BOOKLETS

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DISTRIBUTED ENERGY RESOURCES

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Institution of technical and scientific, educational, and charitable nature created on December 20, 1944 as a private legal entity with the purpose of fully acting in all scientific matters, and emphasizing in the field of social sciences: administration, law and economy, thus contributing to the country's social and economic development.

Acknowledgements

This booklet provides a reflection on Distributed Energy Resources (DER) and their inclusion in the Brazilian power market. Distributed energy, energy efficiency, demand management and energy storage comprise this set of resources, which working closely to the final use of energy, is capable of providing solutions - both from the side of the offer and from the side of the demand - that contribute to balance the energy service.

The understanding about Distributed Energy Resources in Brazil has much to gain in the interaction between national research centers and researchers and professionals from abroad. Thus, we would like to thank the collaboration from several professionals in Brazil and abroad during the preparation of this booklet. We believe the experiences researched when preparing this publication, and now shared with the public in general, may help to better understand and develop DER in Brazil.

On behalf of **FGV Energia**, we thank everyone who provided time to talk about this theme, as well as produced the articles included in this booklet: Ahmad Faruqui, Alex Sandro Feil, Dirk Uwe Sauer, Jorge Luiz Stark Filho, Julia Badeda, Juliana Leão, Kai-Philipp Kairies, Kateri Callahan, Kevin Lucas, Lori B. Brutten, Lucas Bressan, Luiz Moraes Jr., Manuella Lion, Márcio Venício Pilar Alcântara, Matt Stokes, Neil Gerber, Nélson Leite, Richard Kauffman, Ryan Hledik, Solange Bezerra, Tiago Correia, Tais Palácio and other professionals who also contributed to this project.

We also take this opportunity to thank our colleagues at FGV Energia. Maintaining a collaborative research environment, where debate and questioning of multidisciplinary questions affecting the energy sector are daily activities is essential to better understand the policies that affect not only the industry but the country as a whole.

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Table of Contents

PRESENTATION

The Brazilian Electricity Sector (SEB) has been deepening the discussion on tradeoff between environmental and climatic concern, and energy safety. With a reduced capacity of regulating reservoirs and the consequent, almost continuous, flow of thermal power plants since 2012, the search for energy solutions capable of diversifying the Brazilian matrix in a safe and clean way became a key challenge in the scope of national energy policies.

In the global scenario, the signature of the Paris Agreement in the United Nations Climate Change Conference (COP 21), on December, 2015 - and further signature on April, 2016 - strengthens the need to further discuss cleaner energy sources in Brazil. In addition, the growing change in power consumers' behavior in several countries points to a new global trend in power demand, which will arrive in Brazil sooner or later.

Consumers, passive agents in the power sector model before, have been showing an increasingly active behavior in the way they demand power and in relation to the services they can extract from their power consumption. Technology advancements, especially on the demand side, have an important role in this behavioral change of consumers.

Such global and national trends, in addition to SEB peculiarities - predominantly hydroelectric generation and of large size, centralized operation and integrated transmission system basically all over the country - point to the importance of planning and a more effective inclusion in other energy resources available. The Distributed Energy Resources stand out among these resources.

The Distributed Energy Resources work both from the demand and offer sides, and comprise[1]:

1. Bradford et al, 2013.

i. Distributed Generation[2]

ii. Energy Storage

iii. Energy Efficiency, and

iv. Demand Management

From the network operation viewpoint, these resources generally take to the same result: they reduce or transform the load that the network needs to meet. This characteristic is enough to raise the need for studies on DER on its own, once they promote changes to the economic structure of the entire system[3]. From the consumer viewpoint, DER allow for a greater participation in generation and management of the consumption of their own energy.

The challenge of incorporating DER to current electrical models is structural once the change must be made to how these models are thought through. Only introducing some DER elements to current models may not only generate several inefficiencies, but also waste potential benefits these resources may provide. In short, the possible entry of all DER elements in SEB shall imply disturbances in the current structure of the model. Therefore, this booklet will aim at promoting a discussion about distributed energy resources and how their inclusion may change the Brazilian power industry.

2. Not all distributed energy comes from renewable sources. Diesel generators, for example, may generate more pollutants than traditional centralized energy. However, this booklet shall focus on including clean distributed energy in the power matrix.

3. Bradford *et. al.*, 2013.

The Distributed Energy Resources Concept

DISTRIBUTED GENERATION

Just as distributed generation is new to power markets, it is also an old concept, which fell into disuse from the evolution of power generation to a centralized system. At the beginning of electricity development, power was generated through small generating plants close to consumer units. Thus, it can be said that distributed generation is not being included in the power model; it is being reintroduced, since the current model no longer completely responds to all the needs of agents involved in it. Specifically, recent technology progresses have been contributing to transform the relation between end consumer and energy.

Distributed generation may be defined as an electricity source directly connected to the distribution network or located at the consumer's[4]. In Brazil, DG definition is provided in Article 14 of **Decree-Law no. 5.163/2004**:

> "Distributed generation is considered any and all production of electricity from assignees, licensees or authorized agents (...) directly connected to the distribution electrical system of the buyer, except those from: (i) hydroelectric power with installed capacity exceeding 30 MW; (ii) thermoelectric[5], including cogeneration, with energy efficiency below 75%."

4. Ackerman *et. al.*, 2001.
5. Thermal power projects using biomass or process waste as biofuel shall not be limited to energy efficiency percentage of 75%.

In addition, the Decree provides that the utility company interested in hiring energy from distributed generation shall prepare a public notice to inform other possible agents interested. As per Art. 15 of the same decree, the limit for such hiring, however, is 10% of the load of the distribution agent[6].

In addition to this Decree, the Brazilian regulatory framework associated with distributed generation is represented by three important Resolutions:

- **Normative Resolution no. 167/2005**, which provides for conditions to trade energy from distributed generation;
- **Normative Resolution no. 482/2012**, responsible for establishing the general conditions to access micro and mini generation distributed to electricity distribution systems; and

6. Brazil, 2004. For self-projects, there is no 10% limit.

The power network available is used as a backup when the energy generated locally is not sufficient to meet the “prosumer” demand needs

- **Normative Resolution no. 687/2015**, which improves Resolution 482 in order to reduce barriers for the development of distributed generation in Brazil.

In Brazil, distributed generation is based on net metering, in which consumer-generator (or “prosumer” - producer and consumer), after discounting his/her own consumption, receives a credit in the account for the positive balance of energy generated and included in the network (energy compensation system). Whenever there is this positive balance, consumers receive a credit for energy (in kWh) in their next bill and will have up to 60 months to consume it. However, “prosumers” are not allowed to trade the exceeding amount of energy generated through DG among them[7].

The energy network available is used as a backup when the energy generated locally is not sufficient to meet the “prosumer” demand needs - which is usually the case for intermittent energy sources, such as solar.

However, the net metering system is criticized by several agents. “Prosumers” argument that the benefit they provide for the system is not entirely measured, such as the reduced emission of pollutant gases due to the greater use of renewable sources, for example. On the other hand, utility companies and consumers that do not use distributed generation claim that the costs for maintaining this network as a backup for DG are passed disproportionately to them, due to the current rate. Such matter will be further discussed in the next chapter.

7. The new resolution enables consumers to gather in consortium to acquire power by distributed generation of an independent third-party micro-producer. The consortium term, however, cannot allow the payment to vary with the volume of power traded. The consortium agreement should stipulate a fixed amount to be paid for power.

ARTICLE

Distributed generation is an initiative that combines economy and sustainability

Tiago Correia, director of the Brazilian Electricity Regulatory Agency (ANEEL)

Since April, 2012, when the Power Compensation System was created, Brazilian consumers may generate their own energy from renewable sources or qualified cogeneration and provide the surplus to the network of their distribution concessionaire. Such generation, connected to the network through consumer units, is called distributed micro generation (installed power up to 75 kW) or distributed mini generation (power above 75 kW and below 5 MW).

Both the compensation system and general conditions to the distribution system's access of micro and mini generation were established by the Brazilian Electricity Regulatory Agency (ANEEL) in ANEEL Normative Resolution no. 482/2012, regulation that enabled progress in relations between consumers and their utility company, and combines technology innovation, financial economy, social and environmental awareness and sustainability.

The compensation system, also known as net metering, allows that the active energy injected per consumer unit with micro or mini generation is granted, through free loan, to the local utility company and is later compensated with active power consumption. Generate energy credits are valid for 60 months.

This system encourages the generation of power close to the load, thus implying potential benefits for the Brazilian power industry, such as: diversification of the energy matrix with low environmental impact; creation of direct and indirect jobs associated to the installation; and promotion of the national industry. Other advantages of distributed generation over the traditional centralized one are, for example, the economy in transmission investments, reduced losses in networks and improved quality in the electricity service.

In order to reduce current barriers to the implementation of distributed generation, I had the opportunity to report the process of review of this standard, approved unanimously by the Collegiate Directorate of ANEEL in November, 2015.

The review of resolution 482, which came into force on March 1, 2016, established four different configuration forms to use the energy generated through micro or mini distributed generation: local use, remote self-consumption, developments of multiple consumer units and shared generation. The first two configurations (local use and remote self-consumption) consist, respectively, in the generation of power at the same consumer unit and credits will be used to deduct consumption and use surplus credits of a particular consumer unit in other facility of the same owner (same CPF or same CNPJ). Both possibilities already existed in the Normative Resolution no. 482/2012 original text and were only enhanced in 2015's review.

A third form of participation in the Compensation System is made through ventures with multiple consumer units to install micro or mini generation in condominium with apportionment of credits between tenants at percentages previously defined by the own condominium. The fourth and last possibility of arrangement for participation is through shared generation. In this scheme, a group of consumers of a certain concession are may gather in a consortium or cooperative, install a micro or mini distributed generation on behalf of such consortium/cooperative and share the energy credits among all associates in order to reduce the amount of their bills.

Reduced cash flow of utility companies was also estimated in the regulatory impact analysis, from the variation in low voltage market revenue in 2024 without the distributed generation and the revenue this market would have for each scenario of inclusion of micro generation. However, as consumers bills will be increased, part of the reduction noted by utility companies is deducted. Reduced energy bill for consumers with distributed generation was calculated from the sum of their average economy for each scenario in 2024. With this, it was concluded that the measure provides low economic cost for distribution concessionaires and average economic gain for consumers - which makes it beneficial.

Simulations made by the Agency showed only 200 thousand consumer units with installed capacity of nearly 500 MW in 2019 in the most optimistic scenario. A major acceleration in the number of new systems would take place only after 2020, when over one million consumer units and 4.000 MW additional installations are expected. In this sense, a new review of the standard focusing on the economic aspect should be made until the end of 2019. After such review, ANEEL shall certainly preserve the principle of regulatory safety and maintain the legal status of consumers that may join the distributed generation system during the term of the current version of the standard.

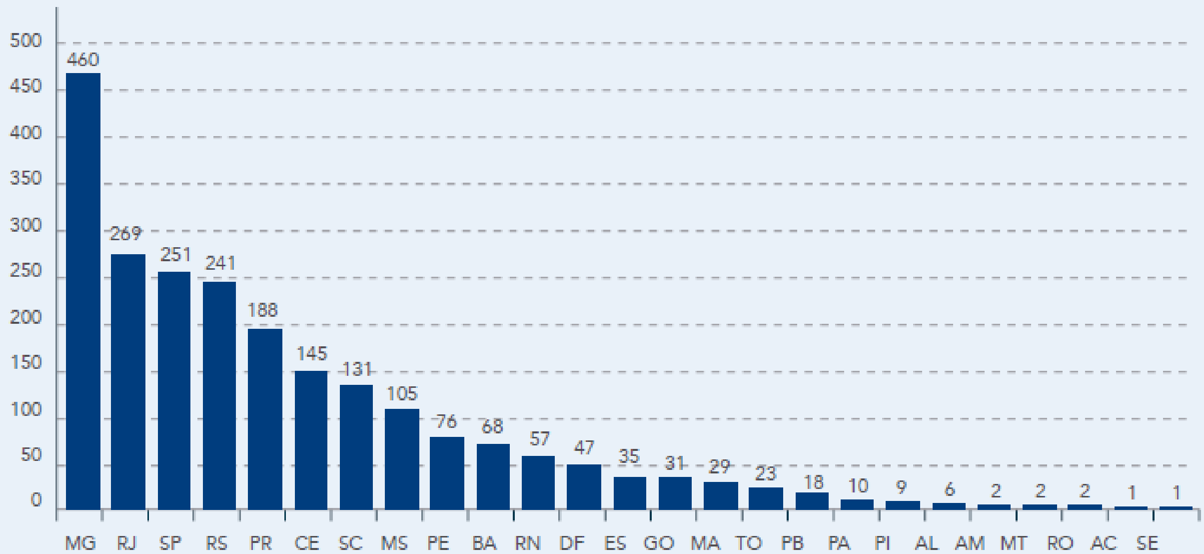
However, not all barriers to the implementation of distributed generation are the competence of the regulatory body. The tax matter, for example, implied a broad dialogue between

ANEEL and the National Council for Financial Policy (Confaz). The initiative resulted in ICMS 16/15 covenant with 15 units of the Federation currently part of it (SP, PE, GO, AC, AL, MG, RJ, RS, RN, CE, TO, BA, MA, MT, DF). Emphasizing that, in addition to joining the covenant, each State needs to publish its decree to incorporate the exemption so that consumers receive the benefit is important. The chart below shows connections per Federation Unit until January, 2016.

In addition to applying the ICMS, there are still other challenges currently faced by micro distributed generation. Special emphasis should be given to the need of disclosure and lack of broad and attractive finance facilities.

Despite this, ANEEL expects a strong growth in distributed generation. In an estimate for 2024, the almost 2,000 current installation may exceed 1.2 million consumers, with an installed capacity above 4,500

FIGURE 1: NUMBER OF CONNECTIONS PER FEDERATION UNIT

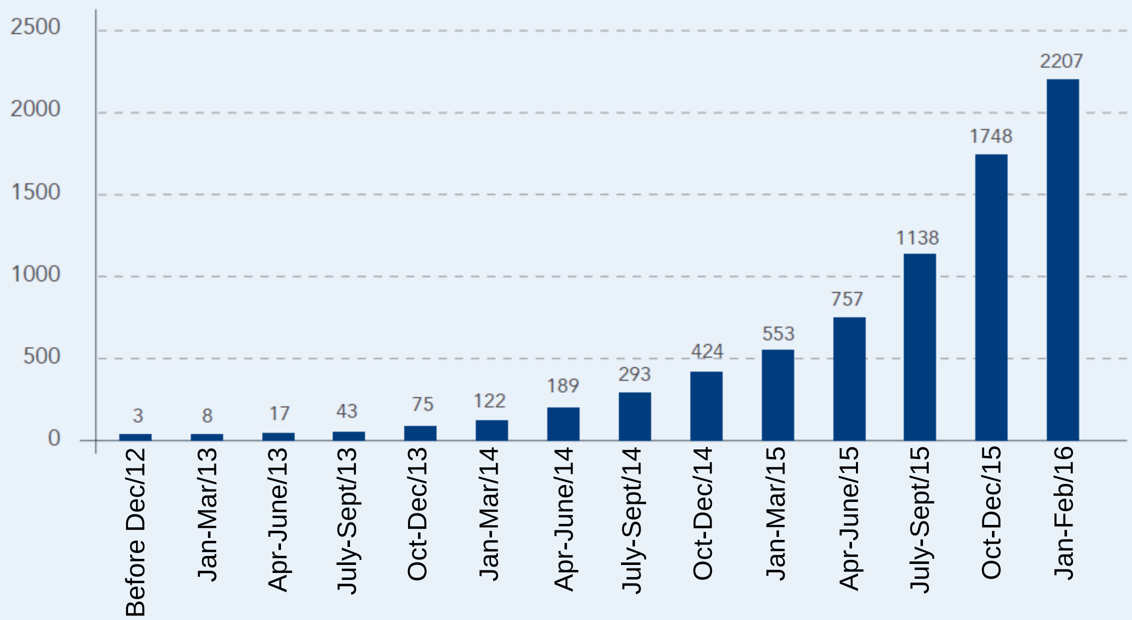


megawatts (MW) - which corresponds to the supply of a State like Santa Catarina

- as shown by the chart below. With this level of adhesion to distributed generation, it will be possible to have economies of scale in installations and, consequently, the possible development of a national industry.

I joined and I am implementing a 2,040 Watts-peak (Wp, energy power measure usually associated with photovoltaic cells) installation at my house. It is a good thing that will bring an economy of R$ 1,900 per year and investment returned expected of almost seven years, without considering the positive impact on the property value and especially the initiative that points to a new, more conscious and sustainable attitude.

FIGURE 2: ACCUMULATED NUMBER OF CONNECTIONS



ARTICLE

Distributed Generation dilemmas in Brazil

Nelson Fonseca Leite,
President of the Brazilian Association of Electricity Distributors
(ABRADEE)

The electricity distribution segment has been facing one sudden surprise after another in Brazil. From 2013 to 2015, an explosive mix of unfavorable hydrological condition with subcontracted utility companies led to a financial imbalance with consequences persisting until today.

In 2013 and 2014, the strategy was to avoid transferring high costs for rates, which led to contributions from the treasury at first and later to loans through the Electric Energy Trading Chamber with payment guarantee when such costs were transferred to rates. This was started in 2015, with the rate realism. Due to the economic retraction, the market collapsed and the sector started to live a completely opposite reality. Energy contracted by utility companies started to be leftover, at the same time energy prices in the so-called short-term market collapsed.

Utility companies must buy energy in regulated auctions. In the current model of the Brazilian power industry, the expansion of the generation park is ensured by funding new plants tied in long-term agreements generators sign with utility companies, which by virtue of their concession agreements must ensure supply to a given area wherein they exercise a monopoly of supply. Therefore, they receive long-term energy purchase agreements with generators that use the guarantee of receivables to finance their projects and thus expand the segment. The model also provides that each distributor can serve up to 10% of its market with energy acquired from distributed generation in their area of concession. The big debate is because utility companies do not use this resource so much. The answer lies on the transfer of rates, which would depend on the maximum amounts established because of past auctions and cause uncertainty, thus being able to bring losses to utility companies.

Concepts of micro and mini distributed generation are a lot discussed today. In fact, it seems that they are a trend and will help to expand the generation, as some consumers may generate part of the energy they consume by injecting or demanding residual amounts of their consumption from the electrical network. However, defining how to remunerate power plants so that they are able to perform such services with increasing quality is also necessary.

Recently, ANEEL's board approved changes to Resolution no. 482/12 with the publication of Resolution no. 687/15 regulating the energy compensation process for these generators. Approved changes include the expansion of sources that can be used; the expansion of limit of the generating central from 1 MW to 5 MW; increased validity of credits from 36 to 60 months; possibility of installing generation in condominiums; possibility of several consumers gather to implement shared generation; implementation of standard forms to request access and reduced deadlines involved in this process. The Agency board expect these changes to facilitate expanding the use of photovoltaic solar power.

During a debate on the proposed changes, ABRADEE presented its contributions for a healthier and sustainable development of this system; however, they were not accepted. Our vision of sustainability is coherent with its three pillars: environmental, economic and social.

There are no controversies on the environmental sustainability of this incentive system for alternative sources, especially in mini and micro generation. By the end of last year, directors of over 180 countries in the world met in Paris for the Climate Conference. Goals to reduce carbon emissions until 2030 were discussed during the event. The power generation industry burns fossil fuels in thermal plants, and is one of the villains emitting these gases that cause increased temperature on Earth. Brazil has one of the cleanest energy matrices in the world. Over 80% of the power generated in our country comes from renewable sources. Aggregating more generation of renewable sources shall contribute to make the Brazilian energy matrix even cleaner.

