PNMC)[14] and the National Climate Change Fund (FNMC)[15]. The PNMC, instituted by Law no. 12.187/2009, introduced a non-binding emission reduction target for Brazil of 36.1%- 38.9% until 2020 and comprised programs in the following sectors: forestry, agriculture, energy efficiency, biofuels and hydroelectricity (Australian Government, 2010). The policy was modified in 2010 by Decree no. 7.390/2010 to include, along with the development of hydroelectricity, the development of other renewable sources, such as wind parks, small hydropower plants and electricity from

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[13] COP15 stands for the 15th Conference of the Parties to the UNFCCC.

[14] PNMC stands for Política Nacional de Mudanças Climáticas.

[15] FNMC stands for Fundo Nacional sobre Mudança do Clima.

biomass. Furthermore, the Brazilian National Plan on Climate Change (PNMC)[16] from 2008, established by Decree no. 6.263/2007, reasserts the importance of "new renewable energy" in its chapter on energy.

Nevertheless, Brazil's climate policies are too recent to have had any significant influence on the development of new renewable energy. Furthermore, their goals will probably be reassessed once the global community decides on a follow-on agreement of the Kyoto Protocol. This might happen soon, at the Rio+20[17] conference, which will take place in Rio de Janeiro in 2012.

Just like the climate policy, the Brazilian energy policy is a competence of the federal government (Xavier & Lanzillo, 2009). The National Energy Policy Council (CNPE)[18] defines the energy policy guidelines according to the National Energy Policy Law[19] (both the existence of the council and the policy are laid down in Law no. 9.478/1997 and Decree no. 3.520/2000). The energy policy law comprises 18 goals, of which number VIII – the use of alternative[20] sources of energy – and number XVII – development of R&D in the area of renewable energy – include a direct mention of renewable energy. There is no specific goal for solar energy to be found in this document.

The MME is the institution responsible for the implementation of energy policies, its areas of responsibility being laid down in the Law no. 10.683/2003. The Empresa de Pesquisa Energética (EPE), a government-owned research entity, delivers the basis of information for the ministry's decisions. The EPE elaborates two of the most important documents in the Brazilian energy policy – the Decennial Plan for Energy Expansion (PDE)[21], which was first published in 2006 and has been yearly revised since then, and the long-term plan PNE 2030 which was published in 2007. These plans embody extensive analyses of the Brazilian energy sector according to different scenarios and thereby have more the character of a prognosis than that of a plan. The latest and still valid decennial plan is the PDE 2020 from 2010, the PDE 2021 pending publication in 2012. This plan foresees an increase in total installed capacity of 56%, from 109,578 MW to 171,138 MW (MME/EPE, 2011). A central role in this increase will be played by hydroelectricity, for which an increase from 83 GW to 115 GW is foreseen, and by alternative

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[16] PNMC stands for Plano Nacional sobre Mudança do Clima.

[17] Rio+20 is the name of the 2012 United Nations Conference on Sustainable Development (UNCSD).

[18] CNPE stands for Conselho Nacional de Política Energética.

[19] Política Energética Nacional

[20] The term alternative energy sources is used in Brazil when referring to the „new renewables".

[21] PDE stands for Plano Decenal de Expansão de Energia.

energy sources, such as wind, small hydropower and biomass, which are said to double their share in electricity generation, from 8% in December 2010 to 16% in December 2020. Nevertheless, solar energy is not mentioned at all in this study.

Comparing the forecasts of the PDE 2020 with the ones of its predecessor, one can note a certain degree of success in the development of renewable energy, especially that of wind energy (see Table 2), which could in turn be the consequence of a successful support policy.

Table 2 Comparison between the forecasts of PDE 2020 and PDE 2019[22] for alternative energy sources

Energy source	Forecast for 2019 in MW (PDE 2019)	Forecast for 2020 in MW (PDE 2020)
Wind	6,041	11,532
Small hydropower	6,966	6,447
Biomass	8,521	9,163
Total alternative sources	**21,528**	**27,142**

Source: MME/EPE, 2010; MME/EPE, 2011, own representation

Looking at even older forecasts, the ones found in the PNE 2030, the first long-term plan for the Brazilian energy sector, it becomes clear that the renewables have only recently come into their own. The reference scenario of this plan considered the building of an additional 88,000 MW in hydroelectric power plants between 2005 and 2030, but only 4,600 MW in new wind parks – a figure that is far below the more recently forecasted 11,532 MW in 2020. This fact, together with the complete exclusion of PV electricity generation from the study, is an indication of a certain degree of opposition in the politics to the support of renewable energy (Salamoni, 2009). So even if wind, small hydro and biomass have progressed rapidly, the road to a significant role in the energy sector planning is still long for photovoltaic.

The transition of the energy sector from large hydropower to new renewables cannot occur on its own. Pointed and well-conceived intervention is required from the government, since laws have the power to boost the development of renewables by establishing favourable market conditions (Mallon, 2006; Salamoni, 2009). This was the case with the aforementioned energy sources. Through PROINFA, the Brazilian feed-in law for wind, small hydro and biomass, the government managed to spur renewable energy development. The program was instituted in 2002 by Law no. 10.438/2002 and was divided into two phases, of which the last one ended at the beginning of 2012. Wind projects awarded through the PROINFA program account for over

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[22] PDE 2019 stands for Plano Decenal de Expansão de Energia/Decennial Plan for Energy Expansion 2019.

95% of the 1,471.20 kW wind power capacity currently connected to the grid (ANEEL, 2012a; GWEC, n.d.).

With respect to the support of grid-connected PV energy, Brazil hasn't yet introduced a policy. Apart from R&D projects, PV has been regarded as a solution for rural electrification, water pumping and public lighting in areas that are not covered by the Brazilian transmission network (SIN)[23]. Through PRODEEM, the program for rural energetic development, ca. 8,700 PV systems with a capacity of 5.2 MW_p were installed between 1996 and 2002 (Jannuzzi et al., 2009). In 2003, the program was integrated in the LPT program, which, since 2003, has brought electric power to more than 2.9 million families in rural Brazil (MME, 2012a).

The reason for not having a legislative framework for grid-connected PV does not lie in lack of parliamentary activity: Currently, there are a number of draft laws, which seek to support other renewable energy sources, including micro hydropower plants, tidal, solar, and geothermic projects, and which are waiting for political action (Salamoni, 2009). Some of those that relate to solar energy are presented in Table 3.

Table 3 Draft laws related to grid-connected PV energy in Brazil

Name of draft law	Description	Topic
Projeto de Lei no. 3.097/2012	Permite a dedução de despesas com aquisição de bens e serviços necessários para a utilização de energia solar ou eólica da base de cálculo do imposto de renda das pessoas físicas e jurídicas e da contribuição social sobre o lucro.	Proposes tax rebates for the acquisition of goods and services related to the use of solar energy.
Projeto de Lei no. 2.952/2011	Institui o Programa de Incentivo ao Aproveitamento da Energia Solar - Prosolar e dá outras providências.	Establishes a support program for solar energy.
Projeto de Lei no. 2562/2011	Dispõe sobre incentivos fiscais à utilização da energia solar em residências e empreendimentos.	Establishes financial support for the use of solar energy in buildings.
Projeto de Lei no. 1859/2011	Dispõe sobre incentivos à utilização da energia solar e dá nova redação ao art. 82 da Lei nº 11.977, de 7 de julho de	Proposes a support mechanism for solar energy.

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[23] SIN stands for Sistema Interligado Nacional/National Interconnected System.

	2009.	
Projeto de Lei no. 2.737/2008	Estabelece incentivos à geração de energia a partir de fonte solar.	Establishes a support mechanism for solar energy generation.
Projeto de Lei no. 2.023/2007	Institui incentivos fiscais para a aquisição de bens e prestação de serviços necessários para a utilização de energia solar, eólica ou outras formas de energia alternativa.	Establishes financial support for the acquisition of goods and services related to the use of solar energy.
Projeto de Lei no. 523/2007	Institui a Política Nacional de Energias Alternativas e dá outras providências.	Creates the National Renewable Energy Policy.
Projeto de Lei no. 3.831/2004	Dispõe sobre incentivos à geração de energias alternativas e dá outras providências.	Proposes a support mechanism for alternative energy.
Projeto de Lei no. 3.259/2004	Cria o Programa de Incentivo às Energias Renováveis, e dá outras providências.	Creates the National Support Program for Alternative Energy.
Projeto de lei no. 630/2003	Altera o art. 1º da Lei nº 8.001, de 13 de março de 1990, constitui fundo especial para financiar pesquisas e fomentar a produção de energia elétrica e térmica a partir da energia solar e da energia eólica, e dá outras providências.	Creates a special fund for research and development of solar and wind energy.

Source: Salamoni, 2009; Câmara dos Deputados 2012, own adaptation

For about 10 years, until 2007, grid-connected PV activities in Brazil were limited to the mentioned draft laws and to a very small number of university faculty devoted to research and teaching in this area (R. Rüther, personal communication, January 10, 2012). In 2007, they initiated a concerted effort to inform both the MME and ANEEL[24] about the huge potentials and cost evolution of PV energy, which in 2008 led to the creation of a working group dedicated to studying grid-connected PV (GT-GDSF)[25] under the supervision and with the collaboration of the ministry (R. Rüther, personal communication, January 10, 2012). The result of their work was a

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[24] ANEEL stands for Agência Nacional de Energia Elétrica/Brazilian Electricity Regulatory Agency. For more information on its role consult Chapter 6.

