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Title: Distributed solar micro generation – an enabler to Brazil's economic development

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Abstract

Taking into account the fact that the sun's radiation is estimated to be enough to cover 10.000 times the world's total energy needs (BRAKMANN & ARINGHOFF, 2003), it is difficult to understand how solar photovoltaic systems (PV) are still such a small part of the energy source matrix across the globe.

Though there is an ongoing debate as to whether energy consumption leads to economic growth or whether it is the other way around, the two variables appear correlated and it is clear that ensuring the availability of energy to match a country's growth targets is one of the prime concerns for any government.

The topic of centralized vs distributed electricity generation is also approached, especially in what regards the latter fit to developing countries needs, namely the lack of investment capabilities and infrastructure, scattered population, and other factors.

Finally, Brazil's case is reviewed, showing that the current cost of electricity from the grid versus the cost from PV solutions still places an investment of this nature with 9 to 16 years to reach breakeven (from a 25 year panel lifespan), which is too high compared to the required 4 years for most Brazilians. Still, recently passed legislation opened the door, even if unknowingly, to the development of co-owned solar farms, which could reduce the implementation costs by as much as 20% and hence reduce the number of years to breakeven by 3 years.

Objective of the research

The overall objective of this research is to provide a broader picture of the underlying importance of energy to economic development, the ways in which solar energy can be an answer to this issue for developing countries and how Brazil is only a few years away from being the next big player in this area.

Harnessing energy has, since the dawn of time, played a key role in the development of the human kind. This thesis will look at Brazil as an example of a developing country with strong economic growth potential, but ailing energy infrastructure, and why solar power may be one of the solutions to its energy problems, specifically reviewing the case for distributed micro generation (solar panels bought and used by individual households for their own consumption and feed-in to the grid to sell the excess generation).

Relevance of the research for business organizations

Although in Europe the use of solar power to generate electricity in a distributed way has been in place for some time, in Brazil the relevant legislation has only been passed in 2012, making this a huge but untapped market for energy companies (so far, only a handful of installations have taken place, most of which in remote areas not served by the country's existing grid).

Also, the push in demand from European countries (which still today are heavily subsidized by local governments) has recently led to a sharp drop in technology prices as more and more Chinese manufacturers go online, bringing the cost of electricity generated in this way close to parity with standard grid prices.

As such, it is important for management to understand not only the underlying factors that support the adoption of this technology (existing grid inability to cope with demand, government green targets, etc.), but also the more practical issues at hand (cost evolution, type of customers, purchase drivers, etc.) in order to deploy it in a timely and targeted way, maximizing its impact both locally and globally.

Short summary of main findings

There is evidence to support that GDP growth and energy consumption are positively correlated and have enabled the exponential development of mankind. Regarding energy production technologies, micro generation photovoltaic systems (PV) may not be the only answer to the world's electricity needs, but are eligible to start by complementing existing grids.

Brazil has a huge landmass in the sunbelt area of the globe, it already boasts one of the "greenest" energy production matrixes in the world, its energy needs will almost double in the coming years and it has just taken the first steps to allow for distributed PV solutions to take off with the passing of necessary legislation in 2012.

However, legislation falls short of that in other countries and potential investors only consider projects with very short breakeven periods (under 4 years), regardless of their average lifespan (25 years in the case of PV), making it unlikely that distributed PV micro generation projects will take off in the short term given their current 9 to 16 years time to breakeven on the initial investment.

Still, the first opportunity for companies to exploit this market seems to be through a loophole in the legislation, which may allow for up to 20% cost reduction and a 3 year drop in the number of years to breakeven, among other significant advantages. Nonetheless, it could take another 5 to 10 years before PV distributed micro generation can be considered a significant source of electricity in Brazil.

Organization of this document

This document will start by reviewing existing research and literature from academic and practitioner sources related to the links between Energy and Sustainable Development, Energy and Growth and Micro-generation versus Centralized electricity production, followed by an analysis of Brazil as case in point and the findings from original research, conducted in São Paulo, to segment potential consumers of micro PV systems.