However, the current regulation does not meet two other sustainability requirements. First because it depends on rate subsidies, that is, it is not sustainable in the economic requirement; and second, it is a perverse subsidy because it will compulsorily reduce the value of the electricity distribution sector and, thereafter, will increase rates for other consumers, including low-income consumers. That is, it is also not sustainable from the social viewpoint as those who have conditions for acquiring equipment for photovoltaic micro generation will be benefitted, but consumers not able to acquire it will have to bear the highest use rate to compensate for others who will stop paying.

The international experience shows that such arrangements are unsustainable in the long run. Several European countries are reviewing their policies to mix fiscal constraints (economic requirement) and the rate impact for other consumers (social sustainability requirement).

Applying a binomial rate is simple to implement. The binomial rate separates the low voltage energy wire use, as it already happens for medium voltage users.

This allowance is not a mere illusion. It is recognized in the documentation prepared by ANEEL, and also has an estimate of amounts involved.

Several proposals were prepared to make the development of the compensation system sustainable. Applying a binomial rate is simple to implement. The binomial rate separates the low voltage energy wire use, as it already happens for medium voltage users. It has no technical restriction as the bidirectional meter that will be installed to measure the consumption balance and energy injection has this functionality.

Despite the sound arguments that Decree no. 86.463/81 granted powers to DNAEE (National Department of Water and Electric Power) to establish different rates for each destination, the Agency understands that a change to Decree no. 62.724/68 is necessary to allow such charge of the system use parcel for low voltage services. It was curious to note that the regulation proposing to encourage the new under unsustainable conditions had to refer to the old, at a time when photovoltaic plates belonged to artificial satellites and men of the space.

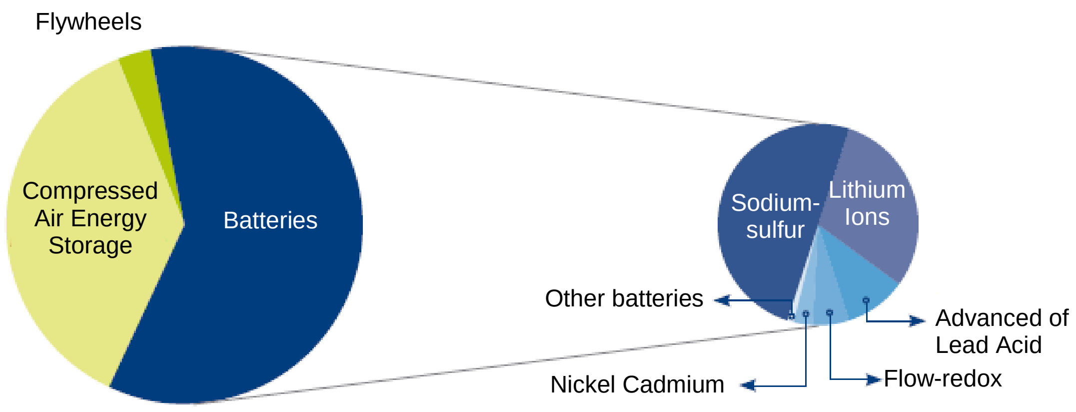
There is no use in promoting sustainability only in the environmental aspect if we ignore the other two, because we will be leaving future generations with a system that is not sustainable in its economic and social dimensions.

STORAGE OF POWER

Knowing that supplementary renewable energies[8] as solar and wind present a major challenge associated with its intermittency[9] and flow, part of barriers to its dissemination is related to the advancement of storage technologies along with the consumer. These systems allow to leverage moments of excessive power generation and store it in order to use it in moments of scarcity.

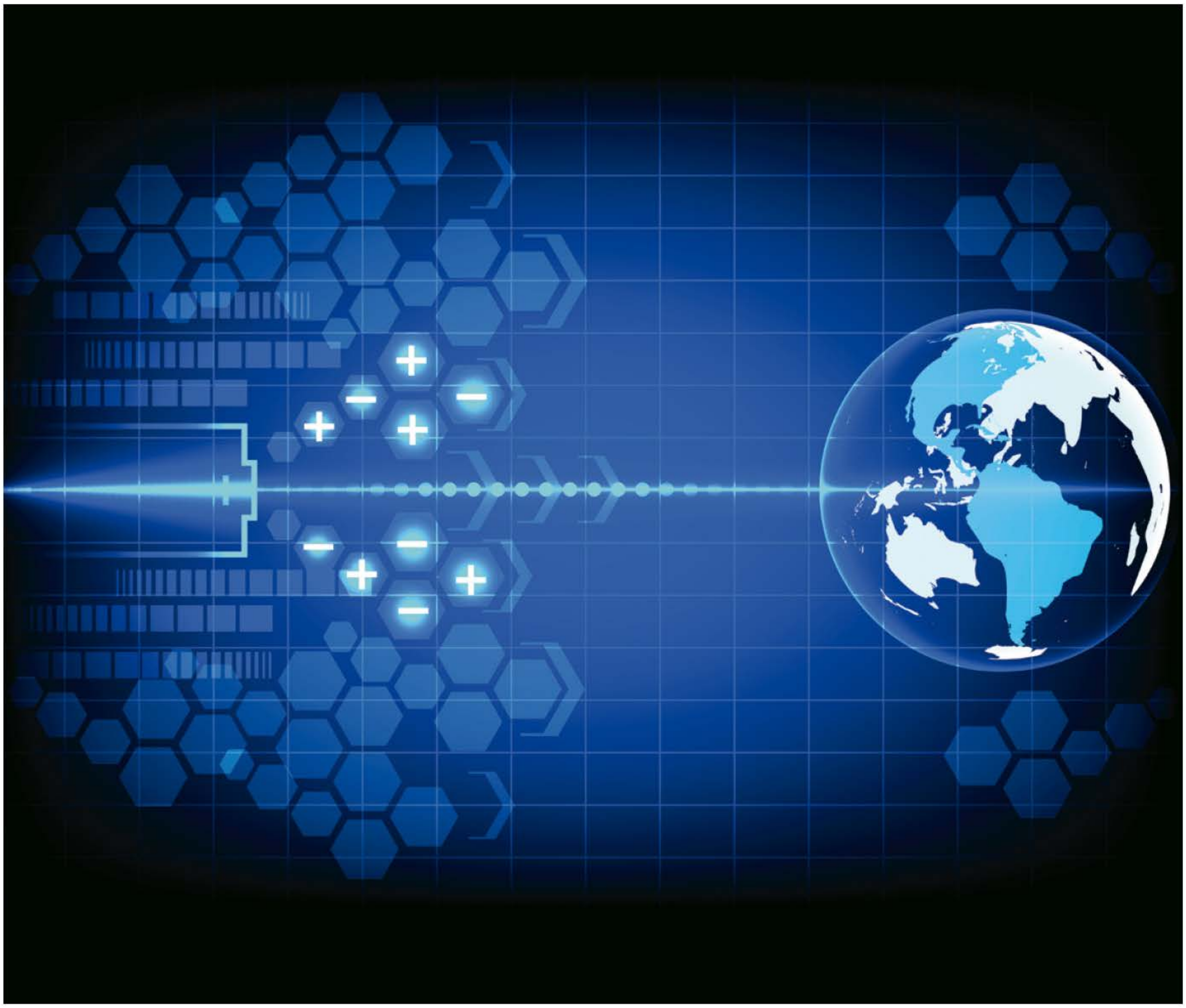
Currently, classification[10] of power storage system can be made in three different forms: mechanical storage (pumped-storage hydropower - PSH, compressed air energy storage (CAES) and flywheels); electrical energy storage (superconducting coils and capacitors); and electrochemical storage (hydrogen and batteries technologies)[11]. Storage technologies in global systems summed 143 GW of installed capacity until 2014. Most of this capacity (over 99%) is comprised by mechanical storage technologies (PSH with 142 GW, CAES with 440 MW, and flywheels with only 25 MW) and the rest (Figure 3) is comprised by electrochemical storage through a mix of batteries (801 MW)[12].

FIGURE 3: INSTALLED CAPACITY IN STORAGE SYSTEMS - EXCEPT PUMPED STORAGE HYDROPOWER (MW) IN 2014



Source: Adapted from IRENA, 2015b.

8. Further information on FGV Energia, 2015.
9. Intermittency: when energy cannot be continuously supplied due to uncontrollable factors (Source: http://energiaheliotermica.gov.br/pt-br/glossario).
10. dena, 2016.
11. For a better description of storage systems, please check IEA (2014), Page 20.
12. Storage of electrical power as a distributed energy resource is still under research and development phase around the world. The United States Energy Department database provides a current list of storage projects in the world (Source: DOE Global Energy Storage Database).



However, recent progresses associated with electrochemical storage technologies, especially lithium batteries, point to a new trend for the sector. Batteries are attractive due to the possibility of implementation close to consumers (consumer-sited storage or consumer-located storage[13]), thus providing short-term benefits, and in remote areas not served by the network. In addition, batteries are interesting for agents interested in diversifying their energy use, whether in electric vehicles or distributed generation (DG) and intermittent generation.

13. Bradford et al., 2013

Storage technologies are more advanced abroad; therefore, it is important for Brazil to follow and bring this progress to the country as it moves forward.

Investments in batteries have increased significantly within the last years. Gigafactory, Tesla's super factor in partnership with Panasonic, is expected to open in 2017 and may contribute even further to reduce the price of rechargeable lithium-ion batteries and increase the total storage capacity of this type of technology until 2020[14]. Another initiative that may contribute to the growth in storage market is Honda Power Exporter 9000 launching, a device that enables the energy stored in electric vehicles battery to be transferred to the electrical network (vehicle-to-grid system). When connected to a car battery, Power Exporter 9000 provides up to 9kW of power for a week. The price should be announced in the first quarter of 2016[15].

The development of new energy storage technologies close to consumers is supplementary to the one of distributed generation. After the evolution and reduced cost of batteries and electric vehicles, "prosumers" may store generated energy that is not consumed. Depending on the amount of stored energy, they may even occasionally disconnect from the network.

Technologies development to store energy is still incipient in Brazil. According to information from ANEEL[16], a strategic research and development (R&D) program was recently launched focusing on studies of energy storage in the country for all storage technologies. Storage technologies are more advanced abroad; therefore, it is important for Brazil to follow and bring this progress to the country as it moves forward.

14. IRENA, 2015b.
15. Stevens, 2015 and EV Expert, 2015.
16. Source: Consultation made with an expert from ANEEL.

ARTICLE

Energy Storage Systems: Current trends and the impact of COP21

Julia Badeda [a,b,c,]

Luiz Moraes Jr. [b,c,]

Kai-Philipp Kairies [b,c,]

Dirk Uwe Sauera [a,b,c]

1. COP21 DECISIONS AND THEIR IMPACT ON THE DEVELOPMENT OF ENERGY STORAGE SYSTEMS

The 21st Conference of Parties (COP 21) established a new context defined by a political will to gradually phase out the era of fossil fuels in the energy sector, supported by many and important countries and companies. The agreement focuses on actions that help to maintain average temperature increase below 2°C, with efforts to limit such increase to 1.5 °C. This includes reduced emissions of CO_2, which may be reached with measures including increased participation of renewable sources systems in power generation.

Important investors see opportunities from renewable energies and consequent need for storage solutions.[17] The International Energy Agency (IEA) recent report established the market transition for a low carbon future in which "(...) the storage and the answer of demand may transform traditional energy markets."[18] Huge investment funds are starting to divest its holdings in companies focused on fossil fuels. Examples include the Rockefeller family fund that is reducing the participation at Exxon Mobil[20], in addition to the Norway[19] pensions fund and the insurer Allianz[21].

a. Electrochemical Energy Conversion and Storage Systems Group, Institute for Power Electronics and Electrical Drives (ISEA), RWTH Aachen University, Germany

b. Institute for Power Generation and Storage Systems (PGS), E.ON ERC, RWTH Aachen University, Germany

c. Jülich Aachen Research Alliance, JARA-Energy, Germany

17. Breakthrough Energy Coalition, 2016.
18. IEA, 2016.
19. Wade & Driver, 2016.
20. Carrington, 2015.
21. Associated Press, 2015.

COP21 agreement provides for a long-term insurance for investors and will lead to increased financial boost for clean technologies and Energy Storage Systems (ESS). Increased financial support may also be observed in green bonds emission in the amount of almost US$ 50 billion per year.[22]

Within such global context, future average electrical networks will probably include a large proportion of fluctuating renewable energy systems (FRE). Wind and photovoltaic generation - with competitive current costs of generation of 0.04 and 0.08 €/kWh - will perform an important role in the power market, which will have greater participation in primary energy consumption of countries. In such systems where demand and generation are not entirely aligned, ESS provide a solution for time flexibility. ESS compensate for the lack of storage in thermal plants, which today is made with coal deposits or gas tanks. In addition to the capacity of incorporating FRE to the electrical system, ESS provide solutions for stabilizing the network and assistance during transition periods - such as activation after a blackout.

2. GENERAL CATEGORY OF ENERGY STORAGE SYSTEMS

ESS are already implemented in all energy markets - from the automotive sector, through air conditioning, and to electricity. In the future, these markets and their storage applications will be increasingly interconnected. ESS may be categorized according to physics, duration of discharge and power range. Some example of classification and associated storage options are provided in Table 1. A detailed description of several storage technologies and classifications can be found in other sources.[23]

Options to store energy may be divided into four main categories, which refer to physics behind a storage procedure:

1. Electrical, such as capacitors
2. Electrochemical, such as batteries
3. Mechanical, such as flywheels and pumped storage
4. Thermal, such as hot water tanks

22. Volcovici, 2016.
23. Fuchs *et al.*, 2012.

]

The size of the storage system is usually chosen based on its efficiency to store energy for short, medium or long periods - defined as per maximum duration of its discharge. This size also gives an idea of the economically feasible period to implement such technology.

Based on the size of the system and its goal, ESS will have different potentials and will be installed in different levels of the network. Large scale systems will be connected to high and medium voltage networks, while small scale photovoltaic units for domestic storage will be placed in the low voltage distribution network.

TABLE 1: EXAMPLES OF ESS CATEGORY IN THE ELECTRICITY MARKET

Examples of ESS in the electricity market		Short-term	Medium term	Long-term
	Duration of the discharge	Up to 15 min	1 to 10 hours	Days to weeks
	Power			
Central storage systems	100MW - 1GW		Water pumping	Gas storage systems
Modular storage systems	1kW - 10MW	Flywheels, Supercapacitors	System of storage in batteries Redox-Flow Batteries	
Multipurpose modular storage systems	1kW - 1MW	Electric vehicles	Photovoltaic domestic storage	

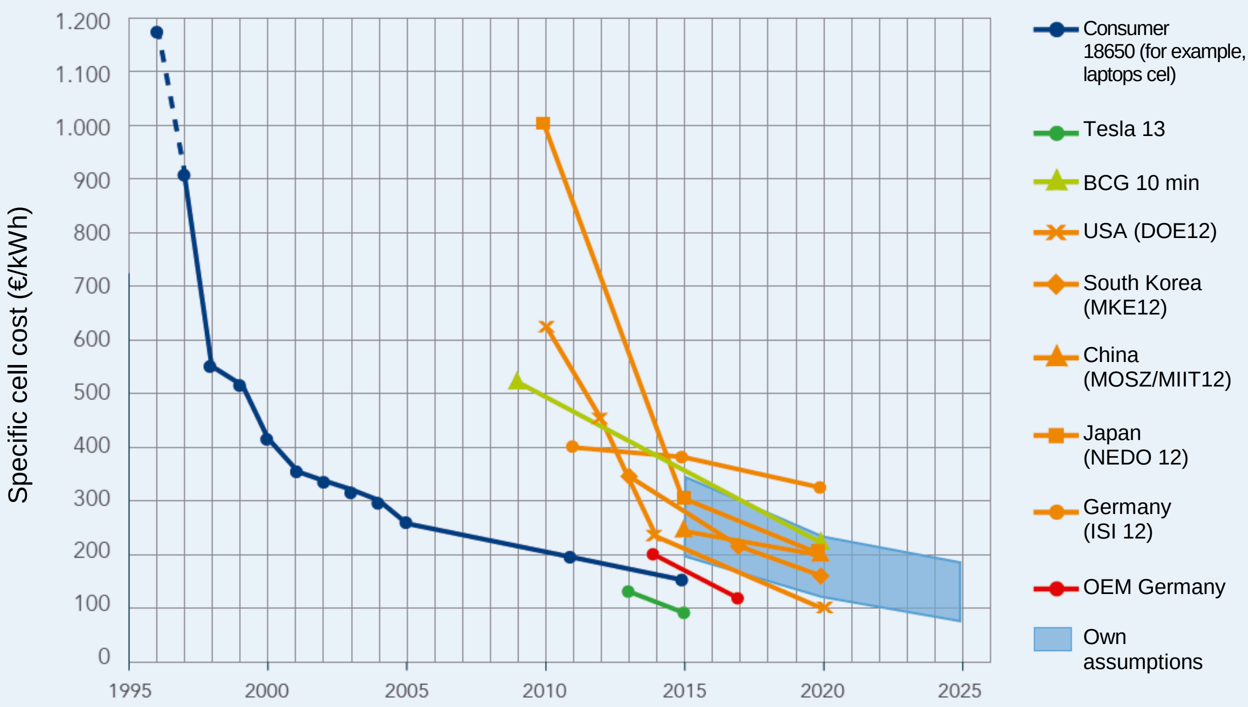
Source: Prepared by the author

3. CURRENT TRENDS

The market for ESS is being strongly developed. The Department of Energy (DOE) maps the most recognized ESS in the world in its database. The installed power almost tripled since 2006 (from 1.4 GW in 2006 to 3.8 GW in 2015).[24] Most of the existing power is in pumped hydro systems while most global projects are focused on electrochemical storage.

The pumped hydro technology is well established and may store energy for several hours, being normally used for daily cycles. Short or medium-term storage solutions are becoming increasingly important, as it happens in Germany, where FRE participation reaches 20% in energy generation.[25] With the dramatic drop in cells prices (Figure 4), lithium-ion batteries appear as a competitive solution in this field of application.

FIGURE 4: EVOLUTION IN PRICES OF LITHIUM-ION CELLS AND PRICES ANNOUNCED BY COMPANIES, AS WELL AS OLD AND FUTURE PRICES EXPECTATIONS FOR LITHIUM-ION BATTERIES*



Source: Prepared by the author

* The key informs the name of the institution and the year of publication of estimates.

24. Department of Energy 2016.

25. BMWi, 2016.

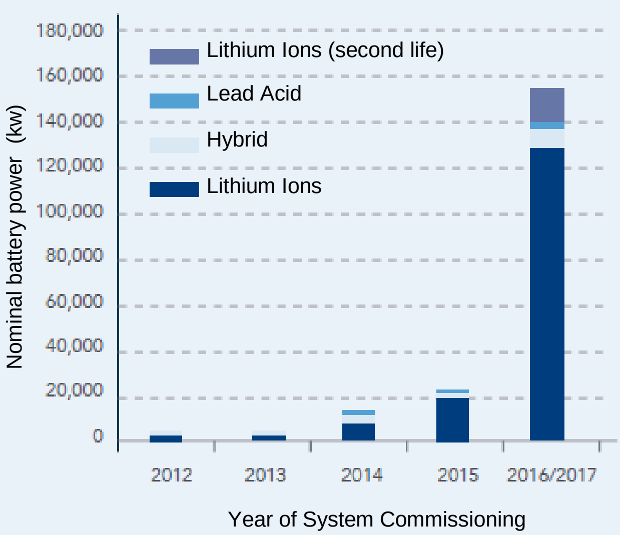
Reduction in prices is especially boosted by an overproduction of batteries for the automotive industry, which did not reach the expected number of electric vehicles on the market. Prices of cells were pressured for below 150 €/kWh in 2015. Automotive companies, as well as Information and Communication Technology (ICT) companies, are now investing in the stationary market with storage products with medium and small batteries.