[25] GT-GDSF stands for Grupo de Trabalho em Geração Distribuída com Sistemas Fotovoltaicos.

report entitled "Estudo e propostas de utilização de geração fotovoltaica conectada à rede, em particular em edificações urbanas", which outlined a series of key issues related to the development of PV, such as the regulatory and fiscal framework, installed capacity or grid connection changes. This development continued with the Consulta Pública no. 015/2010 of ANEEL, a consultation that ended on November 9, 2010 and received 577 responses (R. Zilles & J. Goldemberg, personal communication, February 13, 2012). The goal of this consultation was to present the main legislative instruments for promoting small-scale decentralized generation in Brazil and other countries, and receive the contributions of interested stakeholders on issues policymakers face to reduce the existing barriers (ANEEL, 2010). The positive impact and the strong interest raised by the consultation led to the Audiência Pública no. 42/2011, a public hearing aimed at changing the regulatory framework for small-scale decentralized generation and solar energy in particular.

The main changes proposed by ANEEL refer to the following (R. Zilles & J. Goldemberg, personal communication, February 13, 2012; ANEEL, 2011a):

1. The introduction into PRODIST[26] of a special section covering the grid access of decentralized micro- and mini-generation: PRODIST is a collection of documents drawn-up by ANEEL, which regulate and standardize the technical activities related to the operation and development of the electricity distribution systems (ANEEL, 2012b). They comprise eight modules, of which Module 1 "Introduction" and Module 3 "Access to the distribution grid" require changes. First, the definitions for promoted decentralized micro (100 kW – 1 MW) and mini-generation (< 100 kW) have to be included in the introduction. Second, the grid-connection barriers for the aforementioned electricity generation sizes will be reduced by new regulations included in Module 3.
2. The establishment of a net metering mechanism – Sistema de Compensação de Energia (SCE): The installation of PV modules is economically viable in areas where the residential tariffs of utilities are similar to or above the price of PV energy. Seeing that in Brazil there are already nine utilities that have residential tariffs above the price of PV energy, and 22 more with values equal to the price of PV, the use of the technology in these areas does even not need a financial incentive for its promotion (ANEEL, 2011a). The introduction of net metering would thus spur the development of PV without a financial burden to the state, by offering consumers the possibility of not having to pay for electricity from the grid, which is more expensive than the electricity they can generate themselves. According to the current proposal, the net metering scheme would

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[26] PRODIST stands for Procedimentos de Distribuição de Energia Elétrica no Sistema Elétrico Nacional.

not offer any financial compensation for the excess energy, but would transform it into credits with a validity of 12 months, which offers the possibility of offsetting excess consumption during this period.

3. The reduction of charges for the use of the transmission and distribution system (TUST[27] and TUSD[28]) for PV energy from 50% to 20% (ANEEL, 2011a).

The latest and possibly most significant initiative of ANEEL is the Chamada Pública no. 013/2011[29], a call for grid-connected PV projects ranging from 0.5 MW to 3 MW, which received 18 submissions totaling 25 MW and with a volume of R$400 million (ca. US$ 220 million) (E. T. Serra, personal communication, February 23, 2012). Borne from the results of the GT-GDSF report, this initiative seeks to demonstrate the technical and economic viability of PV generation in Brazil[30] (ANEEL, 2011b). Furthermore, by wanting to provide an informational basis for future legislative acts, it shows the increased interest and openness of the Brazilian administration for a future support policy for large-scale PV.

Conclusion: The hypothesis according to which the existence of overall political climate goals and specific goals for renewable energies facilitates the introduction of a support policy for photovoltaic energy has been validated. Brazil has implemented a climate policy and has included RE goals in its energy policy. Furthermore, it has supported the development of wind, small hydro and biomass through a dedicated feed-in law. Even if solar PV has not been yet contemplated in the medium and long-term plans and is not part of the policies, recent proposed changes in legislation point to a future inclusion. The initiatives of the regulatory body ANEEL – facilitating access to the grid for decentralized generation, introducing a net metering mechanism and organizing a tender for grid-connected PV projects – are steps that could lead to a consistent policy in the future.

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[27] TUST stands for Tarifas de Uso do Sistema de Transmissão.

[28] TUSD stands for Tarifas de Uso do Sistema de Distribuição.

[29] Projeto Estratégico: „Arranjos Técnicos e Comerciais para Inserção da Geração Solar Fotovoltaica na Matriz Energética Brasileira"

[30] For individual projects see Annex 4.

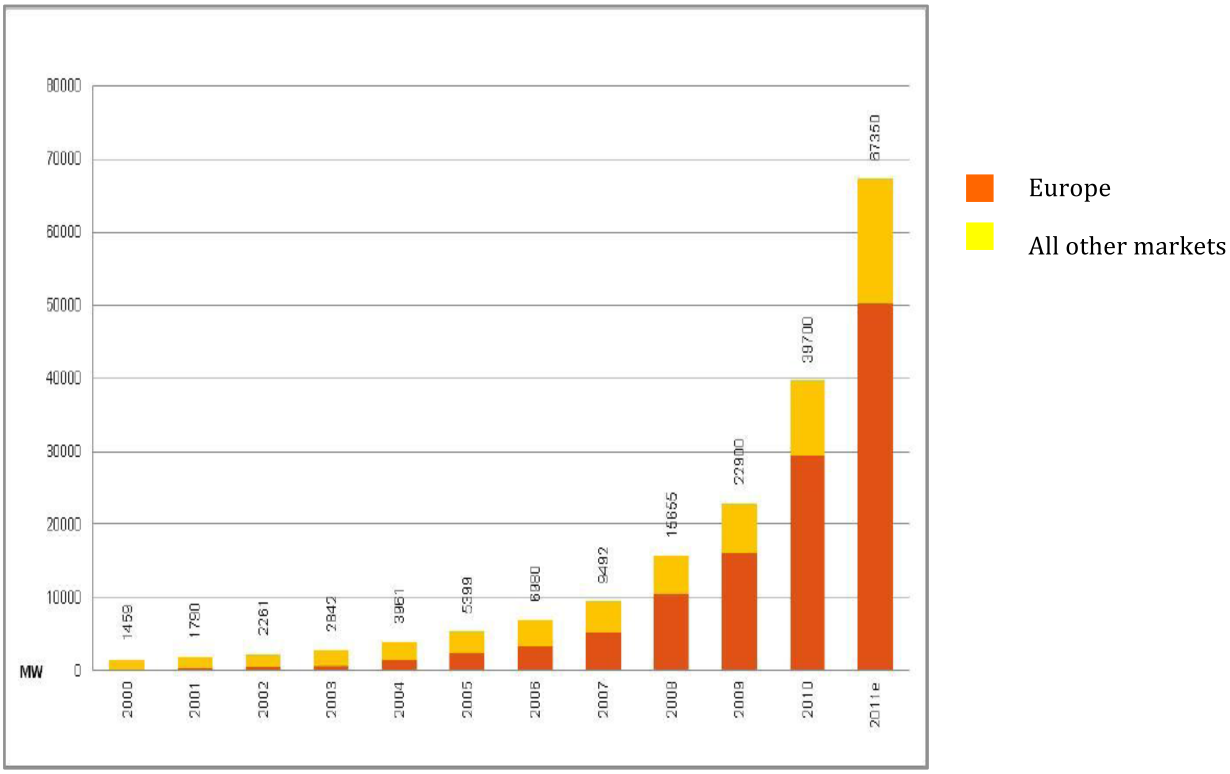
4.3. Economic environment

As mentioned in Chapter 4.1., Brazil has been witnessing an impressive economic growth: The GDP increased by 7.5% in 2010 – the highest growth rate in the past 25 years – and by 2.8% in 2011 (CIA, 2012), and forecasts of a 3.2% and a 5.0% increase in 2012 and 2013 point to a steady continuation of this trend (Allianz, 2012). The investments in renewable energy rose as well. Among developing countries, the largest share of investments was recorded in the three emerging economies of China, India and Brazil, which together account for almost 90% of total investments in 2010 (UNEP, 2011). Brazil occupied the fourth place worldwide with US$7 billion (The Pew Charitable Trusts, 2011).

The necessity for investing in energy in general, and renewable energy in particular, is a consequence of the intensive growth in electricity demand, which Brazil has to accomplish in the coming years. For the last four decades, the energy demand in Brazil grew at an average of 6.7% yearly (MME/EPE, 2007). The PNE 2030, in its four scenarios for the development of electricity demand, expects a yearly long-term growth rate between 3.6% and 6.1% in the period from 2010 to 2030 (MME/EPE, 2007). According to these figures, the electricity demand in 2030 could lie between 950 and 1,250 TWh annually, which will require a substantial expansion of capacity (Salamoni, 2009). For this purpose, priority has been given to hydropower. Photovoltaic was not even considered as an alternative in the above-mentioned study. The main reason, according the literature review and to most of the interviewed experts, is the cost factor.

Despite the fact that solar PV is approaching commercial maturity, it is still largely dependent on subsidies or price support mechanisms for its worldwide development (UNEP, 2011). But the continuous growth track that solar PV has been on recently made it the third most important renewable energy in terms of globally installed capacity in 2011, with grid-connected PV systems reaching an unprecedented 67.35 GW in 2011 (EPIA, 2011b) (see Figure 7).