In essence, it will revolve around the following pillars:

1. <u>The connection between access to power and economic development</u>
2. <u>The use of solar power technology as relevant source of electricity for developing countries</u> thanks to their need for clean, sustainable and renewable sources of energy, as well as its ability to complement existing infrastructure in managing energy demand peaks through the day;
3. <u>Brazil as case in point</u>: analysis of its energy source matrix, how its economic growth trend is outpacing its energy generation infrastructure and why the time for distributed micro generation is about to arrive.

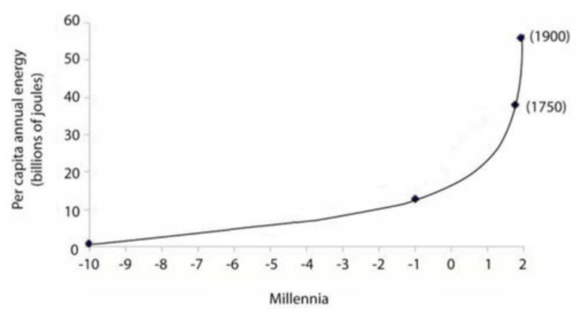
Literature review

Energy and Sustainable Development

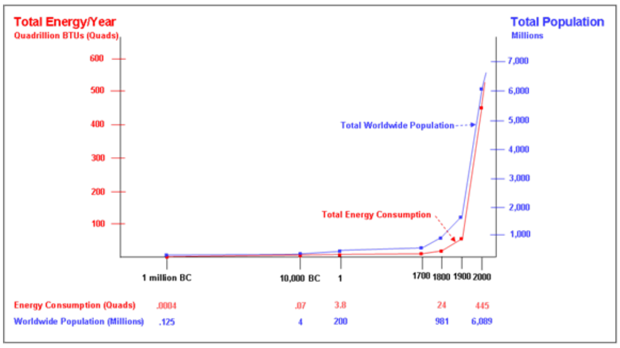
The development of humanity has long been associated with the consumption of energy in what have been called the energy-culture complexes (Caraça, 2003).

The first of such complexes dates back to the moment mankind was able to tame fire. With this new element, not only did the pre-historic man enjoy greater safety, but through the cooking of food several advances in the human body were felt, such as the evolution of the digestive system and the drop of the jawbone that eventually allowed the brain to expand.

The second complex started with agriculture. Due to the ease of edibles collection and the use of animal powered tools, energy consumption tripled and an organized society emerged where each actor had a role to play. The gathering of humans facilitated the exchange of products and experiences, allowing for advances in culture. The incremental use of energy leaped forward with the Industrial Revolution, when mankind learned to use other forms of energy conversion, namely through the use of fossil fuels, increasing energy consumption without precedent.



Graph 1 - Unearthed: The Economic Roots of Our Environmental Crisis (Sayre, 2007)



Graph 2 - Historic Global Energy Consumption and Worldwide Population Growth (Clugston, 2007)

With such pressure on demand for energy and an increased world population, sustainability of growth becomes a major concern. Brent (Brent, 2007) systematizes the sustainable development as one that strives to meet the needs of people to allow for the full development of potential, while acknowledging that there are limits to the exploitation of the Earth's resources and the need to consider intergenerational equity.

This definition is therefore of the utmost importance when considering the impact of choices in the energy sector, as sustainability is a present day concern that will permeate the future discussion in this paper.

Energy & Growth

The correlation between energy and growth is a studied one. Several papers that have been written through the years, based on national indicators concerning defined time periods, try to establish a connection between the two variables and indeed some have attempted to prove direction in causality (whether energy consumption causes growth, or whether it is the other way around). If established, this would have very concrete implications on energy policies.