3.1 MARKETS

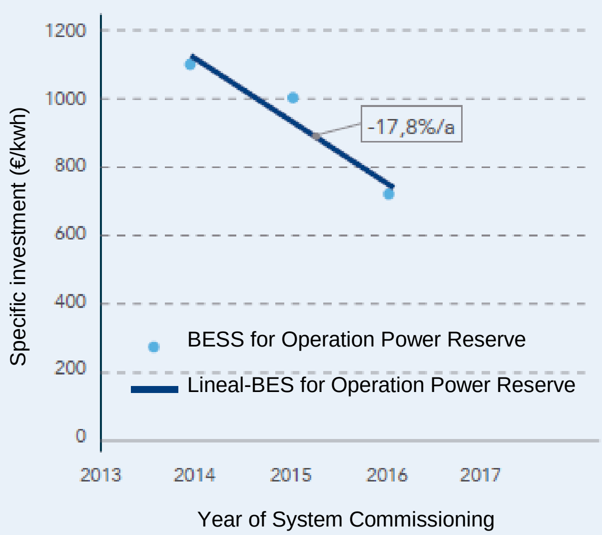
The race for short and medium-term storage batteries can be illustrated with Germany's example. In particular, the German market for primary frequency control is considered a profitable option for ESS[26] - in 2016 and 2017 additional 120 MW will be installed solely with this purpose (Figure 5). System prices, which were announced for three important projects, fell to 17.8% per year within the last two years.

FIGURE 5: INSTALLATION DEVELOPMENT OF A BATTERIES SYSTEM IN THE GERMAN MARKET FOR PRIMARY FREQUENCY CONTROL

Power installed since 2012



Reduction of prices based on the three projects announced publicly[27]



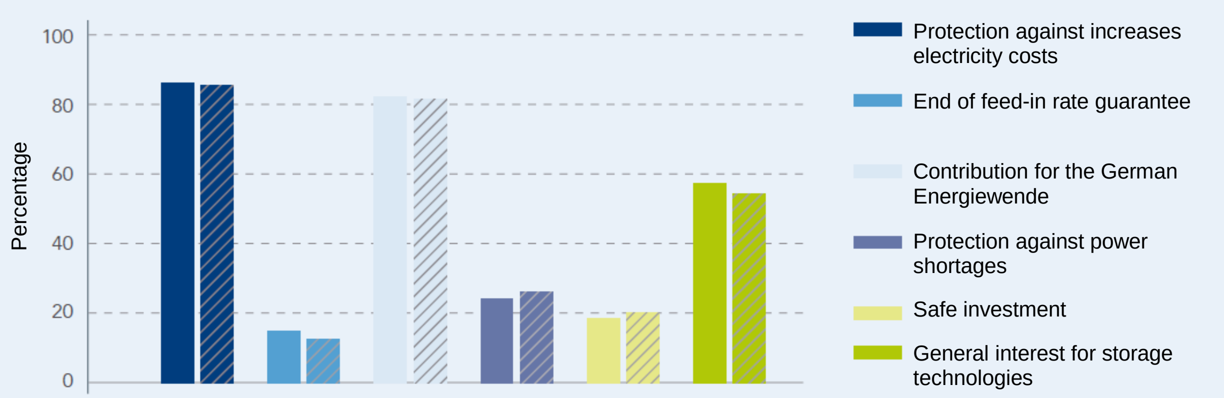
Source: Fleer, *et al.*, 2016

26. Fleer *et al.*, 2016.
27. *Ibid*.

This rapid development of large scale batteries systems may also be observed in the United Kingdom. In 2016, the National Grid Utility of the United Kingdom offered 200 MW to improve the frequency response capacity. Projects with batteries represent 68.3% of the total of 1.300 MW in projects presented. Additionally, the United States is already significant and operating, with 400 MW of electrochemical storage under operation.[28]

Another driver of batteries storage systems are the photovoltaic domestic storage systems, as well as the electric vehicles (EV) market. In particular, possibilities of synergies among multipurpose applications, where batteries purchased for a reason end up being implemented in another market (for example, frequency control), attract investments.[29] While the German market of electric vehicles is not being developed as fast as expected, the photovoltaic domestic storage segment exceeds expectations with almost 35,000 installations since 2013.[30] Batteries sum a virtual storage system of 100 MW/200 MWh with an average size of almost 6 kWh. However, until now the main goals include increased operator autonomy and load relief for the distribution network - goals ensured by restricting the peak power for the photovoltaic generation system. Current investments from private homes and small businesses in photovoltaic domestic systems is mainly encouraged by non-economic factors such as the desire to support the German “Energiewende”, as well as the interest in the technology itself (Figure 6).

FIGURE 6: MOTIVATION TO INSTALL PHOTOVOLTAIC DOMESTIC SYSTEMS (SURVEY MADE WITH ALL REGISTERED CONSUMERS).



Source: Prepared by the author   May, 2013 to December, 2014   January, 2015 to December, 2015

28. Strategen Consulting LLC, Department of Energy Storage Database, 2016.
29. IEA, 2016.
30. Kairies *et al.*, 2015.

ENERGY EFFICIENCY

Energy efficiency means using less energy to provide the same service[31], both from the offer and the demand side.[32] On the demand side, energy efficiency programs emphasize reduced consumption of energy for a long period in order to involve consumers' changes of habits and behaviors. Just as distributed generation, the advance in energy efficiency programs may reduce the need for investments in transmission lines and energy distribution. In addition, investments in efficient equipment usually represent one of the best forms to include DER once they reduce emissions effectively.[33]

Brazil has been making progresses associated to the implementation of energy efficiency measures. Procel, National Electrical Energy Conservation Program, established in 1985, received a boost with the publication of the Energy Efficiency Law in 2001[34] and has been acting in different areas. For example, Procel seal intends to better inform consumers about equipment energy efficiency.

Only equipment subjected to laboratory tests indicated by Eletrobras receive this seal, but the final choice to buy the equipment with Procel seal or not is up to the consumer.[35]

Other measures promote energy efficiency more directly with the end consumer, such as the exchange of little efficient equipment for others that use less energy or replacement of incandescent lamps (which will no longer be manufactured by 2016 in the country). These measures are adopted by local utility companies in order to meet a regulatory requirement.[36]

Energy efficiency in buildings, in turn, is promoted through Procel Edifica, which implemented the National Energy Conservation Label (ENCE) for buildings that meet efficient building standards. Joining the

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31. Napp *et al.*, 2012.
32. Energy efficiency (EE) on the offer side occurs, for example, when a thermal plant becomes more efficient in its energy production. This booklet shall discuss EE operation on the demand side, since it requires a change in current policies and consumers' behaviors.
33. As Faruqui & Faruqui, 2016 say: "The cleanest kilowatt-hour is the one that is not consumed. The next cleanest kilowatt-hour is the one produced from a renewable source."
34. Brazil, 2001.
35. Source: Procel Info.
36. Brazilian utility companies should apply at least 0.5% of its net operating revenue in energy efficiency programs.

program is still optional, but it will be mandatory in new buildings as of 2020 for public buildings, 2025 for commercial buildings, and 2030 for residential buildings.[37]

Procel also acts with the public sector by replacing equipment and improving public lighting and traffic lights, and promotes training programs and support to the Government. Its operation with industries and the trade sector is made through programs of training and optimization of production systems. Lastly, Procel also promotes education campaigns for the population.

Regarding Procel different operation lines, the analysis of energy efficiency policies in different countries allows to note that the scope of such measures goes way beyond the one contemplated in Brazil today. Deeper technical and political analyses capable of levering energy efficiency measures have already been discussed in many countries, particularly the United States. According to the American Council for an Energy - Efficient Economy (ACEEE)[38], the United States have potential to reduce 40 to 60% of the energy use by 2050 through energy efficiency initiatives. Thus, efforts in State and national levels are of utmost importance. Also according to ACEEE, the energy intensity[39] in the United States was reduced by 50% from 1980 to 2014, which shows that the country's energy efficiency policies were successful.

Despite the global consensus that energy efficiency programs are important for the sustainable use of electricity, these programs are developed by utility companies in order to comply with any regulatory requirement in many countries worldwide, including Brazil. On the other hand, the rate setting makes income of utility companies become based on the volume of energy consumed. Thus, there is no incentive for utility companies to promote energy efficiency initiatives, only to comply with the regulation. Then, it is inferred that incentives of the energy efficiency model should be aligned so that energy efficiency and other distributed energy resources are incorporated as products to be effectively developed by utility companies.

37. Eletrobras/Procel *et al.*, 2014; MME, 2010. For federal public buildings, the adhesion became mandatory as of 08/05/2014.
38. ACEEE, 2015. Nonprofit organization created in 1980 in order to ensure energy safety and reduce environmental impacts of the North American energy matrix.
39. Final Energy Consumption/Real Economy GDP (ACEEE, 2015).

ARTICLE

Energizing Brazil's future with Energy Efficiency

Kevin Lucas, Director of Research, Alliance to Save Energy

The use of electricity and other sources of energy has increased constantly for decades in Brazil, despite the recent drop in energy consumption last year caused by the economy slowdown. Between 2001 and 2013, the use of electricity grew on average 4.2% per year and resulted in an accumulated increase of 63%. When the economy recovers, families will return to buy refrigerators and air conditioners, and industrial and agricultural producers will increase their use of pumps and engines. This slowdown period is an opportunity for Brazil to prepare a strategy that meets future energy demands.

While a traditional approach to meet such needs would imply building new power plants, there is a more efficient alternative, which provides meaningful associated benefits and may lead to a better result for all Brazilians. By prioritizing investments in energy efficiency, all Brazilian consumers - Government, companies and residences - will be able to cope with the energy challenges faced by the country. In addition, there are strong reasons to make such investments and strengthen the economy now.

Energy efficiency means to "make more with less". With a less expensive resource, its implementation may improve the economic growth in Brazil and increase its international competitiveness, while reduces the emission of greenhouse gases, thus improving the quality of air and energy safety. Efficient products, services and technologies allow consumers to have the same valuable service without the need to use so much energy. Lamps are a good example: when replacing one less efficient incandescent lamp for one efficient LED lamp, consumers receive the same amount of light using 83% less energy, thus saving energy and money to spend in other items. Another example is the evolution of refrigerators. Compared to a 30-year old technology, common refrigerators today are much bigger and use 50 per cent less electricity.

Despite the costs associated with the change for technologies energetically more efficient, new business models are being created to help consumers make accessible investments in products energetically efficient in their companies. Energy savings performance contracts have revolutionized commercial premises of high efficiency equipment. Instead of making a company pay for heating, ventilating and air conditioning (HVAC) equipment or other highly efficient equipment, an Energy Services Company (ESCO) shall pay and install this new equipment and ensure economy saving compared to the old equipment. Then, the company pays ESCO part of the saving in its energy bill - and the final amount of bills after repaying ESCO is still lower than before. After paying for the total of the equipment, the company continues to benefit from less expensive energy bills.

For small consumers, including small businesses and residences, discount programs sponsored by utilities companies can be more accessible to manage the energy consumption. Such programs may provide consumers with discount prices for efficient equipment as LED lamps or discount to compensate part of the cost of a more efficient refrigerator. A small fee on consumers' energy bills may pay for these programs. Although the initial cost is higher, reduced use of energy makes consumers save more in the end.

Construction codes and appliances standards setting and compulsory measures are another critical public policy solution.

These regulations specify the minimum performance every equipment should meet and are usually updated on multiannual cycles. As the technology improves, standards for appliances help consolidate energy saving by increasing the equipment average efficiency on the market. Construction codes cover the entire structural performance and are equally as important to ensure low levels of energy use for decades.

Private businesses, especially in the agricultural and industrial sectors, have massive electricity consumption in pumps and engines. International Energy Agency data shows that electricity consumption in the industrial and agricultural sectors have grown at an annual average of 3.5% and 5.7%, respectively in Brazil, from 2001 to 2013. It is no surprise that energy demand has grown in the long-term when combined with increased purchase of air conditioners and refrigerators.

Brazil has three options to meet the future energy demand: i) build more plants, ii) increase the import of energy, or iii) implement technologies and general energy efficiency practices. These options can meet the increased energy demand; however, energy efficiency is cheaper, more flexible and better for the environment.

So that energy efficiency becomes the first choice for consumers and provides the expected benefits, it should be properly valued on the market. Although the Brazilian energy sector has a different structure from the United States, the valuation of energy efficiency can be the same. Both public and private entities should consider the various benefits associated with energy efficiency by comparing the net financial and non-financial benefits of efficiency with the alternatives.

The list below is a basic, non-exhaustive compilation of myriad of energy and non-energy benefits provided by energy efficiency. While some energy benefits are more easily expressed in money, non-energy benefits are real and valuable. Many of such benefits, such as energy saving and reduced transmission losses, are easy to valuate and express monetarily. Some of the non-energy benefits, such as improved safety, comfort, productivity of the occupants of a building and improved air quality are more difficult to value. However, if policy makers do not include them in their assessments, then no value will be calculated for them.

Benefits associated with energy efficiency:

- Energy saving
- Reduced peak demand
- Reduced transmission losses
- Avoided cost with the construction of plants
- Avoided cost with the construction of transmission and distribution
- Reduced greenhouse gases (GHG)
- Improved energy safety
- Reduced prices
- Creation of jobs
- Health benefits
- Improved safety and comfort of consumers
- Improve local air quality
- Increased economic production
- Increased competitiveness of the industry sector

Understanding the great benefits the energy efficiency will provide all Brazilians - not only those who use a lot of electricity - may help develop energy policies. Efforts should be expend in order to quantify the energy efficiency benefits and support extensive public campaigns of education, energy efficiency programs managed by utility companies and appliances standards and construction codes. The private industry plays an important role reducing its own energy consumption, which will increase the energy safety and international competitiveness.

Brazil faces real choices of policies to meets its growing energy demand. By choosing energy efficiency as the first resource for the energy future in Brazil, the country can make decisions to optimize benefits for industries, businesses and citizens.

DEMAND MANAGEMENT

Just as what happens with energy efficiency, demand management programs encourage consumers to reduce their energy consumption. However, while energy efficiency programs emphasize a structural reduction in demand, the demand management programs intend to change consumer's behavior in relation to their energy consumption, in order to encourage consumers to move part of their demand for a time when there is less aggregate consumption of energy - or off-peak.

Conventional practices associated with demand management may act directly to control consumed energy or through rating mechanisms.[40] Examples of direct operation mechanisms include Direct Load Control, with previous consumer approval, in which equipment consuming less energy is directly controlled by the utility company and may be turned off or its use relocated for another time; and Interruptible Tariffs, in which consumers agree to reduce their consumption at established times for a pre-determined level - or also at a previously established amount - in exchange for a monetary incentive.

On the other hand, demand management rate mechanisms consist in rate establishment showing demand for energy at a certain period for consumers. As an example, the Time of Use Rate (ToU) energy rate is set previously for a specific period of time (for example, daily peak and off-peak hours). Rates are usually reviewed a few times per year. At Dynamic Pricing rates change constantly in order to reflect system needs. Consumers are notified about the rate change one day or a few hours before, so that they can adjust their behavior properly.[4]

The study of demand management programs emphasizes the potential of answer of consumers to such incentives in some North American States. In California, for example, a program[42] intended to estimate impacts of different consumption rate forms was implemented in 2003. After adopting these different rates, it was noted a relevant demand price elasticity, in particular by low voltage consumers that reduced demand in peak hours under the dynamic rating scheme.

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40. Faruqui, 2010.

41. For other demand management practices, please check: IEA, 2011a.

42. Source: California Statewide Pricing Pilot (SPP). 4 rate adoptions were tested: (i) Basic Rate with monthly rating seasonality; (ii) Time of Use (ToU), with peak ranging from 2PM to 7PM and seasonal variation; (iii) Critical Peak Pricing - Fixed (CPP-F) - ToU rate throughout the year, with a much higher price during 15 days of peak and notification on the day before; and (iv) Critical Peak Pricing - Variable (CPP-V) - applicable to a niche of the population with peak rates per period of 2 to 5 hours and notification only 4 hours before.

Noting that achieving the full potential of demand management practices depend on the development of smart grids is important, once such technology comprises devices that allow the direct control of equipment, a more frequent consumption measurement and greater consumer access to information on their own consumption. It is also worth emphasizing that demand management can be faced as a measure of costs efficiency to the extent that it prevents considerable amounts of investment in generation and, in some cases, in distribution.[43]

Regarding practices related to demand management in Brazil, the adoption of Rate Flags in energy bills of Brazilian consumers since January, 2015 (ANEEL Normative Resolution no. 547/2013) should be noted. The flags system is applied by all concessionaires linked to the National Interconnected System (SIN). Such a measure points to consumers the cost of energy generation due to conditions for electricity generation. The system is comprised by four flags (Figure 7).

Although flags are a way of showing consumers costs associated with energy generation at a certain time of the year, Rate Flags are not a demand management policy per se, once agents do not have the option to move their demand in the short-term for times in which energy costs less. Thus, rate flags have the effect of reducing demand, not managing it.

Another rate proposal seeks to influence electricity consumption habits for low voltage consumers in Brazil. The White Rate enables consumers to pay different amounts for the energy consumed according to the day and time of the week.[44] Three

FIGURE 7: RATE FLAGS

Green flag - favorable energy generation conditions.
Rates are not changed

Yellow flag - less favorable generation conditions.
Rates have a R$ 0.015 increase per kWh consumed

Red flag, level 1 - Costliest generation conditions.
Rates have a R$ 0.030 increase per kWh consumed

Red flag, level 2 - Even costliest generation conditions.
Rates have a R$ 0.045 increase per kWh consumed

Source: Prepared by the author based on ANEEL

43. Bradford & Jennings, 2014.

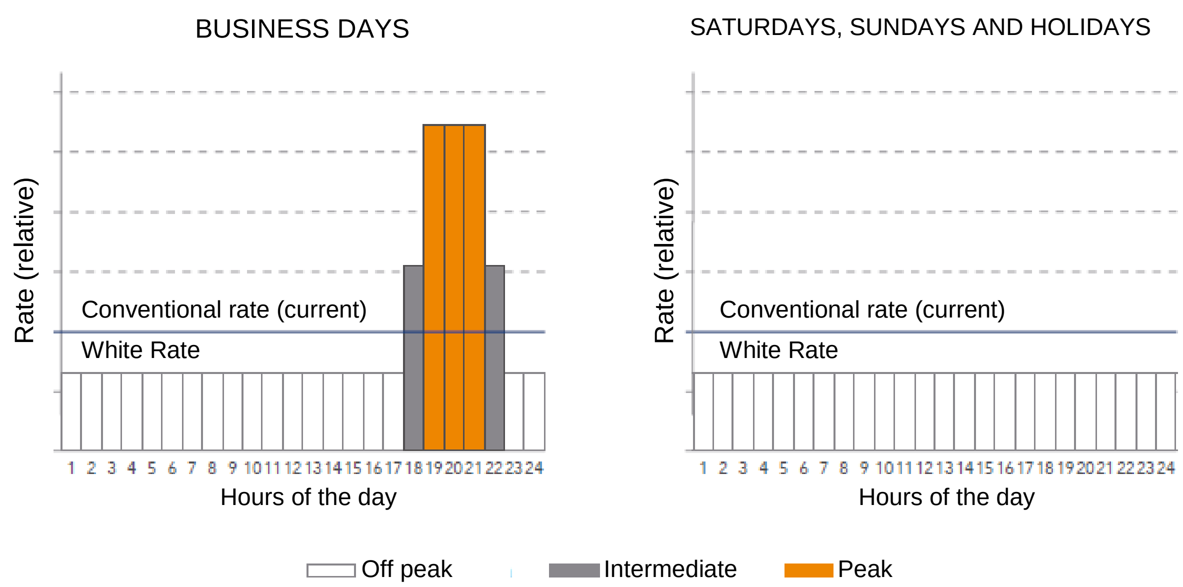
44. For a broader discussion on the White Rate, its benefits and implementation challenges, please check the FGV Energia Situation Bulletin editorial, November of 2014 issue.

types of rates will be used in business days (Figure 8). Intermediary and Peak rates, once these are higher than Off-Peak rate, discourage the consumption of energy during times of greater demand (from 6PM to 10PM). With this, incentives are given to change energy consumption during peak times for periods in which electricity distribution has idle capacity.