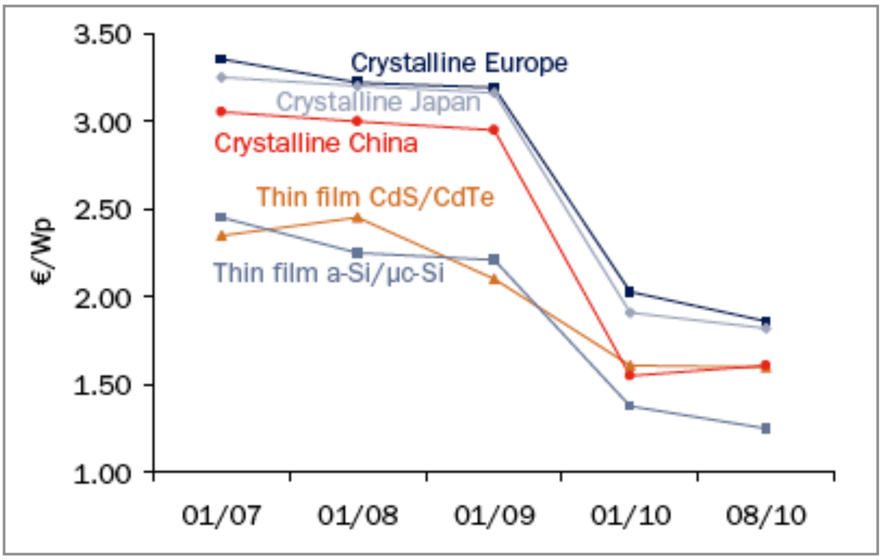
Figure 7 The evolution of global cumulative PV capacity since the year 2000



Source: EPIA, 2011b

This development, combined with the fact that the investment costs of solar PV decline as production capacity is doubled, shows the significant cost reduction potential this technology bears for the future, and the trend of solar modules in recent years can only emphasize this fact (see Figure 8).

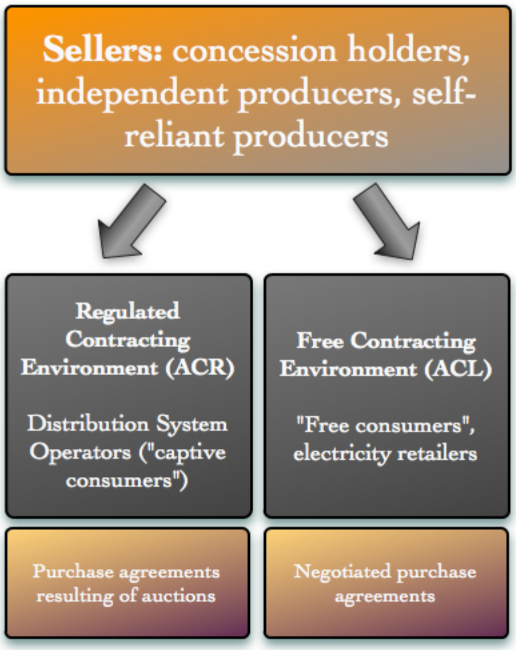
Figure 8 Module price trends worldwide 2007 to 2010 (based on the average selling price)



Source: Sarasin, 2010

Nevertheless, the Brazilian electricity model is based on the guarantee of low tariffs (modicidade tarifária), so it only allows business ventures with low costs (E. T. Serra, personal communication, February 23, 2012; Law no. 10.848/2004). The power trading in this model is based on bilateral purchasing agreements between actors, which are concluded in two predefined market environments: the Regulated Contracting Environment (ACR)[31] and the Free Contracting Environment (ACL)[32] (see Figure 10). Most of purchasing agreements are concluded in the ACR, where the amounts of energy needed are bought through public competitive bidding. The winner of these tenders is normally the project with the lowest costs. In the ACL, purchasing agreements are negotiated between concession holders, power producers, electricity retailers and "free consumers" (consumidores livres), i.e. the ones who opt for the free market environment. Only here can solar PV be commercialized, because its high costs compared to the traditional sources would not allow it to take part in the regulated environment in the short and medium term.

Figure 9 Power trading in Brazil



Source: CCEE, 2012, own adaptation

The cost of solar PV energy in Brazil is estimated at R$500/MWh – R$600MWh (US$ 280/MWh – US$335/MWh). Seeing that it cannot compete with the prices for hydropower in a tendering system – R$100/MWh – R$150/MWh (US$55/MWh – US$85/MWh) (M. Baitz, personal communication, February 23, 2012) – it could still be worth considering for individual

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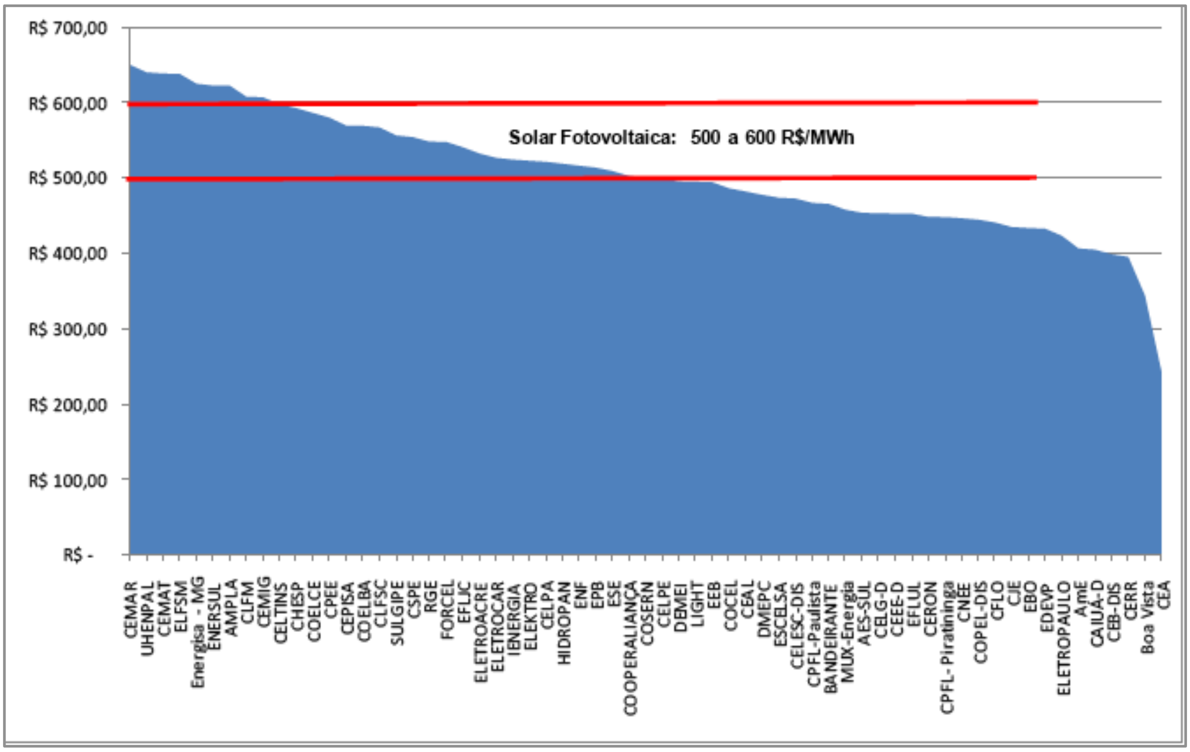
[31] ACR stands for Ambiente de Contratação Regulada.

[32] ACL stands for Ambiente de Contratação Livre.

consumption because of the high residential tariffs charged by utilities in Brazil. Figure 10 shows that there are currently nine utilities with residential tariffs higher than R$600/MWh and 22 with values ranging from R$500 to R$600, for example in the states of Minas Gerais, Maranhão, Tocatins, Ceará, Piauí, Rio de Janeiro (partly), Mato Grosso and the interior of São Paulo (ANEEL, 2011). This is the reason why the Brazilian administration is considering the introduction of a net metering mechanism.

However, due to the fact that residential tariffs include up to 50% federal and state charges (Aguiar, 2011), a future federal policy must take into account the states' interest in collecting them. Burdening solar PV electricity with these charges would make it even more expensive, forfeiting their collection would limit the support of the states. For the price of solar PV to remain competitive, own consumption could be thus exempted from these charges in a first phase, with future action to depend on the speed of the technological diffusion.

Figure 10 Residential tariffs in Brazil (Status as of May 2011)



Source: ANEEL, 2011

Furthermore, if one would consider the negative externalities associated with traditional energy sources in Brazil, such as large hydropower, and the fact that they are not internalized in the market price, the cost gap between "new renewables" and traditional sources would not be so significant anymore. As for PV, which is generally "delivered" as decentralized energy, its cost should be compared with the end-user cost of electricity from other sources, including transmission and distribution costs (Owen, 2006).

Most of the interviewed experts argued that the electricity generation in Brazil is already based on a renewable and sustainable energy source, and have forwarded this argument as the reason for which the "classical" problem setting of an industrialized country does not apply to the Brazilian case. However, this assumption seems to be increasingly challenged by the literature: According to UNCTAD (2011), large hydropower often requires the displacement and relocation of large numbers of people at great social and economic costs and, in many cases, can also have serious impacts on the ecosystem. It shows that renewable energy is not necessarily synonymous with sustainability, and that there is a need to reduce and manage these impacts (UNEP, 2011). For Brazil such management would translate into the development of other generation sources, among them solar PV.

Conclusion: The hypothesis according to which favorable economic conditions are necessary for the development of photovoltaic energy in Brazil has been validated. Increasing electricity demand will require Brazil to expand its generation capacities. For this purpose, priority has been given to hydropower, while solar PV has not even been considered in important government documents. The reason for this lies in the difference between generation costs – PV is expensive as compared to hydro. So the participation of the technology in the public competitive bidding system is not possible. Nevertheless, solar energy is an option for residential consumers in areas where the tariffs charged by the utilities are higher or equal to the PV generation costs including amortization. Furthermore, the cost gap can be challenged: First, large hydropower is not a sustainable source, and the negative externalities caused by the construction and operation of hydroelectric dams are not reflected in its price. Second, since PV is a decentralized energy source, its costs should be compared to the generation costs of traditional sources plus the costs for transmission and distribution.