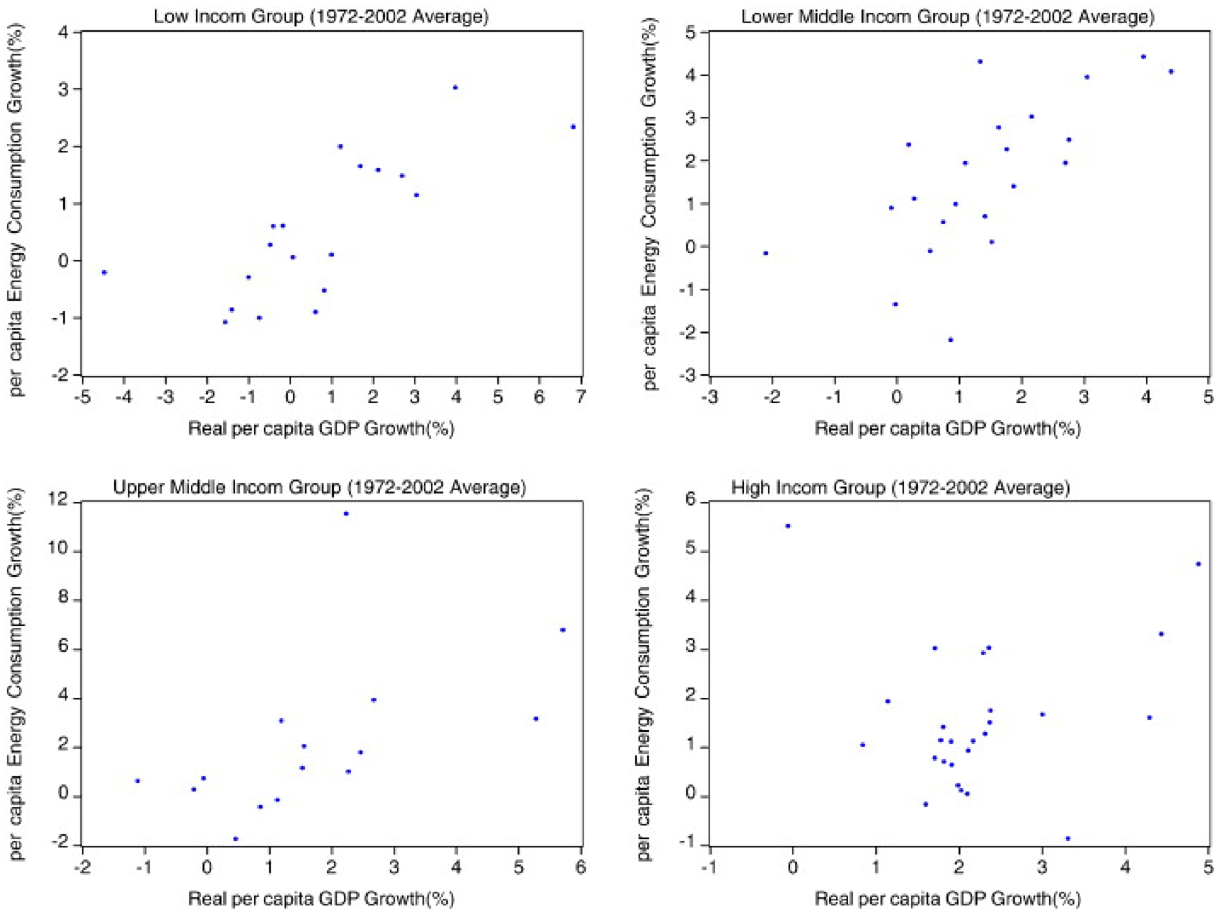
For example, if one considers that energy availability and consumption generates growth then energy conservation policies may be found to deter it, a state which Belke, Dreger and Haan (Belke, 2010) call "energy dependent".

On the other hand, other scholars have suggested the "conservation hypothesis", under which the decrease in consumption would not lead to a slump in GDP. This hypothesis stands on the unidirectionality from growth in GDP to increase in energy consumption.