Consumers who choose the White Rate should make their adhesion formal at their utility company. However, it has not been implemented until now because no intelligent meter model received regulation at INMETRO, which is necessary to adopt the White Rate.[45]

Current initiatives consist in still timid attempts to try to point and manage energy demand and Brazil still has considerable opportunities in relation to the progress of such measures. Among other aspects, the adoption of smart meters countrywide depends on the approval of regulation for their operation and needs to evolve, so that demand management techniques are more effective.

FIGURE 8: COMPARISON BETWEEN WHITE RATE AND STANDARD RATE



Source: ANEEL

The greater the difference between Standard Rate and White Rate off-peak, the greater the incentive to adhere to the White Rate and vice-versa.

45. According to INMETRO "... Until now, no manufacturer succeeded in tests to which they were subjected, especially in software safety tests. Software safety requirements are intended to provide the white rate project with proper conditions for it to be adopted without undue threat or frauds which, if implemented within date and time parameters, would virtually ruin all the efforts so far used to design and implement the white rate project."

ARTICLE

Potential Trends and Opportunities in Demand Response

Lucas Bressan, Ahmad Faruqui and Ryan Hledik, The Brattle Group

The views and opinions expressed in this article are those of the authors and do not necessarily reflect the position of The Brattle Group or of its clients.

Demand Response (DR) is a tool intended to balance the offer-demand equation by reducing or increasing demand. DR may provide a lot of benefits, including the advance in generation, transmission and distribution investments; reduced prices in the wholesale market; and improved system reliability.[46] Thus, DR may benefit Governments, energy companies and consumers.

SEVERAL FACTORS ARE SHAPING THE FUTURE OF DEMAND RESPONSE

During the last few years, DR was characterized by the dominance of wholesale markets, with most part of reductions from non-residential load cuts. Figure 9 shows the participation and savings obtained with DR programs in the United States, in 2014. While residential customers accounted for the majority of subscribers, the industrial sector contributed with more than half of peak demand savings. However, the residential segment seems to have changed with programs based on price and consumer behavior and gained force and demonstrated potential to provide significant reductions in peak demand.[47]

SALE OF ELECTRICITY SHOULD BE INCREASED IN DEVELOPING NATIONS

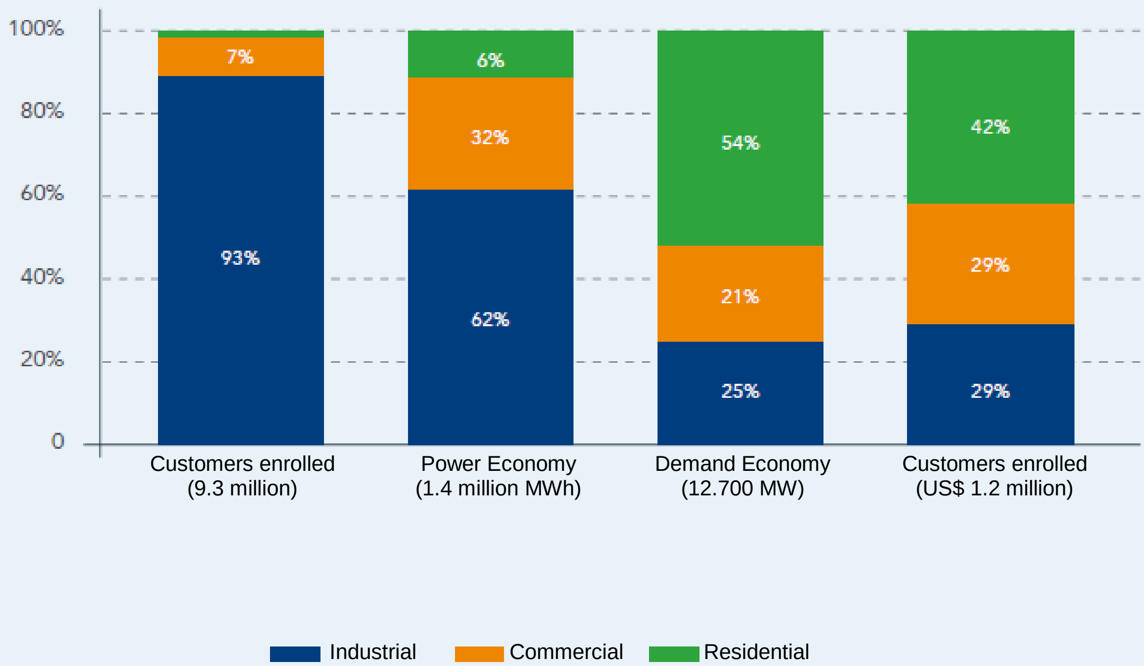
Sale of electricity should continue to grow in many global regions, especially in developing countries. This is a stark contrast to what happens in the US and Europe, where sales growth appears to have reached a "new normal" of very small growth - or even zero growth.

In many South American places, the economic development has been followed by increased demand for

46. For a deeper discussion on these benefits, please check Faruqui *et al*., 2007.

47. FERC, 2009.

FIGURE 9: COMPOSITION OF DR PROGRAM IN THE UNITED STATES PER SECTOR – 2014



Source: U.S. Energy Onformation Administration, Electric power sales, revenue, and energy efficiency Form EIA-861

electricity. Technology advances and drop in home appliances and electronics prices made air conditioners, personal computers and other devices become usual in every home. This factor, combined with the expansion in the power network, will undoubtedly give rise to the need of investments in generation, transmission and distribution capacity. In turn, these trends will create unique DR opportunities.

DECENTRALIZED GENERATION IS FORCING REGULATORS TO RETHINK RATE ESTABLISHMENT

Distributed generation (DG) should grow significantly over the next decades. Residential and small businesses sectors will probably be dominated by solar panels while in commercial and industrial sectors, DG will consist mainly in combined heat and power (CGH) sources. The arrival of distributed generation has the potential to change and even reduce peak demand, and it is likely to drive significant changes in residential pricing.

This may have important implications for the future of DR. Most utility companies use rates comprised by two parts - a fixed charge and one other depending on the energy volume. The fixed charge is usually very small (in some cases even zero) and does not recover fixed costs of the utility company. Introducing demand rates in residential rates and adopting dynamic rates will provide more incentives to expand DR programs.[48]

CONSUMERS ARE ENGAGING MORE

Some countries are witnessing the arising of a generation of “organic consumers”.[49] These consumers are passionate about controlling their energy consumption - not only to save money, but to reduce the environmental impact. The availability of smart devices - smart meters, smart thermostats and other related devices – is turning the adjustment of energy use a lot easier in response to information.

Many United States energy companies are supporting this set of consumers engaged by launching Behavioral Demand Response (BDR) programs intended to increase the engagement of customers in energy management.[50] Customers are usually contacted through customized communication when the system is under stress and are requested to reduce their energy consumption. Implementing these programs is relatively cheap and they are easy to measure if compared to other DR programs that require the installation of devices in houses.

TECHNOLOGY IS ENABLING A FAST AND FLEXIBLE DEMAND RESPONSE

New technologies have the potential to transform DR into a tool that can be used to increase or reduce load at any time, and notifying consumers shortly, in order to facilitate the integration of intermittent resources as wind and solar power. Electric water heating

48. See Hledik, 2014, and Brown *et al.*, 2015.

49. Hledik *et al.*, 2015.

50. For example, the United States Energy Department of the financed a series of consumers’ behavioral studies. See: https://www.smartgrid.gov/recovery_act/overview/consumer_behavior_studies.html and commercial cooling are two final uses with the potential to provide an important amount of flexible load.[51] Several demonstration projects are being carried out in the United States. Devices have been installed to change the load and program supplementation with wind generation. Electric vehicles is another area of application where the battery can be used as drain or as a source of electricity. As prices drop due to increased wind or solar generation, consumers loads will automatically increase - while loads will reduce in response to high prices.

THE POWER OF FIVE PER CENT

The reduction of 5% in peak demand achieved in other jurisdictions, including many electricity markets in the United States may have an enormous impact in the need for infrastructure investments in the power system. Such reduced demand may have multiple benefits: it can be used to postpone the need for investments in generation capacity; it may avoid high marginal costs of energy, especially in years of drought, given Brazil's great dependence in hydropower generation; and, if implemented geographically, it can be used to decrease the need for investments to improve transmission and distribution networks. By using Brazilian peak demand and electricity prices data, as well as illustrative cases of capacity costs avoided, **we estimate that a 5% reduction in peak demand of the system may be translated into over R$ 10 billion in savings over the next ten years**.[52]

Even if the evolution of many of these services seems distant, the countries where DR programs are gaining force will be more benefited. Thus, Brazil is in an unprecedented position to apply the lessons learned in other countries and start designing policies and programs that will maximize the value of demand response.

51. Hledik *et al.*, 2016.

52. The estimate is based on an annual peak demand of 85 GW from the system. The generation capacity avoided is based on a turbine combustion cost of R$ 270/kW-y. Transmission and distribution costs avoided used were R$90/kW-y, based on studies review from other jurisdictions. Energy costs avoided assume ten five-hour events that change the load of peak periods for periods off-peak with a price difference of R$25/MWh peak/off-peak. The current net amount of savings is calculated using a discount rate of 8%. Such an estimate provides an estimate reduction of 5% in peak demand. A deeper analysis should be conducted to refine this estimate and evaluate the DR potential at a more detailed level.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Economic and regulatory aspects to include DER in the power matrix

Most part of electricity generated globally occurs through centralized systems, in which the energy generated in large plants is brought to end consumers through transmission and distribution lines. High investments will be necessary to maintain and expand this infrastructure, especially in developing countries expecting major increase in energy demand. Data from the International Energy Agency (IEA) show that non-member countries of the Organization for Economic Cooperation and Development (OECD) will be responsible for seven out of eight additional electricity demand units.[53]

Seeking for a more efficient generation and consumption of energy is increased in a scenario with climatic changes and necessary reduction in greenhouse gas emissions (GHG). In this context, funding the infrastructure necessary to expand energy access at a cost consumers can afford represents a challenge for developing countries. Among other aspects, the current model of the electricity system was prepared to meet peak demand, which means that substantial investments need to be made for such, but the installed capacity remains unused most of the time.

53. IEA, 2015a.

Including distributed energy resources (DER) in the electricity generation and consumption model may contribute to expand the access to energy, thus meeting decarbonization requirements established in the Paris Agreement. However, besides the evident financial and technological challenge, DER inclusion also gives rise to the need of reformulating the model and the role of the agents involved.

How would this new model of the electricity sector be? In countries where DERs are more developed, as Germany and United States, the need for modifications in their models have been discussed. In the United States, the State of New York is implementing a new regulatory and business model to expand distributed energy resources throughout the State called “Reforming the Energy Vision” (box).[54]

54. For more information on the New York State plan, please visit: http://www.ny.gov/programs/reforming-energy-vision-rev

Reforming the Energy Vision

The Government of the State of New York launched the Reforming the Energy Vision, in 2014, a plan aiming at improving the reliability of the power system by reformulating it and better including DERs.

After implementing reforms, utility companies will have their role entirely reformulated: they will become Distributed System Platform Providers, being responsible for coordinating the distributed energy resources system. The plan "does not eliminate the distribution network operator natural monopoly; instead, the natural monopoly locus is shifted from pure physical delivery of electricity to the management of a complex energy inputs and outputs system..."[55] Utilities are not entitled to own distributed resources, their role will be to operate the platform.

According to the plan, with utilities performing a new role in the model, the dreaded utility death spiral in which it is provided for the extinction of utility companies will not be materialized.[56] Utilities will optimize the system and promote competitive markets for distributed energy resources - and will be paid to do this.[57]

In addition to reformulating the electricity sector, several initiatives are being adopted for the State to achieve its goals of producing cleaner, more accessible and resilient energy by 2030: actions to improve energy efficiency in buildings; modernize energy infrastructure; investments in innovation and R&D (energy storage, for example); and projects in the transport sector. Another innovation provided by the plan is the NY Green Bank, intended to grant loans for renewable energies projects.

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55. Reforming the Energy Vision, 2014.

56. Moody's assesses reforms introduced by the Reforming the Energy Vision as "neutral" from the credit risk rating of utilities viewpoint, in its report of October, 2015. While how utility companies will perform their new role is uncertain (which influences in their credit rates), the change for a new model incorporating new technologies - which would be introduced in the system sooner or later - in an orderly and planned manner is a benefit that mitigates the risk of such changes. More information at: Moody's, 2015.

57. Kauffman, 2016.

In the case of Germany, the Federal Government established goals to reduce GHG emission and recompose the power matrix in its energy policy; however, utilities role in the new context was not reformulated openly. When feed-in tariffs were adopted in the 1990's and renewable energies were prioritized in relation to the conventional electricity (nuclear and fossil), the number of ordinary citizens who started to produce energy through small cooperatives[58] grew so much that, by the end of 2012, only 12% of the country's renewable energy market was administrated by German utilities. This illustrates the significant loss of an important market share by utility companies in Germany.[59]

Results of German companies of the sector reflect the impacts of this policy. In 2014, RWE AG - one of the greatest producers and distributors of energy in Germany - reported €2.76 billion in net loss. However, at the same time German utilities recognize they need to readapt to the new reality, their efforts in the renewables market are focused on large projects, especially in wind power, using the centralized network to deliver the energy generated. They do not seem to have a broader understanding of changing in the business model to fit distributed energy generation as an alternative.[60]

International experiences show that the transition to a new business model including DER should comprise a reformulation in the role of the Government, regulatory, and even consumers. It is also noted that the initiative to introduce DERs in electricity models is first derived from Government guidelines, and implemented by regulators in collaboration with other involved agents, including consumers. However, the role of utility companies in this process is more diffuse as the international experience is not uniform in this regard.

Assuming that including DERs is an increasingly present reality, the contrast of German and New York State experiences makes the importance of redefining the role of utility companies in the power market clear by reformulating their business modela so that they stop being mere suppliers of electricity and become large providers of energy solutions. Within the Brazilian market context, this means that the Brazilian regulatory system would need to be rethought and enhanced to allow utility companies to act as facilitators of greater DER inclusion in the country.

Literature and case studies on changes in business models including one

58. Buchan, 2012.

59. Richter, 2013. In 2014, renewable energies participation in total electricity generation in Germany was 27.4%. (Source: Federal Ministry for Economic Affairs and Energy, 2015).

60. *Ibid*.

or several resources distributed[61] identifies some new possibilities for utility companies to operate: plan new mini and micro energy generators; install and maintain generating plants; install smart meters; offer consulting services for potential "prosumers" in order to help manage their generation and demand; among others. Utility companies revenue comes from charging for their services.

In addition to the revenue obtained with these services, by helping consumers to extract more value from electrons, utility companies increase satisfaction and loyalty of their consumer base.

Some utility companies from other countries also provide funding for investments in solar power for distributed generation (see box below).

Example of Funding in Distributed Generation:

Solar Loan Program, Public Service Electric & Gas Company (PSE&G) from the State of New Jersey[62]

Largest utility in the State of New Jersey, the Public Service Electric & Gas Company (PSE&G) grants funding of 40% to 60% of investment costs for solar power systems for residential, commercial and public sector consumers.

Instead of paying the loan in cash as it happens in ordinary banking loans, Solar Loans can be paid using Solar Renewable Energy Certificates (SREC), which is a benefit for "prosumers". These certificates are clean energy credits issued by the regulator, the New Jersey Board of Public Utilities, as negotiable certificates. Whenever 1000kWh of power is generated, "prosumers" receive a certificate.

SREC exist in American States that provided legislation to encourage power production through renewable sources (States with Renewable Portfolio Standards - RPS). In such States, utilities should whether produce a certain amount of solar power or buy SREC in order to avoid a fine.[63]

Other benefits for the utility are interests received and treatment provided for costs with the program, as administrative, advertising and meter installation fees that are addressed as regulatory assets and included in the utility base rate.

61. Richter, 2012.
62. *Ibid*.
63. For more information, please visit: http://www.solsystems.com/our-resources/srec-prices-and-knowledge/srec-faq.

DER benefits include reduced emissions of pollutant gases, greater efficiency for the electrical system in general and greater rationality in energy consumption.

In short, for the inclusion of DER in the Brazilian power matrix to provide the desired benefits, changes that allow for changes in the current business model must be made to the regulation. However, the initial decision regarding these changes needs to come from Government leaders as part of a broader energy policy, such as the State of New York. Based on this policy's guidelines, regulators and several sector stakeholders may discuss and assess how each agent will act in the new model and what regulatory changes are necessary for everyone to effectively fulfill their roles.

VALUATION OF DISTRIBUTED ENERGY RESOURCES

A recurrent theme when studying the Distributed Energy Resources dissemination scenario is related to the difficulty in valuing these resources. One of the greatest challenges relies on prices' mechanisms capacity to reflect the real costs and benefits of distributed options.

DER benefits include reduced emissions of pollutant gases, greater efficiency for the electrical system in general (once the proximity to load reduces losses and optimizes the transmission and distribution system) and greater rationality in energy consumption, with consumers learning to manage their demand more efficiently.

On the costs side, broader inclusion of DER - especially DG - hinders utility companies planning and imposes challenges associated with investment costs allocation and network operation. Distributed energy acquisition may also give rise to risks for utility companies, as uncertainty when contracting energy. Another matter that should be considered is related to operating difficulties imposed to expand intermittent distributed generation.

In addition, models that use monomial rate with greater DG penetration and consequent increase in self-generation of energy end up having transport and distribution system use costs shared with a smaller base of consumers, once this rate does not separate these costs from those related to energy acquisition.

Thus, in order to value DER efficiently, the benefits and costs these resources provide for the electrical system and the society as a whole must be properly considered. Next, we will discuss the alternatives found until now to value DER and Brazil's case.

DER VALUATION EXPERIENCES IN OTHER COUNTRIES

In several countries around the world, the broad dissemination of distributed energy resources put the pricing and new rate structures challenge on the agenda. Even in countries more advanced on the theme, as the United States and some European countries, the difficulty to properly reflect DER benefits and costs seems to be one of the greatest challenges.

The first valuation initiative in the United States took place through the Public Utilities Regulatory Policy Act (PURPA), in 1978. PURPA was implemented amid the energy crisis in order to reduce reliance on foreign oil by saving energy and promoting independent energy generation and use of alternative sources. One of its most important measures was the creation of a market for energy generated by companies that were not utilities - independent power producers (IPP). Since its enactment, utilities started to buy energy from IPP that produced with a lower cost than utilities would charge to generate the same volume of energy - the so-called avoided cost.[64]

With the greater competition in energy markets in several States over the years - and the significant reduction in avoided costs - some energy utilities are seeking alternatives for pricing distributed generation.[65] Some of these initiatives seek to include benefits of renewables not contemplated by PURPA in pricing, such as reduced emissions.

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64. Avoided costs refers generally to the energy acquisition costs or construction and operation of an additional thermal plant by the utility. Each State could define the methodology for calculating avoided costs in a discretionary way. For more information, please check: Bradford *et al.*, 2013.