4.4. Technological developments

In Chapter 4.3., the high costs of solar PV were assumed to be the number one barrier to the deployment of this technology in Brazil. As a matter of fact, for most PV applications it is difficult to compete with conventional energy sources, because the technology hasn't reached commercial maturity yet. But, among various other electricity-generating technologies, solar PV has the most promising learning rate. For a better overview, Table 4 shows different ranges of investment cost reductions associated with a doubling of cumulative production.

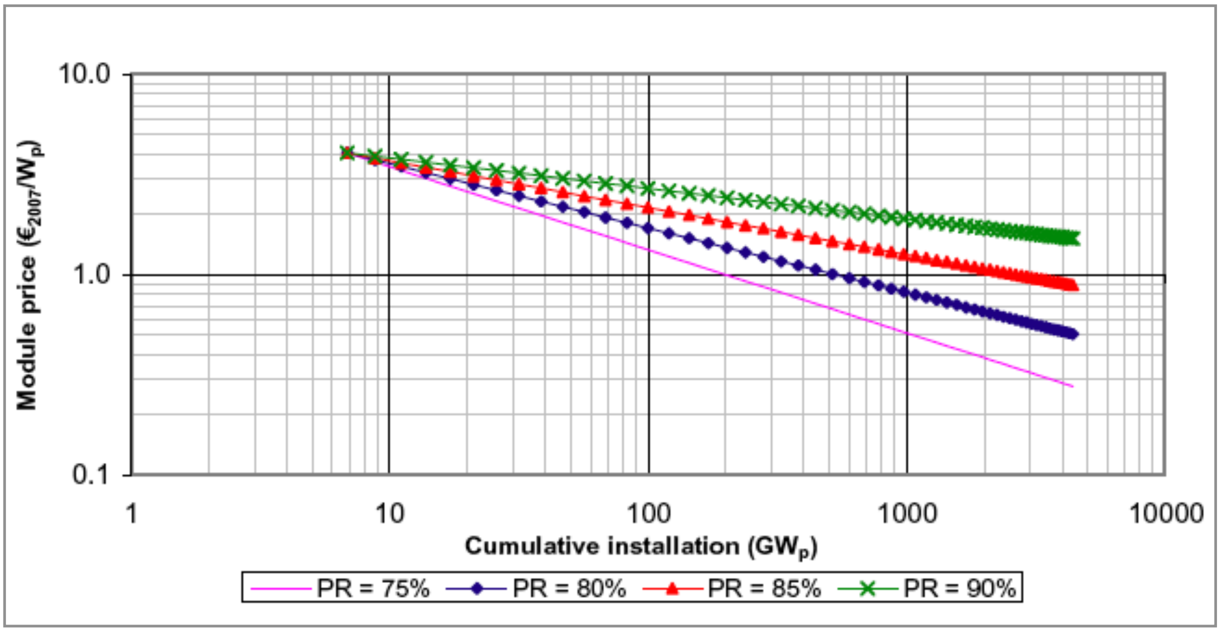
Table 4 Cost reduction potential of electricity-generating technologies

Technology	Investment cost reduction (in %)
Advanced coal	5-7
Natural gas combined cycle	10-15
New nuclear	4-7
Fuel cell	13-19
Wind power	8-15
Solar PV	**18-28**

Source: UNEP, 2011

With the help of government action, improved market conditions would result in a rescaling of the production and lower investment costs, hence lower total production costs and better economic viability (see Figure 11).

Figure 11 PV learning curve based on world module price 2006 to 2060 (according to different progress ratios – PR[33])



Source: Bhandari & Stadler, 2009

To date, Brazil does not have an own grid-connected PV manufacturing industry[34]. The Brazilian PV module market is currently dominated by imported modules, which are manufactured by

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[33] The progress ratio (PR) is the conventional measure of learning (Bhandari & Stadler, 2009).

[34] The focus is on PV modules, since there are no Brazilian manufacturers of grid-connected invertors (Varella et al., 2009).

multinational companies. According to Varella et al. (2009), the following companies were dominating the 2005 PV module market: Kyocera – 50% of the market (Rosell & Krause, 2010), Shell, Isofotón and Atersa. More recent news points to new entries on the market: First, GE Energy will supply 1 MW of thin-film modules and associated power equipment to the first commercial PV power plant in Brazil, MPX Tauá. Installed in the federal state of Ceará at the middle of 2011, the plant stands for an enlargement to 2 MW in the course of 2012 (Recharge, 2011; MPX, 2012). Second, Spire Solar, a company of the American Spire Corporation, launched in 2011 the first Brazilian PV module factory together with Tecnometal.

Regarding PV technology in general, the first development occurred in Brazil in the late 1970s, with Heliodinâmica Company as the first Brazilian company to emerge in early 1980 (Varella et al., 2009). The company still exists, and, in addition to manufacturing solar cells and PV modules for off-grid systems, it offers components for rural electrification systems, motors for water pumping systems, telecommunication systems and electric fences (Varella et al. 2009; Heliodinâmica, 2012).

As for the manufacturing industry for grid-connected PV, the first efforts were made by the Brazilian Centre for Development of Solar PV-Energy (CB-Solar)[35], which was created in 2004 at the Pontificia Universidade Católica do Rio Grande do Sul (PUCRS). The results of this first local production pilot plant were 200 modules produced by the end of 2010 (Ambiente Energia, 2012).

In 2011, the interest in an industrial-scale production of PV modules had though increased considerably. Table 5 shows the first Brazilian panel manufacturing facility, which started operation at the end of 2011, and the new manufacturing capacities that are planned to start operation during 2012.

Table 5 New manufacturing capacities in Brazil (Status as of March 2012)

Nr.	Name of manufacturer	Location	Manufacturing capacity/year (in MW)	Start of production (estimated)
1	Tecnometal	Campinas, SP	25 MW	December 2011
2	Energia Solar Brasileira (Esbra)	Horizonte, CE	25 MW	2011(?)
3	Ecosolar do Brasil (Oerlikon)	Recife, PE	60 MW – 120 MW	Q2 of 2012

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[35] CB-Solar stands for Centro Brasileiro para Desenvolvimento da Energia Solar Fotovoltaica.

4	VIV Energia Renovável	Entre Rios, BA	N/A	July 2012
5	Kyocera Solar do Brasil	N/A	N/A	2013

Source: Smart E-nergy, 2010; Ambiente Energia, 2010; Costa, 2011; Conselho Estadual de Desenvolvimento Econômico, n.d.; Rotas Estratégicas, 2011; Ciclo Vivo, 2010; Diário de Entre Rios, 2011; Portal Energia, 2011, own representation

The absence of a local PV manufacturing industry is reflected in the need to import solar panels at a high cost. The price of the modules increases thus by a third by the time it is sold in Brazil. An outlook on the cost components for an imported PV module in Brazil is given in the following table:

Table 6 Cost components for imported PV modules in Brazil (based on 2009 global average module prices)

Cost description	**Value (in US$/$W_p$)**
Average module price	2.50
Transport and insurance	0.25
Import Duty (II)[36]	0.33
Excise Tax (IPI)[37]	0.00
PIS/COFINS[38]	0.28
Customs broker	0.25
Value Added Tax (ICMS)[39]	0.00
Total cost	**3.61**

Source: Benedito, 2009

In comparison, the average global price of PV panels in 2011 was about US$1.5/$W_p$, following a slight decrease from just above US$2/$MW_p$ in 2009 (Solarbuzz, 2012; Ernst & Young, 2011)).

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[36] II stands for Imposto de Importação. According to CAMEX Resolution no. 94/2011, the tax rate for modules amounts to 12% on the value including transport and insurance (NCM 8541.40.32).

[37] IPI stands for Imposto sobre Produtos Industrializados. According to Decree no. 7.631/2011, PV modules are exempt from the payment of this duty.

[38] PIS/COFINS stands for Contribuição ao Programa de Integração Social/Contribuição para o Financiamento da Seguridade Social (Contribution to the Social Integration Plan/Contribution for Social Security Financing). Regulatory Instruction SRF no. 572/2005 sets the rates at 1.65% for PIS/Pasep-Import and 7.6% for Cofins-Import.

[39] ICMS stands for Imposto Sobre Circulação do Mercadorias e Serviços. PV modules are exempt from the payment of this duty (MME, 2009).

Considering that the module price represents less than 50% of the turnkey system price, a Brazilian system would cost around US$8,000/kW as compared to a global average of US$ 4,000/kW to US$ 6,000/kW (IEA, 2010). As a result, these prices have an even harder time competing with those of traditional energy sources in Brazil.

Last but not least, at PV module level, the learning makes no distinction between local and global learning. Since most of the modules are manufactured by internationally operating companies, they exchange scientific and technological information on module technology (Bhandari & Stadler, 2009). This opens the possibility of developing a local industry by attracting global companies to settle and produce PV modules in Brazil.

Conclusion: The hypothesis according to which the learning curve and the existence of national manufacturing capacities influence the introduction of a support policy for a renewable energy sourcehas been validated. The solar PV has the highest cost reduction potential as compared to other technologies, a fact which has been demonstrated globally. But because Brazil does not have its own manufacturing capacities, the components of a PV system have to be imported, which makes the price of the generated energy soar. The fact that there is no distinction between global and local learning at a module level could be used for fostering strategic partnerships with multinational companies in order to develop a local industry.

4.5. Cognitive environment

When looking at the cognitive capacity present in Brazil, the first central issue to be analyzed is the availability of information. According to the interviewed experts, information on the possibility of developing grid-connected PV is not new in Brazil, but has only recently been brought to the attention of the relevant stakeholders. Local active university faculty exists since 1997, when the country's first grid-connected, building-integrated, thin-film PV system was installed at LABSOLAR, the solar energy research laboratory on the campus of the Universidade Federal de Santa Catarina (UFSC), in the state of Santa Catarina (Rosell & Krause, 2010). The laboratory, led by Prof. Ricardo Rüther, is probably one of the country's most active in the matter of solar energy. It supports a series of master theses and dissertations on topics related to PV, and develops research projects on solar potential mapping and on other PV applications (Rosell & Krause, 2010; fotovoltaicaufsc, 2012).