In a study of 30 OECD countries, Narayan and Prasad (Narayan, 2007) were not able to establish causality for the majority of the studied countries. However, it is worth noting that for eight countries including Portugal the bootstrapped approach to causality found evidence of correlation. Acaravci and Ozturk (Ozturk, 2012) refer to this approach and contrast several other authors, showing how the evidence allows for contradicting results where direction of causality is concerned. The majority state, however, that the two variables (energy consumption and GDP) are interconnected, and the majority of sources finds that energy is in fact a limiting factor in what concerns economic growth. The implication is that negative shocks to the energy supply imply a negative impact on GDP. For the countries studied by these authors using 1990-2006 data, no long term relationship between the two variables were found.

Huang, Hwang and Yang (Bwo-Nung Huang, 2008) have studied the correlation between energy consumption and GDP of the country and have used 82 countries in a 30 year time lapse. In this period they have found that the behavior in terms of energy demand is dependent on the GDP of the country, as may be seen in Graph 3 - Correlation between energy consumption and GDP .

With the sample used, these authors were not able to establish a direct correlation between energy needs and GDP for low income countries, but were able to notice how medium income countries (such as is now Brazil) saw the energy needs rise while the richer countries made efforts to curb the need for energy due to the trend for efficient use and due to environmental concerns.



Graph 3 - Correlation between energy consumption and GDP (Bwo-Nung Huang, 2008)

Amidst the doubts concerning the causality between energy consumption and GDP and the possible implications to policy, the need to curb energy consumption has been put into question with a shift towards a discussion relating to the reasons as to why a decrease in energy is necessary, with pollution being one of the most mentioned factors. However, if pollution is the major problem, a shift towards cleaner means of producing energy may be the way to guarantee that no impact on GDP is risked. In fact, according to Constantini and Martini (Costantini, 2010) this approach may even allow for a growth in development, since it provides a stimulus for the economy as R&D, industry and job creation are vectors influenced by the rise of new technologies.

Micro-generation Vs centralized production

The alternative to the use of electricity mainly consists on the burning of fossil fuels or candles that pose a serious health threat due to the exhausted fumes, and is overall more expensive due to the continued dependence on fuel (Reiche K. C., 2000).

Affordable electricity allows for children's night time studies, entrepreneurs' extended shop hours and even better health coverage due to the proper storing of refrigerated medicines (Yadoo, 2011), acting as a social paradigm shifter. However, to supply populations with electricity several options have to be considered, such as the use of renewable energy technologies over the more established fossil fuel based ones and even the type of energy system needed, be it through the implementation of a centralized or a distributed energy system.

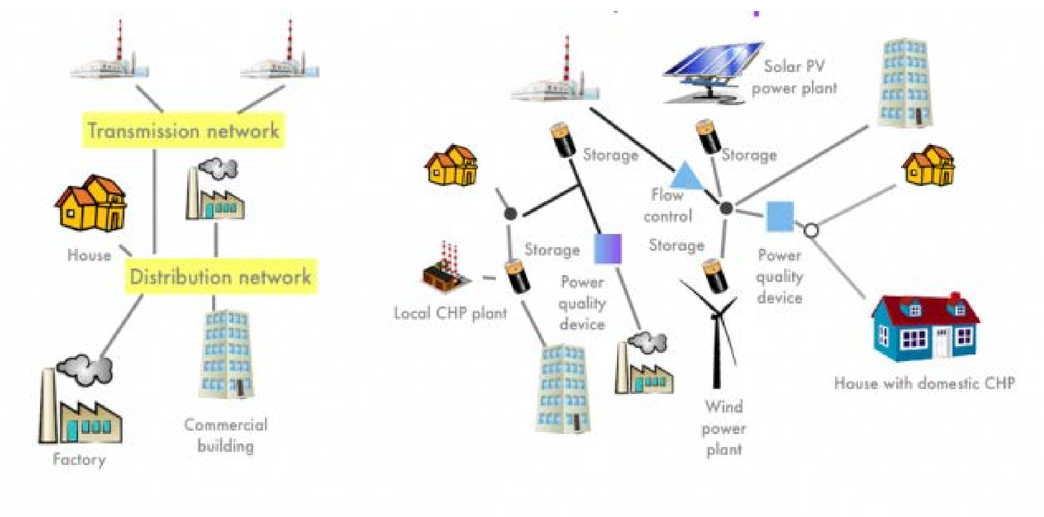
Although not a new subject – in the 1890s this same discussion opposed Tesla and Edison with a loss to the latter – the evolution in technology and the different need for infrastructures means it is useful to revisit the merits and shortcomings of both the centralized and decentralized production systems.