65. The North American Energy Department does not impose price structures in DER pricing for States; however, performs a relevant role in prices policy coordination, in addition to contributing to funding for the sector's technology advances. Despite transferring the planning and monitoring of distributed generation for States, the Federal Energy Regulatory Commission (FERC) remains important in DER correct pricing (Bradford *et al*., 2013).

One example is the municipal utility in Austin, Austin Energy, which replaced net metering for Value of Solar Tariff (VOST). VOST differentiates consumption measurements and energy production by separating the amount consumers need to pay the utility as it eventually uses the network of value that the consumer receives for generating solar power. Consumption is charged per standard rates of the utility, while production is credited from the amount of solar power - a fixed price that is calculated and updated annually.

The solar power amount to be credited includes benefits generated by the DG for the utility - such as reduced costs with fossil fuels - and benefits generated for the society in general, as reduced emission of pollutant gases. In addition, the collection of a fixed amount based on the energy produced by investors in DG makes it easy to receive funding from the credit market.

Market Price Referent is the current pricing model for DER in California. In this model, prices are established through a cash flow in which revenues are equal to investors' costs - that is, the Net Present Value is zero. Fixed and variable components interact through an optimization function by indicating the value of projects associated to distributed resources, but do not necessarily comprise avoided costs from utility companies.[66] That is, while Austin Energy VOST is a short-term pricing mechanism with annual updates, the California Market Price Referent sets a price to be applied in the long-term comprising periods from 10 to 25 years.

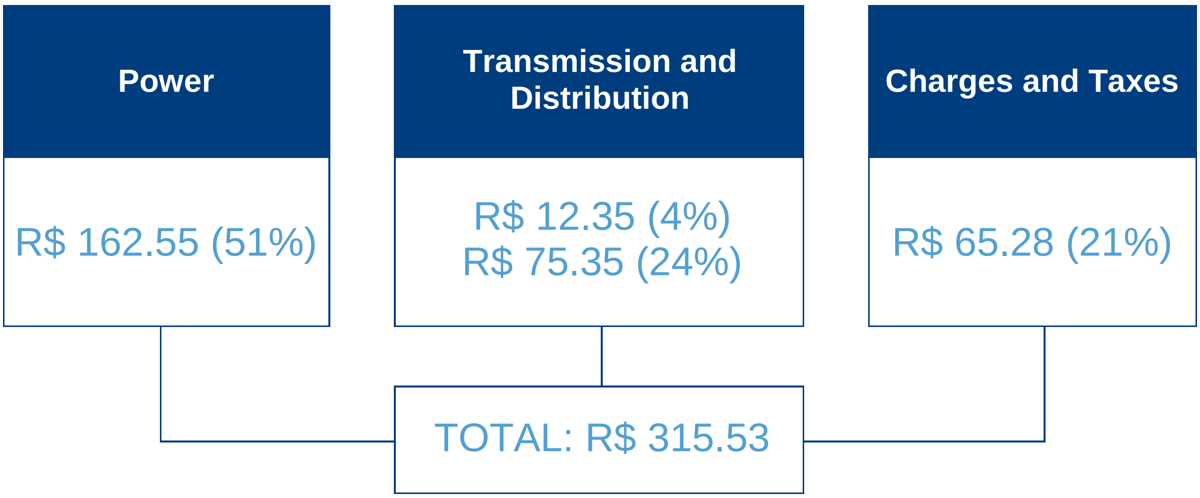
From the examples mentioned, it was noted that there is no single recipe to correctly set prices for DERs. However, a more proper measurement of costs and benefits is sought.

DER VALUATION IN BRAZIL

In Brazil, the energy rate for captive low voltage consumers is monomial[67], covering generation, transmission and electricity distribution costs. This means that, when paying their energy bills, consumers will be remunerating at the same rate: consumed energy, energy transport to their homes (transmission and distribution), and charges and taxes. Inclusion of distributed generation and other distributed energy resources in the power industry model carries some imbalances with this design.

66. For a deeper discussion on the Value of Solar and Market Price Referent, see Bradford *et al.*, 2013.
67. For high voltage consumers, the energy rate is binomial, separating the energy from network use.

FIGURE 10: COMPOSITION OF POWER RATE IN BRAZIL FOR CONSUMERS - AVERAGE RATE R$/MWh IN 2015[68]



Source: Prepared by the author and ANEEL, 2016.

Viewing components helps to illustrate potential unbalances. For low voltage consumers, the monomial rate applied in Brazil does not separate energy cost from network use. This design is a problem for distributed generation, mainly because the network is used as a backup for “prosumers”. In other words, this rate design means that “prosumers” do not bear entirely the cost of using the network as a backup. Adopting a rate that separates these components in Brazil would be a better option for distributed generation. With its adoption, “prosumers” not using the energy supplied by utility companies would continue paying for the network availability and use it only when necessary. This would be the first step to better calculate DG costs.

68. For low voltage consumers, participation in the Transmission and Distribution rate would be almost 40%.

Another program of current rate system employed in Brazil arises from the fact that the current regulatory model - regulation per price-cap - favors volume.[69] This means that utility companies incur quantity risk; as a consequence, as more consumers join distributed generation the volume consumed will drop and will cause an impact on utilities' revenue. The same reasoning applies to energy efficiency projects, which aim to make consumption the most efficient - therefore reducing the volume consumed.

Disseminating distributed generation usually emphasizes the negative points of the rate structure based on volumetric rates, as it happens in Brazil.[70] While the revenue flow is variable, increased DG penetration threatens the financial health of utility distributors in a scenario in which business models remain intact. Additionally, the current rate clearly does not entirely translate DG benefits to SEB. One of these benefits is related, for example, to DG contribution as a resilience measure[71] when supplementing the system demand needs, thus increasing supply reliability and safety.

In the case of Brazil, this benefit is relevant due to the difficulties noted during the construction of transmission lines and new power plants with reservoirs.

Regarding the purchase of energy from distributed energy, ANEEL authorizes utility companies to purchase up to 10% of their demands from such sources. The amount attributed to DG in consumers' rate energy part is defined as the highest value between the Annual Reference Value (VR) and the Specific Annual Reference Value (VRES)[72] VRES was established by the Energy Research Company (EPE) upon request of the Ministry for Mines and Energy (MME) at R$ 454/MWh for photovoltaic energy and R$ 329/ MWh for qualified combined heat and power. VRES calculation methodology seeks to assess the most proper price to enable solar power and combined heat and power projects in Brazil.

To encourage DG, the Federal Government exempted PIS/PASEP and COFINS over distributed generation in charges and taxes incident over the energy rate. The National Council for Financial Policy (CONFAZ) enacted Covenant ICMS 16/2015 that exempted paying ICMS

69. As price-caps encourage minimizing the average cost, this scheme may encourage the maximization of volume, in order to dilute fixed costs (Stoft, 1995).
70. Faruqui, 2015.
71. Bradford *et al.*, 2013.
72. Brazil, 2015a.

over the compensated energy (generated energy minus consumed energy) from distributed generation. However, not all States joined the new Covenant, thus making distributed generation more advantageous to consumers in States that did.[73]

Topics addressed above illustrate the need to reformulate the regulation and the rates system so that DER are fully developed at SEB once the inclusion of DER elements in a centralized model may provide more costs than benefits. Rate reformulation, taking into account the lessons learned from foreign cases, is important in a scenario of greater DG inclusion and other DER in the Brazilian power matrix.

73. CONFAZ decided to let States decide on how to charge ICMS for energy compensated in distributed generation. For a full list of ICMS collection *status quo* per State, please visit: http://www.greenpeace.org/brasil/pt/O-que-fazemos/Clima-e-Energia/energia-solar/icms/

Technology for DER development

From the technology viewpoint, inclusion of DER is strongly related to the development of new technologies, especially in generation and storage. In addition, integrating DER more broadly to the power system also includes the use of advanced network technologies that allow to extract all the DER potential - the so-called smart grids.

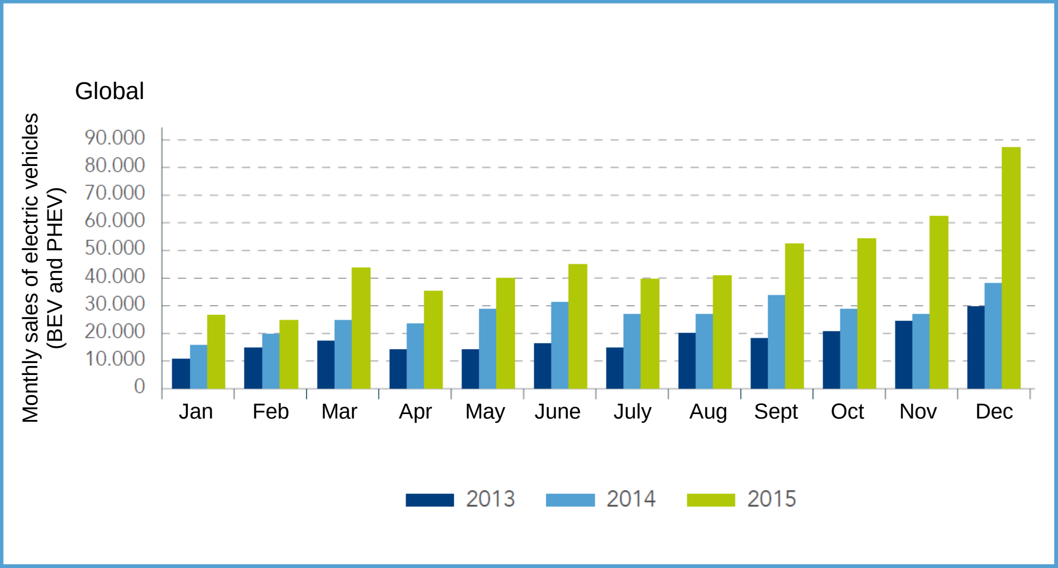
Even in a scenario without a smart grids system, or even lack of storage technologies close to consumers, it is still possible to obtain benefits from the inclusion of DER into the system through other mechanisms. The net metering mechanism implemented in Brazil and several other countries, for example, uses the own network as a virtual battery demanding energy of the network when the generation is not sufficient. This mechanism has proved to be important to enable distributed generation while decentralized storage technologies are not developed at accessible prices for consumers. Likewise, obtaining benefits from energy efficiency initiatives is also possible in this scenario.

Within a broader time horizon, however, as penetrated distributed generation expands, the advance of technologies focused on storage will become crucial to leverage the potential of distributed energy even further. In some cases, if costs of such technologies drop sufficiently, the distributed generation + storage solution can become more interesting from the economic viewpoint than additional investments in transmission and distribution infrastructure. In parallel, the development of electric vehicles indicates additional potential for decentralized batteries (box).

Electric Vehicles (EV)

Although still incipient, electric vehicles (EV) - which include PHEV, BEV and FCEV[74] - are increasingly having more share in the global automotive industry. Over 500 thousand electric vehicles were sold in 2015 in the world, and future trend is increasingly growing. For example, until April, 2016, almost 400 thousand people had already pre-ordered Tesla Model 3, which will be launched by the end of 2017.[75] Recent BEV and PHEV sales progress is illustrated in Figure 11.

FIGURE 11: MONTHLY PROGRESS OF ELECTRIC VEHICLES SALES (BEV AND PHEV)



Source: Ayre, 2016.

CONTINUES ▶

74. PHEV: Plug-in Hybrid Electric Vehicle, in which an internal combustion engine helps to recharge the battery or serves as a backup when the battery runs down; BEV: Battery Electric Vehicle that uses an electric source to trigger an electric engine; FCEV: Fuel Cell Electric Vehicle works as a fuel cells that generates electric current by converting chemical energy of a fuel (such as hydrogen) into electricity. Source: IEA, 2011b and IEA, 2013.

75. Fehrenbacher, 2016.

Several models of electric vehicles are currently available from different manufacturers.[76] BEV more expensive models have greater storage capacity, driving longer distances without recharging (Tesla Model S, which costs US$71,000, travels 265 miles before needing another charge).

Despite the recent growth in EV's popularity, its effective inclusion in the automotive industry still faces barriers. The main barriers for greater EV dissemination include: cost of batteries, which means more expensive cars; low range of batteries in kilometers traveled; availability of recharging infrastructure, especially in workplaces and large cities; and recharging technologies and supply infrastructure standardization for any EV recharged at any place.[77]

On the other hand, EV advantages compared to standard vehicles are many and include the lower level of GHG emissions and reduced engine noise.[78] Besides the obvious contribution to achieving emissions goals in countries established in the Paris Agreement, the greater inclusion of EV may also reduce air and noise pollution, thus bringing potential health and quality of life benefits for the population, mainly in large cities.

Electric vehicles (BEV and PHEV) can be connected to the electric network of a residence, the so-called vehicle-to-grid (V2G), which is another advantage.[79] In this system, electric vehicles and their batteries can be considered valuable distributed resources for the electric network. For example, the energy stored in vehicles battery can be used in times of higher energy demand, thus contributing to stabilize the network at peak times, such as in a demand management mechanism. Another benefit is the use of EV batteries as a decentralized storage alternatives for intermittent generating sources, such as small solar and wind power generation.

EV in V2G system are another option that contribute to greater dissemination of distributed energy resources. However, in order for EV to fully perform this role, smart grids development also needs to evolve.

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76. http://www.plugincars.com/cars
77. IEA, 2013.
78. IEA, 2011b.
79. BEV and PHEV with grid capacity can operate in vehicle-to-grid systems. However, when Honda launches the Power Exporter 9000 this year, any EV with CHAdeMO technology can supply electricity to the grid. Source: EV Expert, 2015. CHAdeMO is the commercial name of a fast charge method for battery electric vehicles supplying up to 62,5 kW high voltage direct current through a special electrical connector.

Similarly, smart grids comprise technologies that supplement DER in some ways once they allow to extend the reach of its benefits. Thus, a more detailed assessment on technologies associated with smart grids, costs relative to their implementation and their relation with DER is important.

SMART GRIDS AND THEIR CONTRIBUTION TO DER DEVELOPMENT

The term smart grid refers to an electrical network that uses digital technologies and other advanced technologies to monitor and manage transport of the power generated from different sources in order to meet end consumers' demands.[80] These smart grids are being implemented in several countries from different motivations - including the need to manage a smart grid more efficiently, flexibly and safely counting on the growing participation of decentralized power generation.

On the utility companies side, the advance of smart grids is capable of increasing operational efficiency, optimizing investments, increasing grid reliability, reducing losses and improving quality indicators as DEC[81] and FEC.[82] On the consumer's side, smart grids may supplement DER. The demand management mechanisms addressed in the Concepts chapter, for example, may achieve their full potential along with smart grids infrastructure.

However, DER evolution is feasible even without the full development of smart grids. A smart meter installation, along with the definition of a different rate per period, already enables consumers to change their consumption for a lower rate time, thus softening their use of power over time. In Brazil, this means that using smart meters in residences of consumers who choose to adhere the White Rate enables them to manage their demand.

Likewise, distributed generation may evolve without using an integrated grid informing the variability in decentralized production in real time when the number of "prosumers" is not as elevated, especially in its beginning.[83] That is, despite acting in a supplementary way, the lack of a smart grid does not prevent the expansion of distributed energy resources to some extent.

80. IEA, 2011c.

81. Equivalent Interruption Duration per Consumer Unit.

82. Equivalent Interruption Frequency per Consumer Unit.

83. However, installing a meter that measures the bidirectional flow of power is necessary.

However, with the increase use of intelligent resources in the system it is possible to extract greater benefits from DER. Using consumptions monitors and displays, for example, facilitates consumers' access to information on their use of power, thus enhancing the results of energy efficiency and demand management mechanisms. By using other smart devices it is possible to implement an even broader set of demand management mechanisms that may act directly on the load through thermostats and appliances controls.

Smart grids technologies also allow a greater integration of batteries with power generation sources that feed them. In a growing transport electrification scenario, smart devices will inform EV owners about the best times of the day to recharge their batteries, for example. Smart grids may also allow electric vehicles to feed from the battery of a residence grid in the long term.[84]

INTERNATIONAL EXPERIENCES IN SMART GRIDS

Nowadays, the level of smart grids technologies penetration is very heterogeneous among several countries and regions in the world. In the United States, investments in smart grids are aligned with the country's energy policy goals of achieving self-sufficiency and energy safety. With this purpose, the American Government[85] chose the development of smart grids and mechanisms able to encourage demand responsibility by consumers as one of its priorities.

However, even with a federal energy regulatory commission (FERC), the North American power industry regulation is mostly determined by State agencies so that progress in smart grids is very heterogeneous among American States. North Carolina, California, Texas, Florida and Pennsylvania are the states with more resources invested and greater development in smart grid programs. States with less resources invested are Missouri, Nebraska and Arkansas.[86]

In Europe, smart grids development is strongly related to the European Union Climate and Energy Package targets adopted in 2008 and updated in 2014. The following stand out among the main targets to be achieved by 2030 in the last negotiations of the European Parliament: a 40% reduction in GHG emissions compared to 1990 levels;

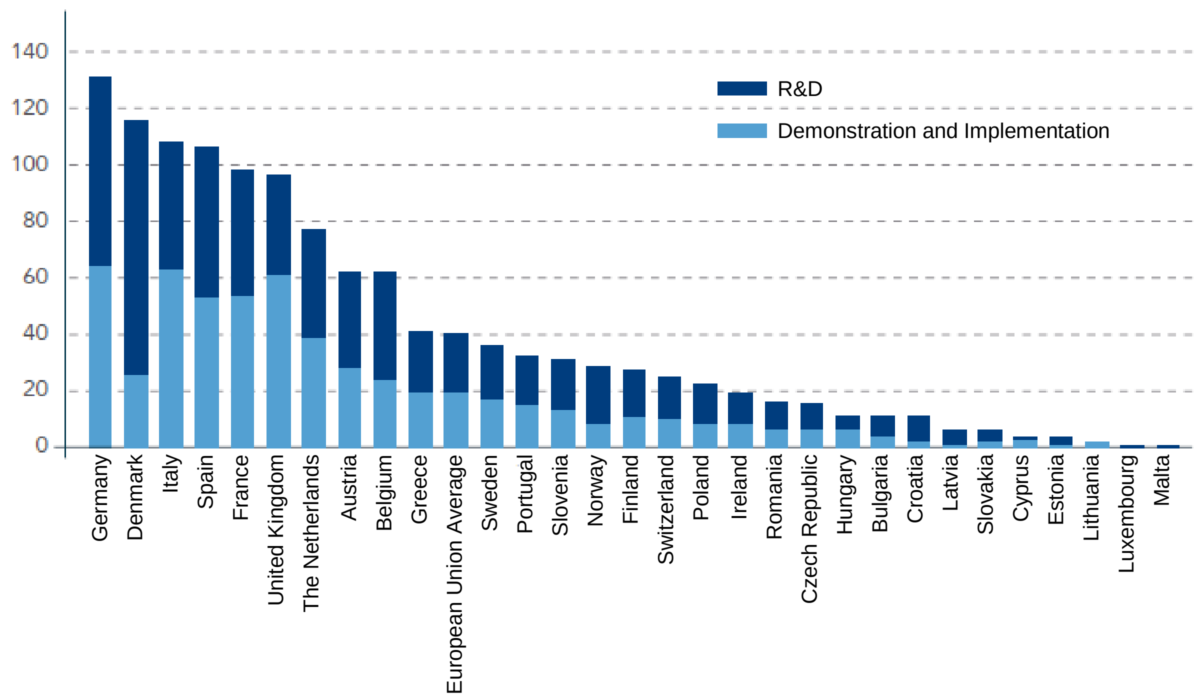
84. IEA, 2011c.
85. FERC, through the Energy Independence and Security Act (2007) and the American Recovery and Reinvestment Act (2009).
86. Source: https://www.smartgrid.gov/recovery_act/project_information.html.

a 27% increase in renewable sources participation; and increased energy efficiency target to 27%.[87]

In view of the need to achieve these targets, the European Technology Platform (ETP - SG) published a booklet with the main smart grids initiatives in Europe, both at regional and national level, in April, 2015. The booklet aims at addressing the main regulatory and technology challenges of smart grids, in order to deepen information and obtain greater coordination among the several countries involved.[88]

Smart grids penetration level is also quite diverse in each country in Europe. Germany, Italy and the United Kingdom, for example, already have several projects being demonstrated and implemented. In other countries, most projects are still under research and development.[89]

FIGURE 12: NUMBER OF SMART GRIDS PROJECTS IN THE EUROPEAN UNION, AS PER DEVELOPMENT STAGE



Source: Smart Grid Projects Outlook 2014.