Another important research center is the Instituto de Eletrotécnica e Energia (IEE) of the Universidade de São Paulo (USP). The energy institute, led by Prof. Dr. Roberto Zilles, operates a 12 kW PV system, which was connected to the grid in 2000. Its area of expertise ranges from projects of photovoltaic electrification, both autonomous and grid-connected to projects in the area of production processes (quality control, evaluation, etc.) (IEE, 2012).

Various other universities are also active in this area. They include: the CB-Solar at the PUCRS, the Departamento de Engenharia de Materiais (DEMA) at the Universidade Estadual de Campinas (Unicamp) in the federal state of São Paulo, and the Departamento de Engenharia de Materiais at the Universidade Federal do Rio Grande do Sul (UFRGS) in the state of Rio Grande do Sul (Rosell & Krause, 2010).

The results of these research activities are usually published in Portuguese, which limits their accessibility at an international level. Nevertheless, translated work has found its way into peer-reviewed articles in journals such as "Energy Policy" and "Renewable Energy". Furthermore, professors like Rüther and Zilles have co-operated closely with the Brazilian administration, offering their expertise to advance solar PV.

A second important issue to be considered is the degree of acceptance of the topic among policymakers and the broad public. Unfortunately, solar PV is not a broadly discussed topic, so the question of whether it is accepted or not is not yet of relevance. According to Rosell & Krause (2010), the awareness about photovoltaic is very low in Brazil. This fact could be a consequence of the lack of media coverage (ANDI, n.d.). Two of the main Brazilian daily newspapers, "O Globo" and "Folha de São Paulo", seem to have next to no media coverage of the topic as compared to European media. Nevertheless, information is available in specialized magazines, such as "O Setor Elétrico" or "Brasil Energia" and on-line, on information portals such as "Ambiente Energia" or "Portal Energia". Another reason for the low awareness might also be the lack of interest for the topic. Most of the experts mentioned large hydro as the most important renewable resource for the future, which points to a low interest in other renewable resources.

<u>Conclusion:</u> The hypothesis according to which that a favorable and well-developed cognitive environment facilitates a more rapid introduction of a policy for the development of the renewable energy source has been verified. The existence of research centers and experts disseminating information on solar PV in Brazil has led to a broader uptake of the topic among certain relevant stakeholders. Nevertheless, the fact that solar PV is not known among the larger Brazilian public prevents the emergence of an open debate.

5. Situational context

A lot has changed since French scientist Alexandre Edmond Becquerel first discovered the photovoltaic effect in 1839. Examples from all over the world have shown that renewable energy technologies have the potential to become the heart of our energy system. Even PV, long thought to be the most expensive renewable technology on the market, is expected to reach grid-parity in many countries in the near future. Given this fact and after the 2011 Fukushima nuclear accident in Japan, the German government took a leading role and decided to phase-out nuclear energy. This, in turn, will lead to more efforts in developing renewable energy and helping the technologies that are not yet so far to reach market maturity.

The example of solar PV shows what governments can achieve with the help of support policies: In Europe, in the last five years, system prices decreased by 50% (EPIA, 2011a). By fostering long-term planning and investment security, the policies led to an increase in manufacturing capacities and lower prices. This led to the establishment of a strong PV industry, which has been recognized as an equal stakeholder by the traditional industries.

Until recently, Brazil has not been involved in the solar PV market (R. Rüther, personal communication, January 10, 2012; MME, 2009). However, the increase in global production capacity and the reduction of installation potential in Europe will drive businesses to look for new markets. Brazil is already getting to experience this interest, with more and more companies (such as Gehrlicher Solar, Sun Edison, SolarWorld) joining the dedicated groups of relevant Brazilian trade associations (ABINEE, 2011a).

Furthermore, Brazil will be host to two significant events in the next years: First, Brazil will host the Rio+20 Conference in Rio de Janeiro in 2012, the most important event in the area of global environmental policy. As in 2009, when the country committed itself to fulfilling emission reduction targets, Brazil could use this opportunity to put itself at the forefront of climate change negotiations by pledging to changes in its electricity generation mix.

Second, it will receive a great number of visitors for the 2014 FIFA World Cup, for which preparations are underway. For this event, in the land where soccer is considered more than just a game, the 12 stadiums taking part will be powered with the help of PV energy. The first of this flagship initiative is the Pituaçu Stadium[40], located in Salvador in the State of Bahia, on which Gehrlicher Ecoluz Solar do Brasil S.A., a joint venture of Gehrlicher Solar AG and Ecoluz

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[40] Estádio de Pituaçu

Participações S.A., will install a solar power system with a cumulated power of 403 kW_p (Gehrlicher Solar, 2011). This initiative is not only a real contribution to clean energy generation, but a lever to promote social change. Stadiums are symbols of collective pride and of a sense of community, more so in soccer-crazy Brazil, so combining sports with solar energy is a good way to achieve a change in the Brazilian mentality.

Last but not least, and not only because of the electrification of the soccer stadiums, the dissemination of information in regard to solar PV is improving. Until 2007, many Brazilian policymakers and stakeholders were lacking information on solar potential and the technological evolution of solar PV (R. Rüther, personal communication, January 10, 2012; Rosell & Krause, 2010). The publication of the MME report on grid-connected PV thus represented the much-needed informational "stepping-stone" for stakeholders and policymakers (M. Baitz, personal communication, February 23, 2012).

Conclusion: The hypothesis according to which the existence of structure-changing events per se is not sufficient for a successful placement of the issue on the political agenda has been verified. There are both local and global events, which might lead to the introduction of a support policy for solar PV in Brazil. However, they are not sufficient for the creation of a "policy window". Rather the actors and their actions are responsible for effecting such a change. For instance the Fukushima nuclear accident and various global events following it brought movement on the PV markets. This might in turn determine actors to enter the Brazilian market. On the local level, the fact that Brazil will be host to two important events in the near future, combined with a better information dissemination, might lead to an increased interest in solar PV and its introduction in the electricity mix.

6. Actors

This chapter seeks to identify and assess the main actors involved in renewable policy in Brazil, as well as possible connections between them. The underlying power structures of all existing stakeholders are difficult to assess, however, because of their complexity and the intrinsic degree of non-transparency associated with the agenda setting in the policy process. Therefore the focus will be placed on those bodies of the Brazilian federal government that define and implement renewable energy policy and on the existence, power and proximity to the state of both the traditional and the renewable energy industry.

To date, the Brazilian energy policy is defined by the CNPE, according to the National Energy Policy Law. The CNPE is an advisory body to the President of the Republic and has as its main attributions the formulation of policies and guidelines in the area of energy and the supply of energy inputs to the remote areas of the country. In addition, the CNPE is responsible for periodically revising the energy mix of various regions of the country, for setting the guidelines for special programs and for the import and export of natural gas and oil (MME, 2012b). Among the members of the CNPE there are seven ministers, including the energy minister, one representative of the federal states, one civilian energy expert and one representative of a Brazilian university, also specialized in energy matters (MME, 2000; GTZ, 2009).

The institution responsible for implementing the energy policies is the MME. It is the federal government body responsible for the formulation and implementation of energy policies in accordance to the guidelines set by the CNPE. Among its responsibilities is also the planning and monitoring of the energy sector (Salamoni, 2009). The relevant department in the MME is the Division of Energy Planning and Development (SPE)[41], which, with the support of the EPE[42], formulates medium and long-term plans, such as the PDE and PNE. Moreover, the SPE is responsible for the analyses required for granting concessions and permits and for the efforts to diversify the Brazilian energy mix, i.e. for renewable energy programs such as the PROINFA (MME, 2012c).

The Brazilian Electricity Regulatory Agency, ANEEL, is an independent regulatory body established in 1997[43] and linked to the MME. Its attributions comprise the regulation and

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[41] SPE stands for Secretaria de Planejamento e Desenvolvimento Energético.

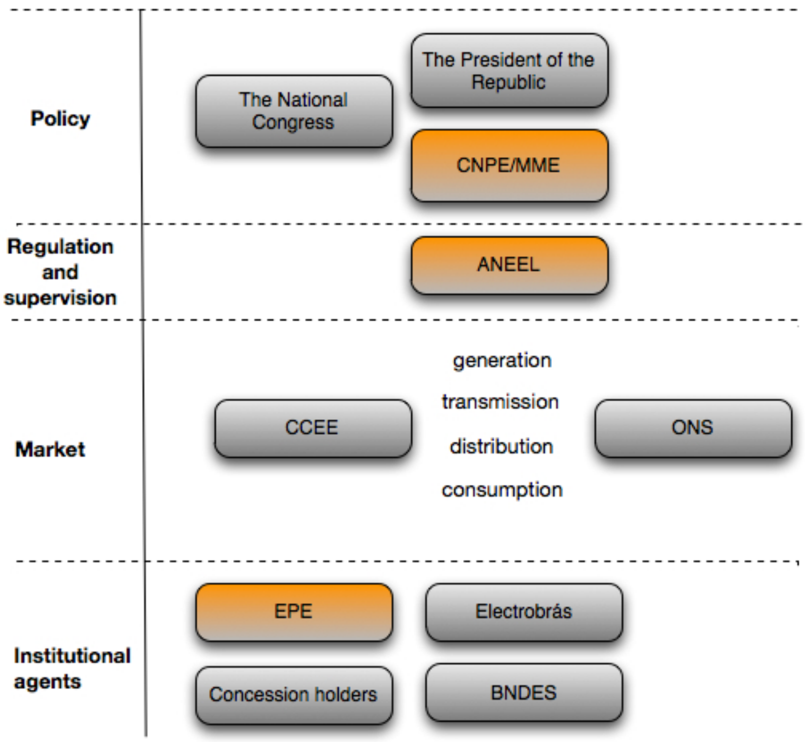
[42] The EPE is a state-owned research agency, which executes studies and forecasts in the area of energy. The P&D attributions belonged to ANEEL before the creation of the EPE.