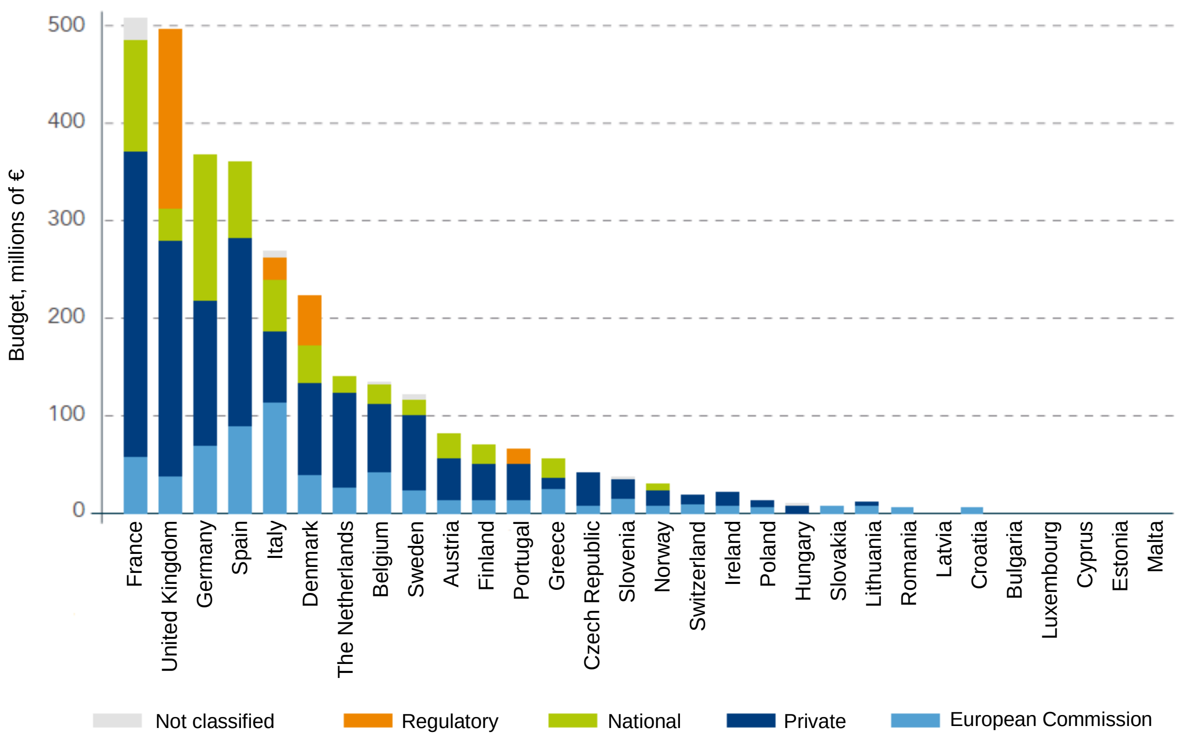
87. European Commission, 2014 and https://ec.europa.eu/energy/en/topics/energy-efficiency. The energy efficiency target will be reviewed in 2020, aiming at a 30% increase. Targets were established before COP 21; however, they are aligned with the Paris Agreement medium term goals. https://ec.europa.eu/transparency/regdoc/rep/1/2016/EN/1-2016-110-EN-F1-1.PDF.

88. ETP-SG, 2015.

89. Covrig *et al.*, 2014.

Regarding smart grids projects funding sources in the European Union,[90] the resources available are mostly from the private sector. In France, for example, private companies, private investors or private capital groups finance most projects. However, the European Commission also invests to implement smart grids projects in almost every member country, with emphasis to Italy. National Governments also invest in smart grids projects, especially Germany. In the United Kingdom, a significant financing share for smart grids projects comes from the regulatory fund (in this case, the Low Carbon Network Fund - LCNF).

FIGURE 13: DISTRIBUTION OF RESOURCES SOURCES FOR SMART GRIDS PROJECTS IN THE EUROPEAN UNION[91]



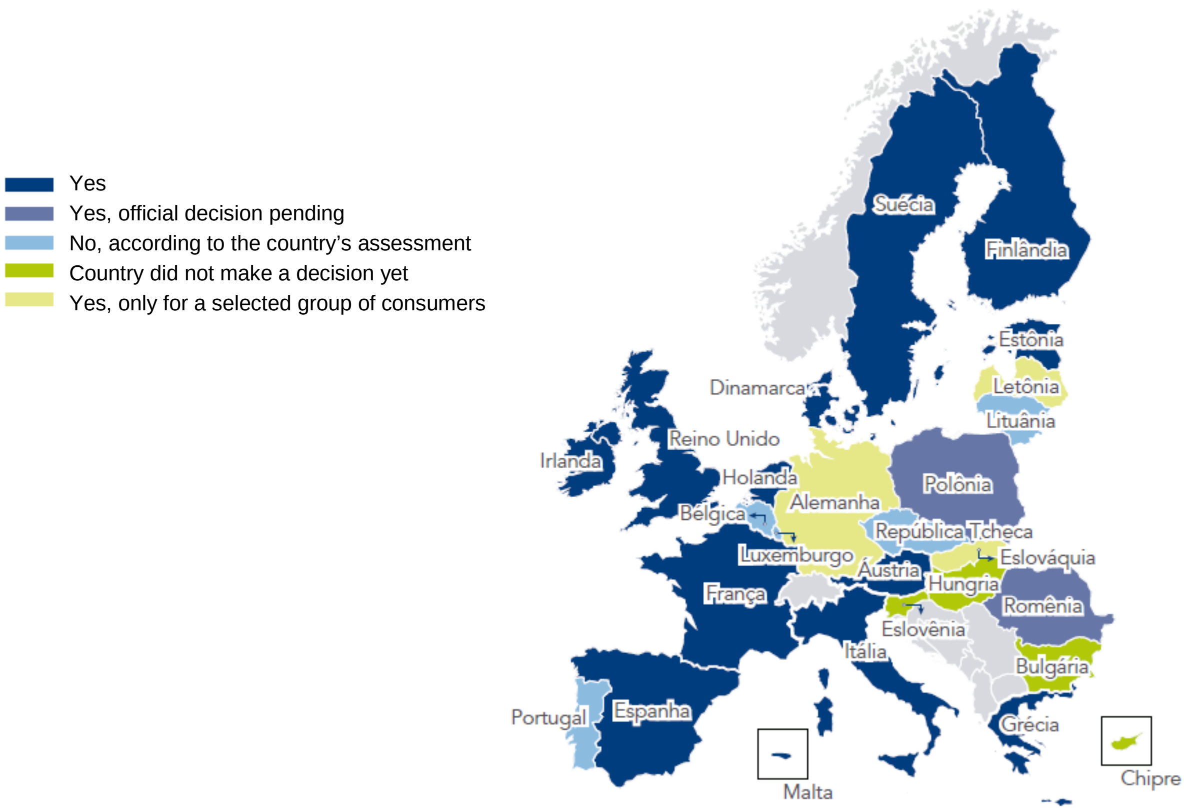
Source: Smart Grid Projects Outlook 2014.

90. *Ibid*.
91. Funding source not classified: information about non-existent source of funding.

Taking into account the heterogeneity to implement smart grids, the European Parliament launched recommendations[92] to conduct a transition process for smart grids - without, however, set a deadline for execution.[93] All members are indicated to conduct the transition, but the final decision is taken by each country based on an implementation cost-effective analysis. If the analysis is positive, at least 80% of consumers in the country are expected to receive smart meters by 2020.[94]

Some individual cases should be highlighted. Despite wanting to implement smart meters by 2020, the Governments of Poland and Romania still haven't taken an official decision about it. Spain decided to implement smart meters even without finishing the cost-effective analysis. The same

FIGURE 14: IMPLEMENTATION OF POWER SMART METERS IN COUNTRIES MEMBER OF THE EUROPEAN UNION BY 2020



92. Such recommendations are also technical, with guidelines to ensure the operation of systems between countries and further technology updates possibilities.

93. Even without a set deadline, Directive 2009/72/EC establishes that countries members of the European Union should guarantee the implementation of smart meters. More information: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=ÜJ:L:2009:211:0055:0093:EN:PDF.

94. Wilson, 2015.

happened in Italy, which can be explained because the country has already being replacing standard meters for smart meters for a few years[95]. In France, the installation of smart meters become compulsory as of 2010 after the publication of Décret n° 2010 - 1022. In the United Kingdom, smart meters implementation shall start in the second half of 2016.[96]

In other countries, cost-effective analyses showed a negative result or were inconclusive (Belgium, Czech Republic, Germany, Latvia, Lithuania, Portugal and Slovakia). Germany, Latvia and Slovakia, however, concluded that the installation of smart meters is economically justifiable only for a small selected group of consumers.[97] Lastly, Bulgaria, Cyprus, Hungary and Slovenia did not conduct the cost-benefit analysis or have plans for implementation. The European Union shall remain monitoring the process to implement smart meters and shall ask countries who chose not to implement them to review their cost-benefit analysis so that the process can start as soon as possible.

Smart grids implementation is very different in the United States and Europe. However, although both the European Union and the American Government let countries or States decide when and how to start the transition for smart grids, emphasis is given to how it should be made, as well as centralized guidelines and coordination for its fulfillment.

TECHNOLOGY INITIATIVES FOR DER DEVELOPMENT IN BRAZIL

In Brazil, the technology evolution necessary to include DER, with its full potential, is still slow. Implementing smart technologies for distribution is still very incipient in Brazil.[98] Thus, modernizing the country's distribution system is essential to integrate distributed energy resources.

To promote the power industry's technology migration and enable the adoption of smart grids, ANEEL launched the Strategic R&D Project called "Brazilian Smart Grids Program" in 2010. More recently, the Ministry of Science, Technology and Innovation (MCTI) launched a report with a parallel between smart grids projects in Europe and Brazil, in order to contribute for smart grids development in the country.[99] As a result, some utility companies have been investing in demonstration projects that will help to implement smart grids countrywide. The main pilot projects, help with resources utility companies should invest in R&D, according to the regulation, are still under the development phase (box).

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95. Telegestore Project, implemented by Enel.

96. http://www.smartdcc.co.uk/implementation/programme/.

97. Countries expect to implement smart meters for 23% of residential consumers.

98. Although generation and transmission systems in Brazil have a reasonably advanced control and monitoring level. Source: Brazil, 2014.

99. *Ibid*.

Smart Grid Pilot Projects in Brazil[100]

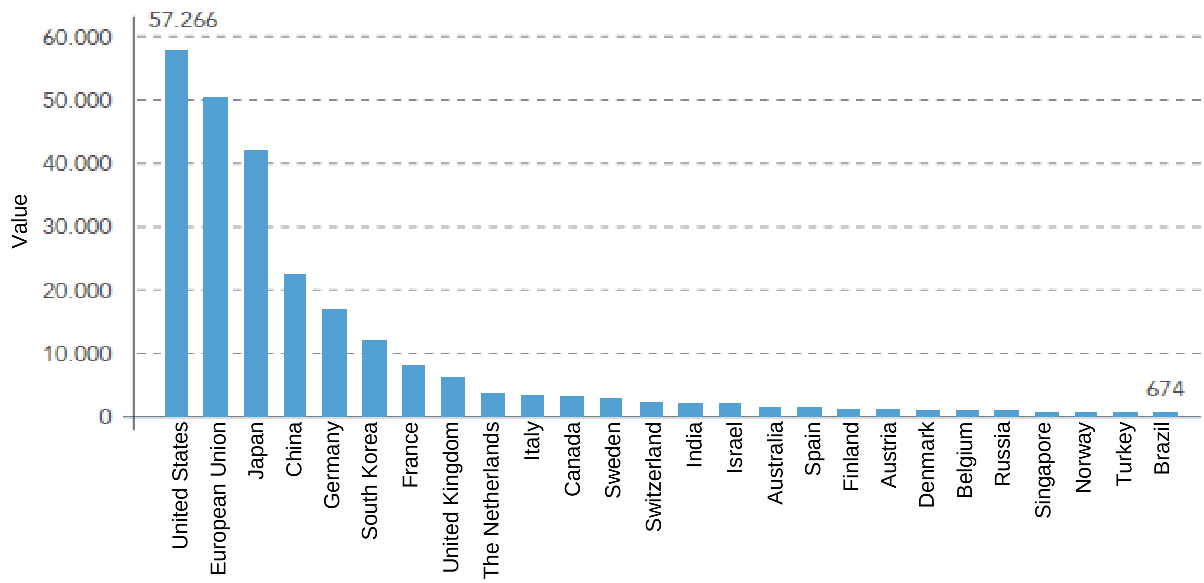
Project Name	Company	Number of consumers served	Place	Current phase
Eletropaulo Digital	AES Eletropaulo	84,000	Barueri, Vargem Grande and Caucaia do Alto	Under development
Cidade Inteligente Búzios (Smart City Búzios)	Ampla	10,000	Armação dos Búzios	Under development
Caso Ilha de Fernando de Noronha (IFN)	CELPE	847	Ilha de Fernando de Noronha (IFN)	Under development
Cidades do Futuro (Future Cities)	CEMIG	8,000	Sete Lagoas, Baldim, Funilândia, Jequitibá, Prudente de Morais, Santana de Pirapama, Santana do Riacho	Operational phase completed. Procedures internalization phase ongoing
Cidade Inteligente Aquiraz (Smart City Aquiraz)	COELCE	19,177	Aquiraz, Katu, Picão, Prainha, Japão, Porto Das Dunas, Tupuiú, Timbú and Mangabeira, Tapuio- Catolé, Coaçu	Under development
Paraná Smart Grid	COPEL	10,000	Curitiba	Under development
InovCity	EDP Bandeirante	35,000	100% of the city of Aparecida, SP	Under development
Smart Grid Project	Light	400,000	Metropolitan region of Rio de Janeiro	Under development
Parintins Project	Eletrobras AM	14,500	Parintins	Completed; however a supplementary step is necessary.
Smart Grid CPFL	CPFL Energia	25,000 (Group A)	Municipalities in the countryside of the State of São Paulo	Under development
Projeto Cidade Inteligente (Smart City Project)	Elektro	6,000	São Luiz do Paraitinga, SP	Under development

100. Source: http://redesinteligentesbrasil.org.br/produtos/category/22-consolidados-projetos-piloto.html, http://www.aneel.gov.br/arquivos/Excel/Projetos_PED-ANEEL_(Res_Norm_316-2008)_Ver2016.01.28.xls e Brasil, 2014.

However, despite the efforts so far, both the ANEEL R&D project and pilot projects did not trigger a National Smart Grids Program by the Federal Government.[101] Given the advance smart grids are showing globally, it would be important for the Brazilian Government to structure this program as soon as possible so that the transition is conducted in an planned and controlled way.

Investing in smart grids development and technologies necessary to implement them and other DER in the country is not easy - among other factors because Brazil is not a country with tradition in innovation. According to the last edition of the Global Competitiveness Report,[102] Brazil is ranked 84 in "innovation" among 140 countries assessed. The Figure below shows the number of patents per country in 2013.

FIGURE 15: NUMBER OF APPLICATIONS PRESENTED TO THE COOPERATION TREATY IN PATENTS IN 2013



Source: OECD.

101. Alcântara, 2014. While the National Smart Grids Program is not implemented, ANEEL has been regulating technologies related to smart grids available in the country, as electronic and smart meters. However, despite being regulated by ANEEL, the latter has not been approved by INMETRO yet.

102 The Global Competitiveness Report, annually published by the Economic Forum, assesses the competitiveness of 140 economies. In the last report edition (2015-2016), Brazil is ranked 75 in the general ranking.

Considering this low-innovation incentive scenario, a starting point to stimulate research, development and demonstration (RD&D) would be to assess options to fund the research of new technologies. In particular, there are a few funding options available in the country for the development of technologies linked to DER (Table 2).

TABLE 2: RESOURCES FOR DER-RELATED TECHNOLOGY DEVELOPMENT

Funding sources	Managing body	Objective	Resources
Inova Energia[103]	FINEP, supported by BNDES and ANEEL	Promote research and innovation in the following areas: **Line 1:** Smart Grids and Ultra High Voltage Transmission (UAT) **Line 2:** Energy Generation through Alternative Sources **Line 3:** Hybrid Vehicles and Vehicle Energy Efficiency	**FINEP:** R$ 1.2 billion BNDES FUNTEC: R$ 1.2 billion **ANEEL** (mandatory R&D resources): R$ 600 million **Total:** R$ 3 billion, for years 2013 to 2016; Up to 90% funding of the total project amount
CT-ENERG[104]	FINEP and CNPq	Fund programs and projects in the energy field, especially in end use energy efficiency field.	Sector R&D charge - Research and development and Energy Efficiency: 0.75% to 1% over the annual net revenue of generation, transmission and power distribution companies.
BNDES Finem - Energy Efficiency line[105]	BNDES	Support projects to reduce energy consumption or increase the national energy system efficiency.	The bank funds up to 80% of the value of eligible items. Minimum funding amount is R$ 5 million.

103. Source: FINEP - Inova Energia.
104. Source: FINEP - CT-ENERG.
105. Source: BNDES Finem.

The availability of funding facilities listed offers a possibility to evolve technologies that support DER development. Encouraging these technologies requires resources that may be supplemented through agendas with the private initiative partnership, if the Government is not able to fully provide these resources, such as national or even international research institutions or through a multilateral distributed energy promotion agenda.

In addition, training quality professionals and better interacting among research and industry sectors should be considered by decision-makers who will contribute to the technology progress in the sector. Lastly, the regulatory framework must be compatible with the incentive to innovate and the hypothetical scenario of increased DER integration, as their penetration impacts the current business model.

ARTICLE

Emergence of the Energy Integrator role in the electricity industry *

Neil Gerber - Director of Strategy, Energy and Environment at IBM and member of the Board of Directors of the American Council on Renewable Energy

The arrival of feasible replacements that encourage structural, technical and commercial changes is a major transformation in the power industry. Such replacements, as solar power, flow demand storage and management, are arising out of the regulation domain and easily operate without legal and operating obstacles from traditional power companies. Other sectors are facing similar transformations with startups as Uber and Airbnb.

Amid these transformations, a strategic need for the **energy integrator** role emerged. This role can be performed by utility companies, new participants or new technical players. Whatever the energy network future may be, however, the energy integrator role will be essential.

MOTIVATIONS FOR THE ENERGY INTEGRATOR ROLE

THE ESSENTIAL NETWORK

Some say that the energy network today will not be necessary in the future, which with the production of distributed energy and emergence of new storage technologies, users may disconnect from it. Although the centralized electricity production will probably decrease in percentage compared to historical averages, a network will still be needed to bring energy to consumers. The role of an entity structured to operate the network, although modified, will still be necessary and this entity is the energy integrator.

MARKETS

Large portions of power supply continue to be administrated through regulated mechanisms of traditional utility companies. However, the direction in many parts of the world - including Brazil - aims at creating energy markets to replace monopoly parts of traditional utility companies. The energy integrator will use these mechanisms to support a robust market for electricity and associated services.

SUSTAINABILITY

Sustainability as social and imperative political purpose is increasingly being adopted globally, thus boosting a migration of fossil fuels for other resources, and Brazil is not an exception. For energy integrators, adopting and even promoting sustainability is essential. It is an opportunity to innovate with financial reward structures that do not need to be traditionally regulatory.

THE MODERN AGE POWER NETWORK

Such transformation in the energy industry sets basis for a new era of design, management and use of the power network. The industry is quickly leaving behind the Industrial Era energy Grid (IEeG) and planning and building the Modern Era energy Grid (MEeG).

IEeG was planned for electrification mainly driven by centralized supply. MEeG will support an economy that is more electrical than in the past, provided by a more distributed and variable infrastructure in operation. It will be planned for sustainability and connection of a diversified set of offer and demand resources, which will be optimized to cope with the technical uncertainty inherent to newer energy technologies. Underlying funding and reward structures will be increasingly based on the market instead of being based on regulations and assets.

As in other operating sectors that underwent transformations, some elements of operations where safety and reliability are paramount, are more likely to innovations to less tightly controlled than others. In the airline industry, for example, an aircraft flight is tightly controlled with innovation possibilities projected and regulated with extreme dedication. Still, innovation has been implemented with success (for example, a modern “glass” cabin). On the other hand, the passengers administration process is mostly free from engineering and regulation aspects; therefore, more receptive to less directed innovations.

A similar pattern should be followed by the power industry, with network operations progressing at a more tightly controlled innovation scheme while innovations for customers operations will probably vitalized by more entrepreneur means. Such balance between well-established, safe and reliable power supply methods and innovations necessary to meet future requirements sets the bases for energy integrator.

An energy integrator is not necessarily a single entity, but more likely a constellation of entities that manage according to a set of common and coordinated processes.

OPERATION LEVELS FOR THE ENERGY INTEGRATOR

NETWORK OPERATION LEVEL: SAFETY AND RELIABILITY

Consumers and regulating entities' expectations to have a safe and reliable power supply need to be continuously met. Even though most part of the traditional structure of IEeG utility companies is preserved in this level, it will be transformed by transition for MEeG, and the greater complexity MEeG introduces. It is likely that a metric similar to the system stability measures in the transmission level is developed to operate the distribution, as the complexity, interconnection and variability of supply and demand increase.

INNOVATION LEVEL: SAFETY AND SUSTAINABILITY

The importance of cybersecurity in MEeG is increasingly important to reliably manage the network. Managing cyberthreats is traditionally limited to the internal borders of substations and companies. However, MEeG will face threats that reach physical units of customers - or derive from them. Thus, the management of this threat becomes essential by the energy integrator.

Also in the operation level is a considerable broadened role to integrate sustainable energy resources in the distribution network. This comprises distributed energy, as well as centralized renewable generation, demand response, storage, energy efficiency and innovations yet to be defined.

Roles addressed in this level generally do not fall within the remit of regulation of traditional utility companies and therefore are open to business opportunities for those who undertake the role of energy integrator. They will be well served by business innovation, a notion that traditional regulatory agencies are beginning to understand. Thus, the authorization for energy integrator to commercially innovate can be very big.

Many of the technologies necessary to conduct this innovation already exist and are being industrialized. Many of the necessary innovations can in fact derive from business models and public policies, which allows these technologies and innovations to be triggered.

MARKET LEVEL: PRICE AND LIQUIDITY

Markets should define prices of several services through a set of mechanisms allowing all energy resources to participate, regardless of the source. The market level provides energy integrators with the opportunity to operate commercially through non-traditional regulatory mechanisms. It is likely that third parties arise to act as energy integrator along with more traditional entities.

Developing an energy compensation chamber concept that allows participants to identify feasible markets, provide power services and perform transactions with the full range of markets available is essential for the success of the energy integrator role.

CONCLUSION

The energy integrator concept briefly includes the main challenges, capacities and opportunities that will arise as the model of traditional utility company transforms. There will be market, public policies and technologies transformations at different levels. New participants - whether companies established from other sectors or new companies - will compete with innovative utility companies to conquer this high value space. Innovation will be the only common denominator in this dispute.

*This article was prepared as part of the program Climate Partners Brasil: https://climate.america.gov/

Incentives for DER Development

Each country designs the proper incentive mechanism to achieve the goals outlined in their energy policies with the peculiarities of each location. DER inclusion speed results from the incentive policy, defined according to the environment where it is executed and properly implemented. To deal with the high costs associated with the DER implementation, defining financial or tax incentives policies has been important for their development.

Funding enables initial investments of agents who wish to start generating their own power, for example. Funding can be offered by private financial institutions or the public sector may act to supplement the distributed energy funding market. The New York State Green Bank is an example of how the public sector acts to supplement the renewable energies credit market by mobilizing resources from the private sector in order to invest in these projects.

Fiscal incentives are another mechanism that has been used to encourage greater DER adoption. The American Government through the Business Energy Investment Tax Credit (ITC), for example, deducts 30% of the amount invested in photovoltaic solar panels[106] from the Federal income tax. Such

106. http://energy.gov/savings/business-energy-investment-tax-credit-itc a fiscal incentive is seen as one of the major responsible for increased solar generation in the United States.[107] Other fiscal incentives, this time to improve energy efficiency in residences are the Residential Energy Efficiency Tax Credit and the Residential Renewable Energy Tax Credit, in which consumers may also deduct a percentage of the amount invested in their houses from their income tax.[108]

In addition, the adopted incentive policies depend on the DER type in question. Specific incentives for distributed generation generally include part of a broader policy to promote renewable energy sources. The main incentive schemes seen globally to develop distributed generation are Feed-in-Tariff (FiT), Renewable Obligation (RO), Fiscal Incentives and Net Metering (NEM).

107. Mooney, 2016.
108. Casey, 2016.

Distributed generation incentive policies

Feed-in-Tariff (FiT) - are long-term contracts (10 to 25 years) to purchase renewable energy imposed to utilities. Such contracts ensure access to the grid and usually have pre-established prices above the market price for power, defined based on the costs of the technology used for generation. Prices are set to follow costs reduction from the technology advance.

Renewable Portfolio Standards[109]/Renewable Energy Certificates (REC) - is a policy defined by the Government that establishes that a share of power supplied by Utilities must come from renewable sources. Generators receive negotiable energy certificates for each unit of energy generated from the eligible renewable source. Utility companies that need to achieve a generation target through renewable sources, for example can purchase these certificates.

Fiscal Incentives - Deduction from taxes contribution that may have different forms depending on the regulation.

Net Metering (NEM) - system to calculate energy taken and injected in the distribution network, in which consumers/generator receive credits in case of excessive generation, or only a deduction from their energy bill in case there is not. Depending on the regulation adopted, the energy credit can be monetized and a deadline to use such credits can be established.

Public BeneFIT Funds - set of resources created with the charge of small fee (or surcharge) on electricity rates in order to invest in the supply of clean energy.

Renewable energy auctions - auction mechanisms for long-term contracting of renewable energy. They have been used to expand the capacity in some countries, especially Brazil. Despite successful in expanding the installed capacity of renewables, Brazilian auctions were directed to expand the capacity of centralized generation until now.

109. Other names used include Renewable Electricity Standard (RES) or Renewables Obligation (RO). Source: Maurer e Barroso, 2011.

The most popular incentive policy for distributed generation globally is FiT, adopted in several European countries, in some United States and Indian States, in Japan and China.

The most popular incentive policy for distributed generation globally is FiT, adopted in several European countries, in some United States[110] and Indian States, in Japan and China. Other countries adopt combinations of incentives, as Italy and Great Britain that use FiT and REC (or Renewable Obligation - RO). Fiscal Incentives and Net Metering are also very popular in the United States, while India also uses NEM and REC.

FiT's main advantage is long-term contracts that have a considerable reduction in risks for the investor. In addition, capital costs of renewable sources noted in countries that adopted FiT are smaller than in countries that adopted other instruments involving higher risks of investments' future profitability.[111] However, FiT should be compliant with the costs of each technology in order to avoid an uncontrolled market growth, so that the rate must be constantly adapted according to the degree of capacity expansion in relation to the Government target.[112] Some countries have already replaced FiT for other types of incentives, such as NEM, or intended to abolish FiT completely (box).

110. DG incentives in the USA are defined by States. The lack of a DG national policy is criticized by some authors as Zhang *et al*. (2013).

111. Zachariadis *et al*., 2013.

112. Telaretti, 2015.

FiT in Germany[113]

After publishing the Renewable Energies Act - Erneuerbare-Energien- Gesetz (EEG) in 2000 - Germany officially chose FiT as an incentive to increase the participation of renewable sources[114] in its power matrix. EEG was updated in 2004, 2009 and 2012 to reflect the changes in market conditions and include renewables throughout years.

The main EEG characteristics are:

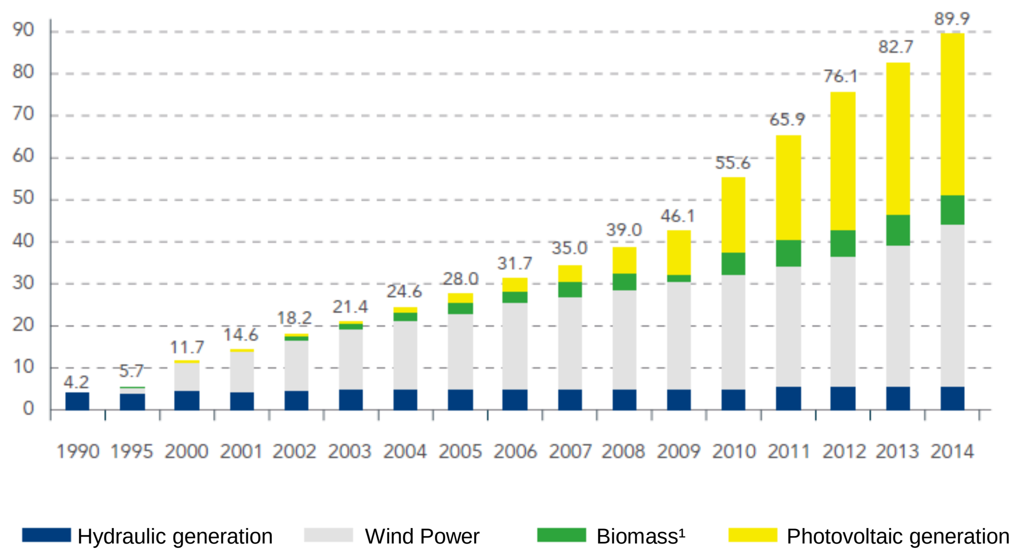
- Protection of investments in renewables through fixed FiT rates, with a 20-year term;
- Guarantee of connection between renewable sources and the power network;
- Priority to use these renewable sources by the system operator;
- Decreasing FiT values that reduce annually for new facilities (the purpose is to encourage owners of renewables to reduce their costs); and
- Consumers' funding through EEG rates: FiT subsidy is completely financed by consumers. Renewable energy generation is traded in wholesale markets and receive market price. The difference between market price and FiT amount pre-established by the Government is paid by consumers as part of their energy bills through the EEG rate - renewable energy rate or surplus - which is applied differently to consumers (industrial consumers only pay a fraction and energy-intensive consumers are exempt).

The expansion in German power matrix renewables was significant, in particular the participation of photovoltaic solar generation, the renewable source most benefited by FiT.

CONTINUES ▶

113. Poser *et al.*, 2014.
114. EEG's goal is to increase the participation both of large renewables as large onshore and offshore wind plants and distributed renewables as solar.

FIGURE 16: DEVELOPMENT OF THE RENEWABLE INSTALLED CAPACITY IN GERMANY (GW)



Geothermal generation plants are not shown here due to their small scale.

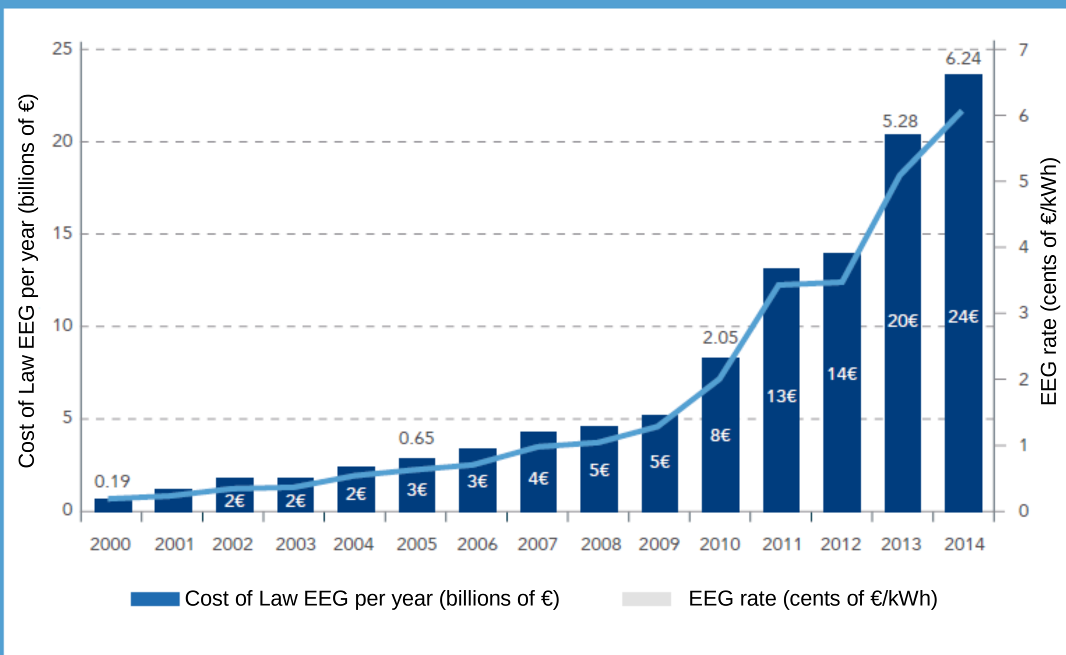
¹ Includes solid and liquid biomass, biogas includes biomethane, gas from landfills and sewage; excludes biogenic fraction of waste.

Source: Federal Ministry for Economic Affairs and Energy, 2015

Total cost of the FiT program should reach €680 billion in 2022 according to estimates of the German Ministry of the Environment.[115] In absolute terms, the German subsidy for renewable energies increased dramatically throughout years. While the total subsidy amount for renewable energies was nearly €1 billion per year from 2000 to 2003, it exceeded €20 billion in 2013 (Figure 17).

In addition, with the greater inclusion in renewable generator plants in the market, the subsidy paid by EEG rate grew from 0.19 cents of euro/kWh in 2000 to 6.24 cents of euro/kWh in 2014. The main factors that led to increased EEG rates over the years was the rapid growth of renewables (especially solar power), tax exemptions for the industry and decreasing price of renewable energy sources in the wholesale market. As the EEG rate is passed on the consumers, the power price increased from €0.14/kWh in 2000 to €0.29/kWh in 2013, in Germany.[116]

FIGURE 17: SUBSIDY AND EEG RATE DEVELOPMENT IN THE GERMAN FIT PROGRAM



Source: Poser *et al.*, 2014.

Although FiT has been fulfilling its role in the German matrix expansion of renewable energy sources, it also gave rise to significant costs[117] for the society. Bearing this in mind, the European union advised its member countries to cease the use of incentives for renewable energy including FiT as of 2017. Effectively, these incentives will be replaced by an auctions system (with the exception of emerging technologies and smaller plants) and prices will be directly linked to the wholesale market. Germany is currently using EEG to implement this change.[118]

115. Poser *et al.*, 2014.
116. Besides EEG, other factors contributed to increase power price in Germany - for example, imposition of new rates for network maintenance due to increased renewables in the grid.
117. Other unforeseen consequences of the greater inclusion of renewables in the German market: increased use of thermal plants as backup; anticipated depreciation of thermal plants as they are only triggered when necessary; drop in the marginal system operation cost (once renewables have preference in the merit order), which prevents the operation of thermal plants with higher marginal cost; impact on energy prices for industries not exempt from EEG fee.
118. Appunn, 2016a.

Energy efficiency policies, in basically all countries, are outlined by Governments and implemented by utility companies to meet regulatory requirements.

Regarding demand management, the energy market liberalization contributes to such policies show more effective results. In the liberalized market, prices reflect the real cost of electricity, which makes consumers free to change their consumption whenever they want including by choosing from who they buy energy.[119] In addition, incentive policies success is directly related to consumers' demand price elasticity. For residential consumers, long-term policies tend to be more successful once the answer of residential demand to oscillations in energy prices is greater in a broader time horizon.[120] Similarly, demand management policies should be followed by better power metering technologies so it can extract all of its potential benefit.

Energy efficiency policies on the other hand, in basically all countries, are outlined by Governments and implemented by utility companies to meet regulatory requirements.[121] However, it is increasingly noted a greater interaction with other power sector agents to enforce these policies. In OECD countries, some funding practices for energy efficiency projects are available for consumers. "Financiamento

119. The power market liberalization may lead to an increase or drop in power prices. Distance between regulated prices and market prices will guide the change. In the State of Illinois, in the United States, with energy prices frozen not reflecting the increased price of natural gas, it was noted an increase in power prices after the liberalization in 2007.
Texas saw the opposite effect. For further details, see IEA, 2011a.

120. *Ibid*.

na conta", for example, is a program in which consumers have access to Government or utility companies fund to make improvements that promote energy efficiency in their houses. Loan payment is discounted on the monthly energy bill.[122]

Changes in buildings codes and regulation, in turn, encourage greater energy efficiency in new constructions. Fundings also help to make investments in energy efficiency for older buildings.

121. IEA, 2015.
122. IEA, 2015b.

Incentive policies to encourage the adoption of energy efficiency programs by utility companies.[123]

Revenue decoupling - disruption of the relationship between income and volume of energy sold by volume, causing no impact in the revenue of utility companies with the adoption of energy efficiency policies.

Energy efficiency rate design - design of rate that encourage consumers to invest in energy efficiency. For example, if consumers invest in energy efficiency that reduce congestion in the distribution system or peak demand, the operator can compensate consumers for benefits that such investments provide the system with.

Energy efficiency obligations - energy efficiency targets set by utility companies, which are achieved when consumers save energy.

Performance incentives - payments or adjustments in rates for utility companies to achieve certain goals. This financial incentives practice can be combined with other methods.

Capacity markets - price of consumption avoided by adopting energy efficiency policies.

Integrated resource planning - process in which regulators force utility companies to invest in energy efficiency as part of their energy planning.

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123. *Ibid*.

While the world walks faster towards distributed energy resources, Brazil takes baby steps on this theme.

Incentives to develop storage technologies are closely linked to DG expansion by intermittent sources. Incentives and funding for distributed generation that include storage technologies are a way to better develop and integrate such distributed resource. Other forms of encouraging the development of storage technologies may occur through Government regulation[124]; the launching of research and development (R&D) programs intended to better understand how storage can be developed; the creation of pilot programs and direct subsidies (fiscal incentives).

Implementing all these new concepts in distributed energy needs incentives that lead agents to know better and finally adopt these new technologies. Also, the implementation should be made with the greatest interaction possible between public, private sectors and consumers, which not only ensures transparency in the process, but also broad and efficient adoption of these resources.