[43] By Law no. 10.847/2004 and Decree no. 5.184/2004

monitoring of the generation, transmission, distribution and marketing of electric energy. The agency has to ensure the quality of energy services, to promote their universal availability and to establish fair residential tariffs, taking into account the economic and financial viability of the industry (Salamoni, 2009).

The figure below illustrates the institutional structure of the power sector, and presents the above-mentioned actors and the levels on which they operate.

Figure 12 Institutional structure of the power sector in Brazil



Source: ANEEL, 2008

On the political level, there are two more entities to be named: the Ministry of Development, Industry and Foreign Trade (MDIC)[44] and the Ministry of Science and Technology (MCT)[45]. The MDIC is responsible for the policies concerning import duties on PV modules and for questions related to a local content of policies, while the MCT is responsible for planning, coordinating and supervising S&T activities in priority areas, such as the area of renewable energy. Unfortunately, a statement on the degree of coordination of their policies in the area of solar PV is not possible, since no indication to it was found in the relevant literature.

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[44] MDIC stands for Ministério do Desenvolvimento, Indústria e Comércio Exterior.

[45] MCT stands for Ministério da Ciência e Tecnologia.

On the other hand, a close relationship can be noticed between the MME and Eletrobras[46]. Founded in 1961, Eletrobras is Latin America's biggest power utility company. With a share of 52.54%, the Brazilian government is the majority stakeholder (Eletrobras, 2012a). The generation capacity of Eletrobras, including energy from the Itaipu Binacional[47], represents 36% of the total energy produced. Further, Electrobras holds 56% of the transmission lines in Brazil (Eletrobras, 2012b). Only as a consequence of previous privatization efforts has the share of the company in the total distribution capacity been reduced, to amount to a mere 5%[48] in 2010. Despite curtailment of its scope, especially in the areas of generation and distribution, the role of Eletrobras and its connections to the state are still significant (GTZ, 2007).

Prof. R. Rüther (personal communication, January 10, 2012) clearly assessed the government institutions (CNPE, MME, EPE, ANEEL) as having been shortsighted and having hindered PV development in Brazil. His statement is not surprising, since the traditional energy sector, represented by Eletrobras, has a close connection to the government. The state monopoly in the area of generation is of major importance: Because of the fact that solar PV is a technology that does not need vast initial investments, it is accessible to a number of smaller private companies, which cannot usually realize big energy projects. The large numbers of firms active in the market stimulates competition and thus reduces the influence of the traditional power companies such as Eletrobras.

Opposition to the introduction of a support policy for PV might also come from the hydropower lobby, organized in the ABRAGE[49], the Brazilian association of power producers. This trade association represents mostly major producers of hydroelectricity and comprises about 70% of the total electricity production (GTZ, 2009).

Further opposition might be encountered from other trade associations: First, the public utilities, organized in the ABRADEE, could oppose the development of solar energy, because the distribution grid in which solar PV is fed requires investments on their side. Hence they might become a "stumbling block" if not adequately and timely included in the planning (R. Rüther,

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[46] The company's full name is Centrais Elétricas Brasileiras S.A..

[47] Itaipu Binacional is the largest hydroelectric dam of the world. The energy it produces is divided equally between Brazil and Paraguay (Eletrobras, 2012b).

[48] According to own calculations: On the web page of ANEEL there are 63 concession holders for energy distribution (ANEEL, 2012c). 41 of these companies, both public and private, are represented in the ABRADEE (Associação Brasileira de Distribuidores de Energia Elétrica), the Brazilian Association of Electric Power Distribution Companies. Their market share is 99% of all Brazilian consumers (ABRADEE, 2012a, 2012b). Seeing that the private companies in the ABRADEE made for 94% of the total, the share of Eletrobras lies at only 5%.

[49] ABRAGE stands for Associação Brasileira das Empresas Geradoras de Energia Elétrica.

personal communication, January 10, 2012). Second, the ABRACE[50], the Brazilian Association of Major Power Consumers and Free Consumers, has already urged policymakers in regard to the loss of competitive advantage caused by increased energy prices (ABRACE, 2011). As many European examples show, once the PV technology reaches a certain development stage, the opposition of the industry to its development will only become louder.

As for the "proponents" of new renewable energy, Salamoni et al. affirmed in 2009 that there is no relevant Brazilian lobby for solar PV. Since then, an increasing number of companies have manifested their interest to actively support the development of a market. This led to the establishment of a dedicated group in the ABINEE (Grupo Setorial de Sistemas Fotovoltaicos). Created in January 2011, this group offers a platform for discussions regarding the development and the market structure of photovoltaic industry. The group unites 98 companies along the value chain (see Table 7) and covers various topics in five working groups: WG Tenders, WG Market, WG Inverters/Systems (equipment), WG Taxes, WG Standards (Smart E-nergy, 2011; ABINEE, 2011b).

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[50] ABRACE stands for Associação Brasileira de Grandes Consumidores Industriais de Energia e de Consumidores Livres.

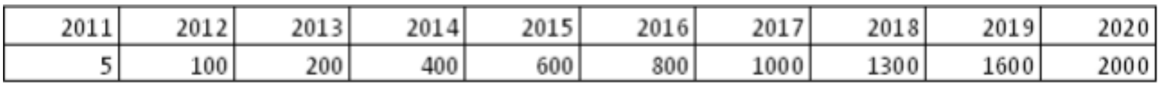
Table 7 Members in ABINEE's Grupo Setorial de Sistemas Fotovoltaicos (Status as of September 2011)

3M do Brasil	Enel	Newmax - Baterias Industriais
ABB	Energis8	Nexans FICAP
Able Eletrônica	Enfinity	Opex Energy
Acumuladores Moura	EPCOS do Brasil	Orbe Brasil
AFAP Eletro Mecânica e Eletrônica	Eudora Energia	Ormazabal
Alupar Investimento	Exide	Petrobrás
Alusa Engenharia	EXXA Global	PHB Eletrônica
Alwitra	Fairway	Phelps dodge
Amphenol TFC	FC Solar Energias Alternativas	Phoenix Contact
BlueSol	Finder Componentes	Power Electronics
BR Solar	Fulguris	Renova Energia
Brunari	Furukawa Industrial	RIMA
BVMW	GE Energy	Saint-Gobain
CB-Solar	Gehrlicher	Santerno
Cebrace Cristal Plano	Grupo Fairway	Saturnia
Cegasa	Guascor Solar do Brasil	Schneider Electric Brasil
CEMIG	Helenium Services	Semikron Semicondutores
Centrotherm	Hydro	Siemens
Condumax	Incesa	Sky Solar Sunbean
CP Eletrônica	INPE	Solaria Brasil
CPFL Energia	Intercedere	Solaris - Tecnologia Fotovoltaica
Criem	Intermarket Industrial Films LLC	Solaric
Donauer Solar Systems	Jema	SS Solar
CTI	Kraus & Naimer do Brasil	Sun Edison
Dow Corning	Kyocera Solar do Brasil	TecnoMetal Energia Solar
DuPont	Lacerda Sistemas de Energia	Toshiba
EBES	LC - Labramo Centronics	Tucana Consulting
EC13	LG Electronics	Vogel Solar
Ecoluz	M.E.S Energia	W3 Ambiental
Econova	Magmattec	WEG
Ecosolar do Brasil	Manserv	Wobben Windpower
EFACEC	MPX	World For You Consulting
Eltek Valere	New Generation Power	**98 EMPRESAS**

Source: ABINEE, 2011b

Despite the fact that it is a new lobby group, it has had quite a resonance: From March 2011 until September 2011 the group almost doubled its members. Furthermore, it has asserted itself in the political arena by establishing a clear position and communicating it to the other stakeholders. So, for example, in August 2010, even before the official constitution of the group, five members organized an inter-ministerial meeting with the MCT, MME and the MDIC to announce the initiation of the group and to present a document with suggestions for a support program for the development of the PV sector ("Propostas para a Criação do Programa Brasileiro para o Estabelecimento do Setor Fotovoltaico") (ABINEE, 2011a). Subsequently, they have elaborated a plan for the introduction of solar PV in the Brazilian energy mix ("Plano de Inserção da Energia Solar Fotovoltaica na Matriz Elétrica Brasileira") with the purpose of creating a Brazilian PV industry, of analyzing the economic and financial viability of the technology and creating a relevant industrial policy (ABINEE, 2011b). The PV generation capacity they envision for the next years is in accordance to these goals (see Figure 14). The forecast was also communicated to the government by being included in the contribution they delivered for the PDE 2020, which is expected in 2012 and might be the first decennial plan to consider solar energy.

Figure 13 ABINEE's projected evolution of PV generation capacity (in MW)



2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
5	100	200	400	600	800	1000	1300	1600	2000

Source: ABINEE, 2011b

Conclusion: The hypothesis according to which the actors or the configurations of actors that are involved with the introduction of a support policy for grid-connected PV influence its chances to succeed has been validated. It is asserted that the close connections between the Brazilian institutions responsible for renewable energy policy and the government-owned Eletrobras, which is responsible for 36% of the total electricity generation, have hindered the introduction of a support policy for PV. Furthermore, if such a policy is introduced, opposition can be expected from various other groups, such as the lobby of the traditional energy sources, the utilities or the big consumers. The lobby of the solar PV is still young, but on a good way of asserting itself.