PERSPECTIVES FOR DER DEVELOPMENT IN BRAZIL

While the world walks faster towards distributed energy resources, Brazil takes baby steps on this theme. Despite having a relatively clean power matrix, the decentralized and distributed energy world is very incipient in the country. Distributed generation and energy

124. The State of California is a successful example of development of a favorable regulatory apparatus to penetrate renewable sources and storage technologies. With the installation of 2.4 GW of solar generation and 23 MW of wind generation in 2014, agents established goals for the storage capacity evolution, thus showing efficiency in coordinate and plan this region's power industry.

efficiency are the DER that most recently evolved in Brazil. On demand and power storage management, efforts are more timid.

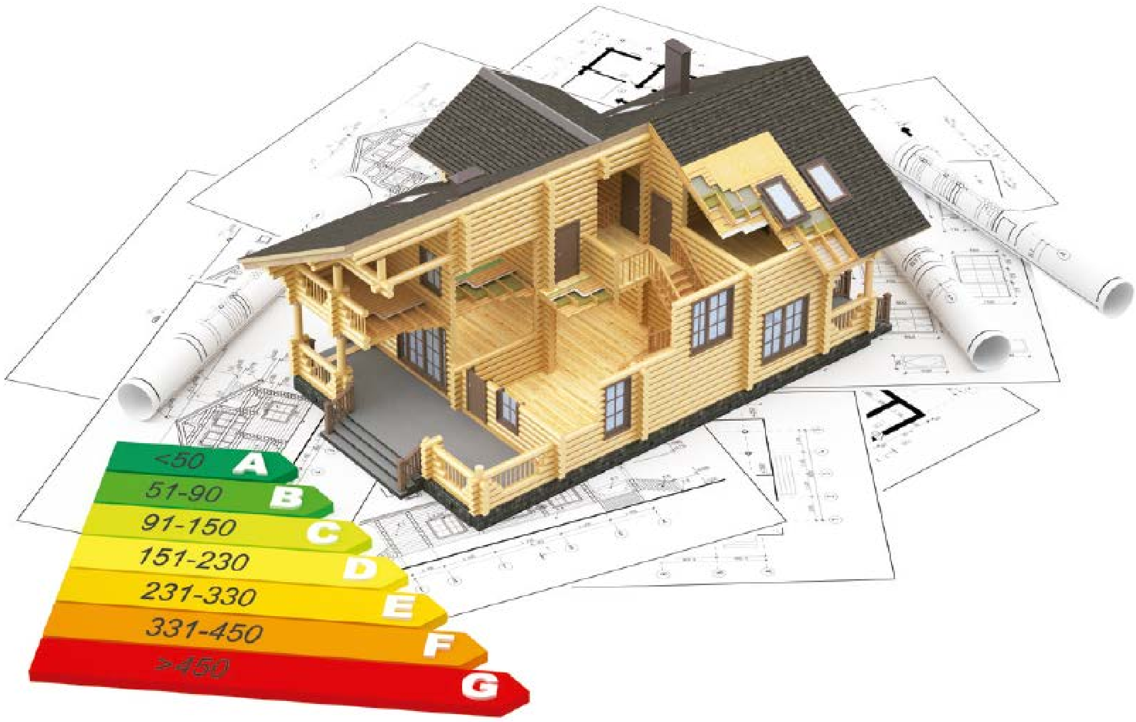
In energy efficiency, the projection for Brazil in EPE (National Energy Plan - PNE 2050) long-term planning provides cumulative efficiency gains of 331 TWh by 2050. Such efficiency gain shall represent almost 17% of reduction in total energy consumption in the period. Out of this total, the residential and commercial sectors will contribute to 19% each and the industrial sector to 12% - the remaining 20% correspond to other consumer categories. According to EPE, achieving these goals depends on improving the energy efficiency in national production processes, extinguishing incandescent lamps, improving residential equipment's efficiency and labeling and public lighting energy efficiency improvement programs.[125]

There is funding available to promote energy efficiency in Brazil in order to achieve these goals. Such funding comes from national (BNDES, for example) or international sources (World Bank, United Nations Development Programme - UNDP and United States Agency for International Development - USAID, for example).[126]

However, the energy efficiency goal established in PNE for 2050 is timid when compared to other countries. In Germany, for example, the energy efficiency goal for power consumption only provides for a 25% reduction by 2050 compared to the levels of 2008.[127] The European Union energy efficiency target as a whole is 27%, which may increase to 30% when the target is reviewed in 2020.[128]

In the United States, some laws still being discussed in the Congress intend to set a national energy efficiency goal. Meanwhile, States establish their own goals.[129] The State of California, for example, recently approved a law that will result in a total reduction of the State's electricity need by approximately 25% until 2030, if effectively implemented.[130]

125. EPE, 2016.
126. More information on funding for energy efficiency projects at: http://www.Procelinfo.com.br/main.asp?View={9D124FD8-783C-4806-8896-342043A41AB1}
127. IRENA, 2015a.
128. https://ec.europa.eu/energy/en/topics/energy-efficiency.
129. Source: http://aceee.org/topics/energy-efficiency-resource-standard-eers
130. Sources: http://focus.senate.ca.gov/sites/focus.senate.ca.gov/files/climate/505050.html and Borgeson, 2015.



Incentive policies to develop distributed generation are the ones that most evolve in Brazil in comparison to other DER. With the launching of new regulatory rules, the Government and regulators expect the DG has a significant advance in the country (see article "Geração distribuída é iniciativa que conjuga economia e sustentabilidade" in the introduction).[131] In PNE 2050, photovoltaic distributed generation is expected to reach an installed capacity of approximately 118 GWp in the New Policies[132] scenario by 2050, with a bigger growth after 2030.[133]

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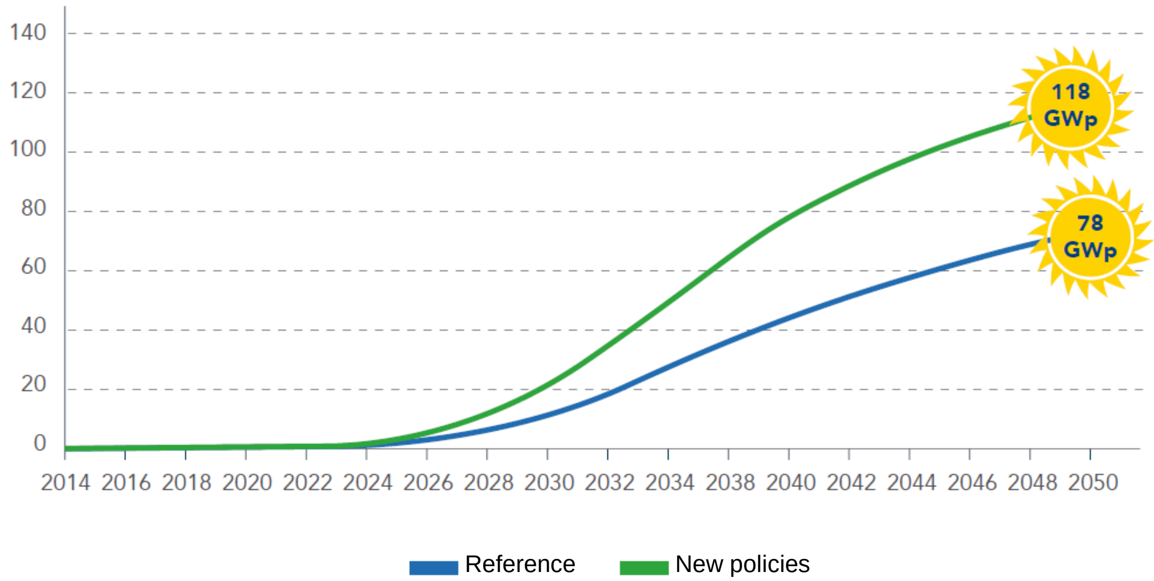
131. Another novelty of the new resolution are shorter deadlines for utility companies to authorize the connection of distributed systems on their networks. Total connection process time established in the new resolution dropped from 82 to 34 days in the case of micro generation, and to 49 days for mini generation. In 2014, the observed average of days for DG connection to the power grid was 180 days.

132. PNE 2050 projections use two possible scenarios: (i) Reference Scenario set based on assumptions about the growth of global and Brazilian economies. From these assumptions, the demand per energy consumption in 2050 was projected; (ii) New Policies Scenario, which considers assumptions from the Reference Scenario to take place at a larger scale because of policies to promote decentralized photovoltaic generation. The new resolution (RES 687/2015) is included in the New Policies Scenario (EPE, 2016).

133. On April, 2016, the installed capacity of solar power was 23 MW in the country (0.0152% of the installed capacity in the country). Source: Banco de Informações de Geração (BIG), ANEEL.

FIGURE 18: PROJECTION OF THE DISTRIBUTED PHOTOVOLTAIC INSTALLED CAPACITY ACCUMULATED IN THE LONG-TERM (IN GWp)



Source: EPE, 2016.

Greater DG penetration in the Brazilian matrix has the potential to contribute for the country to achieve the goals established by Brazil in the Paris Agreement - which provide for a 45% renewable energies participation in the power matrix by 2030.[134] To achieve this goal, the country committed to increase the quota of supplementary renewable energies in power supply for at least 23% by 2030[135] - today this amount is nearly 15%.[136] Once

134. Including power plants. Today, this amount is 40%. Source: Brazil, 2015b.
135. *Ibid*.
136. Banco de Informações de Geração (BIG), ANEEL.

the most EPE optimistic projections point that photovoltaic DG inclusion in the power matrix will start in the most disseminated way after 2030, it appears that the planner projects that these goals are achieved by expanding other renewable sources.

Germany, in turn, expects that 80% of its power consumption comes from renewable sources in 2050, especially wind and solar generation[137] - this amount currently corresponds to almost 27%.[138] The United States expect that renewable energies participation in the final electricity consumption increases from 11.4% in 2010 to 16.3% in 2030.[139]

Comparing Brazil to other countries, targets that include distributed generation from photovoltaic solar source to expand supplementary renewable sources are expected to follow global trends (except for Germany). However, the doubt is related to the effective participation of distributed energy in this amount. Until now, these sources are being expanded from centralized generation, especially wind, encouraged by auctions promoted by the government.

OTHER INCENTIVES FOR DG

Another incentive to develop DG in Brazil was the creation of the Distributed Generation Development Program for Energy (ProGD),[140] which provides for over R$ 100 billion in investment by 2030. The program established Specific Reference Values (VRE) for solar distributed generation and combined heat and power as discussed in the Chapter "Economic and Regulatory Aspects". Other actions to be proposed within the ProDG scope include: creation and expansion of credit and funding facilities; incentive to the components and equipment industry; training and qualification of human resources; and promotion and attraction of national and international investments.

Other incentive policies to generate power through renewable sources, which may have an impact in distributed generation include:

- **Bills to adopt Green IPTU (Property Tax).** IPTU is a municipal tax over urban territory and building. Green IPTU would be an incentive to reduce the tax given to homeowners who adopt measures to preserve, protect and restore the environment. Some of these

137. Appunn, 2016b.
138. Federal Ministry for Economic Affairs and Energy, 2015.
139. IRENA, 2015c.
140. MME Ordinance no. 538/2015.

An important incentive policy would consolidate a competitive credit market to develop not only DG, but also DERs

measures include wind and solar generation systems at residential scale. Some municipalities already approved and enacted the Green IPTU, such as São Carlos - SP.

- **Edification certificates** that use power from renewable sources, such as the Solar Seal.[141] This certificate accredits companies, residences and public and private institutions whose annual electricity consumption from solar energy exceeds 50%. However, the certificate does not have market value and cannot be traded, being explored as environmental marketing.

In general, loans available to promote DG are directed for the installation of photovoltaic solar panels. BNDES and Banco do Nordeste (BNB) grant financing for legal entities. Legal entities may access credit facilities to improve residences granted by the Federal Savings Bank and Bank of Brazil. Some private banks also provide support for the acquisition of photovoltaic systems. In addition, the Bill 371/2015 is also pending in the Senate, which will allow for the use of resources from the Government Severance Indemnity Fund (FGTS) to acquire and install equipment for self-generation of power in residences.[142]

However, these financing initiatives do not seem to broadly encourage micro "prosumers". The installation of photovoltaic solar panels is still

141. The Solar Seal was created in 2012 and is an initiative of Ideal Institute and the Electric Power Trade Board (CCEE); this certificate accredits companies, residences and public and private institutions investing in solar power.

142. http ://www25.senado.leg.br/web/atividade/materias/-/materia/121833

is costly and efforts to grant credit are isolated and disintegrated. Thus, an important incentive policy would consolidate a competitive credit market to develop not only DG, but also DERs, such as in the Green Bank in the State of New York.

An important measure for fiscal incentives would be the adherence of all Brazilian states to ICMS Covenant 16/2015. According to Absolar, ICMS exemption in distributed generation impacts in 30%. In addition, other fiscal incentives can be searched, such as discounts in photovoltaic solar panels acquisition, for example.

PERSPECTIVES FOR DEMAND AND ELECTRICITY STORAGE MANAGEMENT

Since the Brazilian power industry is regulated for captive consumers, prices of demand management are not freely adjusted to reflect the energy demand and offer. Still, the Federal Government has been seeking to implement policies in order to better manage the consumers demand (Rate Flags and White Flag). However, as it has been discussed, the White Rate is not in force yet.

For energy storage, the launching of the Strategic R&D project **"Technical and commercial arrangement for inserting energy storage systems in the Brazilian electricity sector"** - intends to develop this technology countrywide. The idea is to leverage storage technologies in the country reaching the final phase of implementation.[143]

The effort to better understand how to implement storage technologies in Brazil comes in a good time, given the forecast of distributed generation growth in the country. Abroad, storage technologies are being developed faster. Thus, the recent technological breakthroughs in the international storage market should also be included in the national scenario as distributed generation is increasing its participation in the Brazilian power generator market.

Lastly, one of the best incentives to develop the distributed energy resources in Brazil would be the reformulation of the current sector model - starting by regulatory standards, going through business models and incentives for utility companies and reaching in the redefinition of the roles of all agents involved.

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143. Source: Consultation made with an expert from ANEEL.

Conclusions

The Distributed Energy Resources study showed that the development of each of its pillars (distributed generation, energy efficiency, demand and storage management) is strongly interrelated. DER progress translates a global trend of generating and consuming power in a more rational, clean and sustainable way.

DER development may bring benefits for the whole society. From the individual consumer viewpoint, DERs bring value by expanding the range of choices available for these agents, from the generation and storage of their own energy to its efficient management.

Distributed generation development in particular, by constituting a new form of diversification of the energy mix, relieves centralized generation, thus giving greater safety to the national system. Technology advances tend to reduce even further costs of technologies already employed in distributed generation through incremental innovation. In addition to this factor, DG, when associated to renewable sources and storage technologies, minimizes environmental impact and considerably reduces the need for investments in transmission and distribution lines, thus optimizing the power system as a whole.

The demand management measures and energy efficiency analysis showed that despite acting in different ways, they encourage consumers to better use energy. Thus, demand performance has an impact on the supply side, since it tends to reduce the need for energy. It can also be said that DER advance constitutes an efficiency strategy in what regards to overcoming tradeoff between environmental concern and energy safety.

However, in Distributed Energy Resources evolution analysis in Brazil it is possible to identify that limitation still occur associated to their dissemination - including access to technology and financing, and incentives in the current Brazilian regulatory and business model. However, DER development as a whole has a lot to contribute to build the power matrix in Brazil in the future.

With the growing climatic concern, DER will have an essential role to build a less-carbon intensive energy sector. Adopting a regulatory structure that enables the development of new business models for the power industry incorporating DER is an initial step in this transition. This Booklet seeks to present the international experience in DER, in addition to surveying the main aspects (regulation and business model, technology, funding and incentives) and possible barriers to DER development in Brazil.

The greater goal is to deepen the discussion on the theme and bring the analysis of possible alternatives to expand DER in Brazil to the agenda.

List of Acronyms

ABRADEE - Brazilian Association of Electricity Distributors

ACEEE - American Council for an Energy-Efficient Economy

ANEEL - Brazilian Electricity Regulatory Agency

BDR - Behavioral Demand Response

BEV - Battery Electric Vehicle

BNB - Banco do Nordeste

BNDES - National Bank for Economic and Social Development

CAES - Compressed air energy storage

CCEE - Electric Power Trade Board

CELPE - Companhia Energética de Pernambuco (Energy Company of Pernambuco)

CEMIG - Companhia Energética de Minas Gerais (Energy Company of Minas Gerais)

CMO - Marginal Operation Cost

CNPq - National Board for Scientific and Technological Development

COELCE - Companhia Energética do Ceará (Energy Company of Ceará)

COFINS - Social Security Funding Contribution

CONFAZ - National Council for Financial Policy

COP 21 - 21st annual session of the Conference of the Parties of the United Nations Framework Convention on Climate Change

COPEL - Companhia Paranaense de Energia (Energy Company of Paraná)

CPFL - Companhia Paulista de Força e Luz

CPP-F - Critical Peak Pricing - Fixed

CPP-V - Critical Peak Pricing - Variable

CT-ENERG - Sector Energy Fund

DEC - Equivalent Interruption Duration per Consumer Unit

DNAEE - National Department of Water and Electric Power

DOE - Department of Energy

DR - Demand Response

EDF - Electricité de France

EE - Energy Efficiency

EEG - Erneuerbare-Energien-Gesetz

ENCE - National Energy Conservation Label

ENEL - Ente Nazionale per l' Energia Elettrica

EPE - Energy Research Company

ESCO - Energy Services Company

ESS - Energy Storage Systems

ETP-SG - Smart Grid European Technology Platform

EV - Electric Vehicle

FCEV - Fuel Cell Electric Vehicle

FEC - Equivalent Interruption Frequency per Consumer Unit

FERC - Federal Energy Regulatory Commission

FGTS - Employee Dismissal Fund

FINEP - Studies and Projects Funding Agency

FiT - Feed-in-Tariff

FRE - Fluctuating Renewable Energy Systems

FUNTEC - BNDES Technology Fund

DG - Distributed Generation

GHG - Greenhouse gases

HVAC - Heating, Ventilation, and Air Conditioning

ICMS - Tax on the Circulation of Goods and Services

IEA - International Energy Agency

IEeG - Industrial Age Energy Network

IFN - Ilha de Fernando de Noronha

INMETRO - National Institute of Metrology, Quality and Technology

IPTU - Urban Territory and Building Tax

IRENA - International Renewable Energy Agency

ITC - Investment Tax Credit

LNCF - Low Carbon Network Funds

MCTI - Ministry of Science, Technology and Innovation

MEeG - Modern Age Power Network

MME - Ministry for Mines and Energy

NEM - Net Metering

OECD - Organization for Economic Cooperation and Development

OFGEM - Office of Gas and Electricity Markets

PBM - *Plano Brasil Maior* (Greater Brazil Plan)

R&D - Research and Development

RD&I - Research, Development and Innovation

PDP - Productive Development Policy

PHEV - Plug-in Hybrid Electric Vehicle

PIS/PASEP - Social Integration Program and Civil Service Asset Formation Program

PITCE - Industrial, Technological and Foreign Trade Policy

PNE - National Energy Plan

UNDP - United Nations Development Programme

PROCEL - National Electrical Energy Conservation Program

ProGD - Distributed Generation Development Program for Energy

PSE&G - Public Service Electric & Gas Company

PSH - Pumped-storage hydropower

PURPA - Public Utilities Regulatory Policy Act

REC - Renewable Energy Certificates

DER - Distributed Energy Resources

RGR - Global Reversion Reserve

RO - Renewable Obligation

SEB - Brazilian Electricity Sector

SIN - National Interconnected System

ICT - Information and Communication Technology

TOU - Time of Use Pricing

TUSD - Time of Use of the Distribution System Pricing

TUST - Time of Use of the Transmission System Pricing

VOST - Value of Solar Tariff

VR - Reference Value

VRE(S) - Specific Reference Value

UAT - Ultra High Voltage

USAID - United States Agency for International Development

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