7. Strategies and instruments

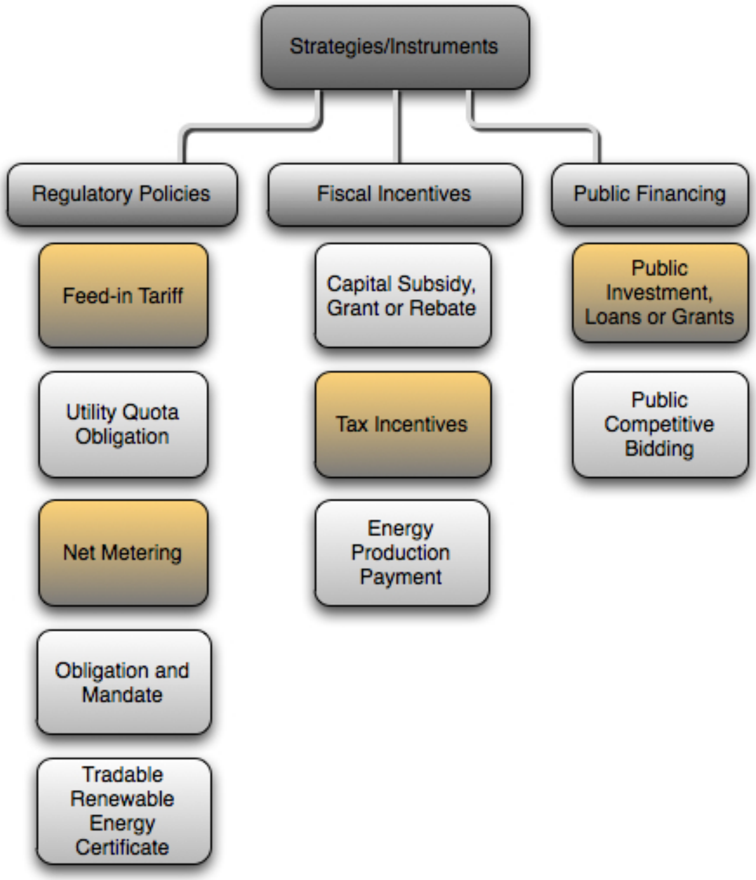
7.1. Overview of policy mechanisms for promoting renewable energy

The first misconception about solar PV is that some great new idea will come along and revolutionize its production, making it cheap (Mallon, 2006), when in reality the main thing required to make solar PV affordable is to scale up the market size, as was described in the previous chapters. Furthermore, the universal agreement that renewables are a good idea is not sufficient to develop market size. For this, government intervention, in form of support policies, is required. In this chapter the strategy and instruments for the development of grid-connected PV in Brazil will be discussed. The key issues to be looked at are the existence or the choice in favor of a certain support policy and its design.

The term "strategy" does not have a generally agreed upon definition: It can refer to a long-term plan of action, to a general vision, to a position or to all of these simultaneously. Jänicke (2003) refers to it as the formal umbrella term for various aspects of environmental action, such as goals, instruments or policy style. His operationalization of the term is useful in that it provides a golden thread when analyzing individual actions the Brazilian government might take in regard to solar PV.

The instruments, in this case the policies, are thus more important. They are usually employed with the goal of removing barriers for a broader market penetration and increasing the installed capacity, of enjoying the corresponding environmental benefits and of leading to the creation and sustainable growth of a PV industry (Haas, 2003). They can be either direct or indirect. The focus of the paper is set on the direct instruments, as they are presented in Figure 14.

Figure 14 Direct support instruments for renewable energy[51]



Source: REN21, 2012, own adaptation

To date, the only benefits grid-connected PV enjoys in Brazil are tax rebates for panels (IPI and ICMS – see Chapter 4.4.), but these not even applicable for inverters, which are a necessary component for grid-connected PV systems (Benedito, 2009).

In addition, the Brazilian administration is considering another instrument, i.e. a net metering mechanism. Net metering is a regulatory, price-based[52] mechanism, which stimulates decentralized generation. Under this scheme, independent power producers are allowed to connect to the grid and use it as a "virtual storage", as they can consume part of the electricity they generate at another time within their billing cycle or receive compensation (Ackermann et al., 2001; Jacobs, 2010). For it to be considered net metering it is important that production and consumption ensue at the same time.

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[51] The instruments that are particularly relevant for Brazil have been highlighted.

[52] As opposed to quantity-based

This mechanism should not be confused with a feed-in tariff. A FIT is also a regulatory, price-based mechanism, which comprises at least the following design aspects: a purchase obligation and a stable tariff payment, which is guaranteed over a long period of time. Therefore, net metering schemes lack two important components of a FIT: When offering a financial compensation for the excess energy fed into the grid, the price is not fixed, nor is it guaranteed over a long period of time. This results in a lower degree of investment security (Jacobs, 2010).

Feed-in tariffs have proven to be the best support mechanism for the rapid increase in renewable energy production and use worldwide (Mendonça et al., 2010). Despite of this instrument not yet existing in Brazil, it has been often advocated in the literature. No later than 2010 an article by two of the interviewed experts was making a case for grid-connected PV and proposing the introduction of a FIT tailored to the Brazilian reality. Furthermore, the 2011 call for grid-connected PV projects of ANEEL, with the goal of assessing the relevant aspects of the insertion of PV into the grid, might be an indication of a future feed-in tariff law.

Two of the interviewed experts argued that public competitive bidding is the most appropriate support mechanism. It is true that the mechanism has been used in the past to promote other renewable sources, such as wind. But for solar PV, the participation in the tendering system would result in high transaction costs, which would in turn make some applications economically unviable (J. Kissel & D. Aßmann, personal communication, February 11, 2012). The advantage of solar PV lies primarily in its decentralized character, so increasing the price for small-scale applications would be against the wish of the Brazilian administration to increase the deployment of this source without high costs. Furthermore, this option has not been discussed in the literature or advocated by any of the other interviewees. Therefore, it was considered less plausible and has not been analyzed further.

In conclusion, Brazil is tending to the introduction of a regulatory, price-based support mechanism. The shape of a strategy is starting to become apparent: The introduction of a net metering policy for the regions in which solar PV has reached grid parity might then be followed by the introduction of a feed-in law to bridge the period to grid-parity in the other regions.

7.2. Design aspects of a support policy

As important as the choice of the instrument is, it is the design that is decisive for its success (Bechberger et al., 2003). The design of policy instruments has become increasingly complex, with basic and advanced options, with options for industrialized countries and emerging economies, and many others. Among the many options in which the instruments can differ, there are though four, which are valid for all instruments and significantly influence the success of the policy: differentiated tariffs, compliance with legislation, institutional controllability and long-term planning and investment security.

Differentiated tariffs: Bechberger et al. (2003) point to the design of tariffs according to the technology, i.e. different tariffs for each technology when designing a price-based instrument for multiple technologies. This leads to the creation of a broad supply spectrum and prevents the technologies with lower generation costs hindering the market integration of the more expensive ones. In Brazil, the cost factor of grid-connected PV is a significant barrier, so a model based on the "modicidade tarifária" (see Chapter 4.3.) would not create a "fair" competitive environment. Furthermore, the tariff for PV should be set so that it allows it to compete not only with hydropower, but also with the other new renewable sources.

Another possibility is differentiating the tariffs by location, so to avoid windfall profits. This allows for a policy combining net metering with a feed-in law, in which the differentiation is made according to grid-parity. To the regions that have already reached grid-parity, a net metering system would be applied. For all other regions, and for large-scale PV applications, a FIT would be implemented, in which a differentiation by location would be included – that means that tariffs would be lower in the regions closer to grid parity and higher in the ones with less favorable geographical conditions. This sort of differentiation would allow locations to be excluded from the scheme as soon as they reach grid-parity, therefore keeping the costs for the financing low.

Another possible differentiation, typical for emerging economies, regards the financing mechanism of the support policy. In case one opts for a feed-in law and for the distribution of costs among consumers, the tariffs should be differentiated among consumer classes. In Brazil, of the 55 million urban residential consumers, 18 million are classified as low-income residential consumers ("consumidores de baixa renda") (Rüther & Zilles, 2010). Therefore, this class should be exempt from participating in the financing mechanism.

Compliance with legislation: Brazil, like many other countries, is looking not only to expand the domestic use of renewable energy, but also to develop a local industry to serve this newly created demand. This is reflected in the wish to introduce a local content option (indice de nacionalização) in a support mechanism. Local content is defined as "the total value added to a national economy through the localized production of select services and key materials, equipment and goods related to target sectors of the economy" (CCI, 2011). This option, already present in the PROINFA, has also been approved by almost all of the interviewed experts. However, the PROINFA serves as an example to how a 60% obligatory rate for equipment and services from national production or national supply can spoil a support mechanism (Kissel et al., 2009). Therefore, one should consider the simultaneous introduction of a financial incentive for the development of local manufacturing capacities (P. C. Silva, personal communication, February 27, 2012).

Furthermore, a local content regulation bears the risk of being inconsistent with international trade law, which is overseen by the World Trade Organization (WTO) (Lewis, 2007). To this end, policies that require the use of domestically produced components could be construed as "protectionist" and therefore challenged as trade barriers (Lewis & Wiser, 2007).

Institutional controllability: This option refers mainly to the political enforceability within the context of existing regulation and to the transparency and the possibility of monitoring the instrument. In Brazil, a support policy might be difficult to enforce, because of the close connection between the state institutions responsible for implementation and the generation sector represented by Eletrobras. Even stronger opposition might be expected from the public utilities. Therefore, they have to be included in the design of the instrument. In order to achieve broad acceptance, the support mechanism has to be transparent and designed so that it keeps transaction costs low and prevents possible abuse.

Long-term planning and investment security: This is possibly the most significant design option (Kissel et al., 2009) and one of the reasons for which some feed-in laws, such as the one in Germany, have been so successful (Bechberger et al., 2003). From this point of view, a FIT offers more security than a net metering mechanism, because it guarantees both the price and the period of time to receive payment. In the Brazilian context, the proposed net metering mechanism would not even offer direct financial compensation for the excess energy (ANEEL, 2011a). It is therefore questionable, whether it can stimulate the creation of a local manufacturing industry.

The long-term planning and investment security could be increased by the introduction of a feed-in law, especially if it is limited in time and size, as proposed in the literature (Rüther &

Zilles, 2010). Nevertheless, only the existence of a FIT does not necessarily lead to more security. Rather it depends on the financing option included in the support policy. A widely used financing mechanism is the distribution of costs among consumers. Nevertheless, due to the particularities of the Brazilian residential sector, other financing mechanisms have been suggested (MME, 2009), which in turn influence the degree of security.

One of the possibilities for the financing mechanism is the Global Reversal Reserve (RGR)[53]. This fund was created in 1957 and is fed by monthly charges paid by concession holders (for power generation, transmission and distribution). It is used to fund projects to promote universal availability of energy, such as the LPT program, and energy efficiency. It was extended twice, in 2002 by Law no. 10.438/2002 and in 2011 by Law no. 12.431/2011 (Senado Federal, 2011a) and was valued at R$16 billion (US$ 9 billion) at the end of 2011 (Senado Federal, 2011b). Some of its financial resources could be used for financing grid-connected PV energy. This option, however, includes several risks (Mendonça et al., 2010): First, it is unstable in the event of political changes. Second, depending on the duration of the support scheme, it has to set aside large reserves, as tariff payment has to be guaranteed over a certain period of time. Due to these reasons, it might not provide the desired long-term planning and investment security.

Last but not least, an additional aspect has to be counted among the relevant design options of a policy in Brazil: the inclusion in the policy of a provision connecting it to public or private financing. This option is not found in the extended environmental policy analysis model, because the availability of and access to finance depend on the country specific investment climate (World Bank, 2007). The model included only general framework conditions, which are more likely to be encountered in other emerging economies. Furthermore, support policies are usually financially sustainable, which in turn fosters easy access to finance. In Brazil, the proposed financing mechanisms for a feed-in law or the fact that a net metering mechanism would not offer financial compensation for the excess energy might though lead to high financing costs for the realization of PV projects. This connection would thus help overcome this barrier and increase investment security.

This challenge has apparently been recognized by the Brazilian development bank (BNDES)[54], which has recently announced the release of R$4.5 billion (US$2.5 billion) for investments in renewable energy in 2012 (Instituto Ideal, 2012). This figure is significantly higher than the financing for 2010 and 2011. Furthermore, the bank has assured that for solar energy, credit lines similar to the ones for wind and small hydro are available. The minimum funding

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[53] RGR stands for Reserva Global de Reversão.

[54] BNDES stands for Banco Nacional de Desenvolvimento Econômico e Social.

requirement is R$10 million (US$ 5.5 million), the maximum contribution is 80% of the value of the project and the amortization period amounts up to 16 years (for more details see Annex 5) (BNDES, 2012).

For small-scale PV systems, the financing could be done through the program "Minha Casa, Minha Vida"/"My House My Life", which is implemented by the Brazilian state bank CAIXA[55]. This is a massive public housing campaign launched by the federal government with a budget of R$72 billion (US$40 billion) (The Rio Times, 2011). Otherwise, because of the expensive financing options available, the use of grid-connected solar PV and thus the "use" of grid-parity would only be open to those actors who can afford it (J. Kissel & D. Aßmann, personal communication, February 11, 2012).

Conclusion: The hypothesis according to which the design of the instrument is one of the most important determinants for introducing a support policy for grid-connected PV has been validated. Despite the fact that Brazil has not yet enacted any support policy, the design aspects were applied to two price-based regulatory policies, which have been considered in the Brazilian context (according to the literature and the experts). These are net metering and a feed-in law. Two design aspects are especially relevant for both policies: First, the compliance with existing legislation has to be insured. A local content component might be considered "protectionist" and challenged by the WTO. Furthermore, it might not lead to the development of a local industry, as long as it is not connected to a financing mechanism for PV manufacturing companies wanting to settle in Brazil. Second, the access to public and private finance has to be anchored in the policy. This could offset the difficulties that Brazilian companies and consumers face when making long-term investments.

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[55] The bank's full name is Caixa Econômica Federal.

8. Conclusions and recommendations

This paper provides insight into the relevant framework conditions for the introduction of a policy that promotes grid-connected PV in Brazil. These determinants are illustrated in the extended environmental policy analysis model, an own adaptation of Jänicke (2003) and Bechberger et al. (2003). The framework conditions are divided into structural and situational framework conditions, actors and policy instruments. Each of them was operationalized by means of concrete aspects and a hypothesis for their relevance was put forward (see Chapter 2.3.). Subsequently, the application of these aspects to the Brazilian case was described (Chapters 4 to 7). The goal was for these aspects to give an indication of whether a given framework condition is or is not relevant for the introduction of a support policy in Brazil.

Having completed this analysis, the framework conditions can now be grouped according to their possible influence on the introduction of a support policy: The ones supporting the introduction – having a positive impact – are considered to be drivers. The ones hindering the introduction – having a negative impact – are considered to be barriers. Not all conditions could be sorted in one of these two categories, so there are some that can function both as a driver and as a barrier (see Table 8).

Table 8 Framework conditions according to their influence (based on own perception)

Framework condition	Classification	Relevant aspects
Structural framework conditions		
Geographical conditions	Driver/Barrier	For: availability of solar resource and of silicon reserves Against: availability of other energy resources, with high untapped potential (hydropower)
Political environment – Energy and climate policies	Driver	For: the existence of climate policies, the inclusion of renewable energy goals in the energy policy
Economic environment	Barrier	Against: the low price of hydropower as compared to solar PV due to not internalizing negative externalities

Technological developments	Driver/Barrier	For: the learning curve of solar PV Against: the lack of manufacturing capacities in the country coupled with difficulties in regard to the local content instrument design option
Cognitive environment	Driver	For: the existence of experts and their inclusion in the energy planning
Situational framework conditions	Driver	For: recent and future events opening a “policy window” for solar PV
Actors	Driver/Barrier	For: the creation and development of a solar PV lobby group Against: the existence of other established lobby groups and the close connection between the state and the traditional energy sector
Strategies/Instruments	Driver	For: the discussed options suggest a good design of the policy, which in turn influences the chances of its adoption

Source: own representation

According to my own perception, the most important framework conditions are the technological developments and the design of the policy instrument: First, the technological developments are the framework condition most closely related to the costs of solar PV, and costs are considered to be the main barrier to introducing this technology in Brazil. As shown in Chapter 4.4., the solar PV technology has a significant cost reduction potential for its deployment in Brazil. On one hand, the learning curve shows that with each doubling of the installed capacity, the manufacturing costs for solar modules decrease by 20%. On the other hand, the development of a local PV manufacturing industry can lower costs even further, because the modules don’t have to be imported expensively.

Second, the design of the instrument is essential to any support policy that the Brazilian government chooses to introduce. The existence of a policy does not necessarily guarantee successful implementation. In contrast, a well-thought-out design that is in accordance with the realities of the Brazilian case, can lead to a policy encountering less opposition and being more easily deployed. It is furthermore important to note that in Brazil's case, the inclusion in the support policy of a provision connecting it to public or private financing might lead to increasing the investment security through favorable and reliable credits. Since this design option might also be valid for other emerging economies, it could be included in the extended environmental policy model.

Brazil is endowed with abundant renewable energy resources and their existence creates a competitive environment for solar PV. However, there are sufficient reasons to introduce a support policy for its deployment: Brazil is a large country with decentralized settlements, has a high solar radiation, commands vast reserves of silicon, and the decentralized character of solar PV is a good fit to the daily demand curve in commercial areas with a high midday peak. The main bottleneck remains the high cost of PV energy as compared to other electricity sources.

Policy analyses are often used as means to provide policy recommendations. This paper thus seeks to provide recommendations to both local policymakers and those in countries with similar challenges in regard to their energy policy. First, they are advised to detach themselves from misconceptions related to certain energy sources. For instance, large hydropower as a renewable source forms the basis for Brazil's electricity generation. But renewable does not necessarily mean sustainable. Large hydroelectric dams cause significant impacts both in the phase of their construction and during their operation. The diversification of the energy mix will only gain speed if the dominant mentality on this topic is changed. Furthermore, future climate change impacts might change the hydrological regime, leaving Brazil more vulnerable to droughts. In conclusion, due to the high dependence on hydroelectricity, the security of supply and thereby the continuation of sustained economic growth might be endangered.

Second, the current connections between the government institutions and the government-owned Eletrobras, which represents the traditional power sector, have been identified as a barrier in developing other RE sources. Therefore, a decoupling of the agenda-setting process of the responsible institutions from the interests of the traditional energy sector might result in a quicker and more successful deployment of solar PV.

Last but not least, the informational basis for both policymakers and the public has to be improved and diversified. The observed progress towards the introduction of a support policy for solar PV in Brazil is also due to the efforts of university professors, who have initiated various efforts to disseminate their expertise. The role of the universities in continuing research and preparing a skilled workforce, which will be available to facilitate the implementation of the policy, is not to be neglected.

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Annexes