Major differences

Not a recent concept, it should be noted that decentralized energy generation was actually how all energy consumption started, with wood being collected and burnt at local level (Alanne, 2006). Only with the industrial revolution and efficiency concerns, as well as the organization of society in large urban areas, was there the trend for centralization of energy production.

A current view of an energy system is comprised of production, transmission, distribution, commercialization and consumption. Other separate elements exist as well, such as regulatory and political dimensions. This value chain is responsible for the end to end conversion and delivery of energy in a centralized fashion.

In a decentralized system, the consumer is closer to the generation, thereby rendering the transmission element of the value chain unnecessary. Taken to the limit, decentralization may make each consumer its own producer.



Graph 4 - Centralized vs Decentralized electricity System (Farrell, 2011)

Just as the telephone system once relied on wiring or the computer industry was once a synonym of huge rooms full of technology to which researchers flocked, so does the centralized energy system seem to have its days numbered. Where cell phones broke all barriers of communication and laptops became ubiquitous, so may micro-generation give rise to a safer, reliable and secure source of energy, connecting consumers just as the internet or wireless networks did (Brent, 2007).

Micro generation can, however, use several distinct technologies, be they of renewable or fossil sources. As such, from diesel powered generators to biomass, photovoltaic or wind, several options may be available with the ability of interconnectedness.

Such a global and complex issue, the alternative for the use of a decentralized energy system should be approached from a broad perspective to encompass economic, social, technical and environmental dimensions (O'Neill-Carrillo, Irizarry-Rivera, Colucci-Rios, Perez-Lugo, & Ortiz-Garcia, 2008).

Economic

Many of the 1.3 billion people without access to electricity (International Energy Agency, 2012) live in remote or isolated communities. The sheer cost of implementing a structured grid to reach such populations renders the project too costly. As an alternative, the implementation of distributed networks has long been seen as promising, although the lack of interconnection still poses some reliability issues, such as the dependence of single energy generators that is no match to an energy grid with overcapacity generation.

With the soaring of the cost of capital, capital intensive alternatives are losing ground to simpler and scalable solutions. Although cheaper per energy unit produced, the centralized system not only requires an upfront investment in the production equipment, but also is of little use without the necessary transmission and distribution networks. Without the need to face such costs that shies away investors, the distributed generation may be implemented gradually and therefore pose as a less risky alternative, since it is mostly done at the initial expense of individual consumers.

The development of local economies through energy has also been studied. One such example was EDP's Kakuma project, where EDP was able to develop a refugee camp in Kenya by creating an economy around the use of solar energy, be it with photovoltaic panels or simply with solar ovens. This has shown how, if implemented properly and with the involvement of the local population, development is a reality. In contrast, the implementation of centralized networks requires specialized knowledge which is mostly imported and with low knowledge transference.

Social

The availability of electricity tends to have a massive social impact, going far beyond the change of production patterns to also move the power balance within a community (Brent, 2007).

The implementation of projects such as Kakuma or Azuri (Azuri, 2013), along with other Africa based programs to allow for access to energy, namely without the hassle and health concerns of kerosene burners, have shown the shift that is available at a low cost. Society makes the most out of the artificial lighting by allowing shopkeepers to stay open longer hours, women's role is strengthened by the increase in productive hours as well as the improved health of the family and a new social balance that reduces marginalization from the faster paced economy is found (Reiche K. C., 2000).

The implicit status attributed to schooled technicians responsible for the maintenance of the system that are truly a part of the community further helps to create the feeling of self reliance, that ultimately drives the population's motivation toward a renewed hope and expectation on the future.

Technology

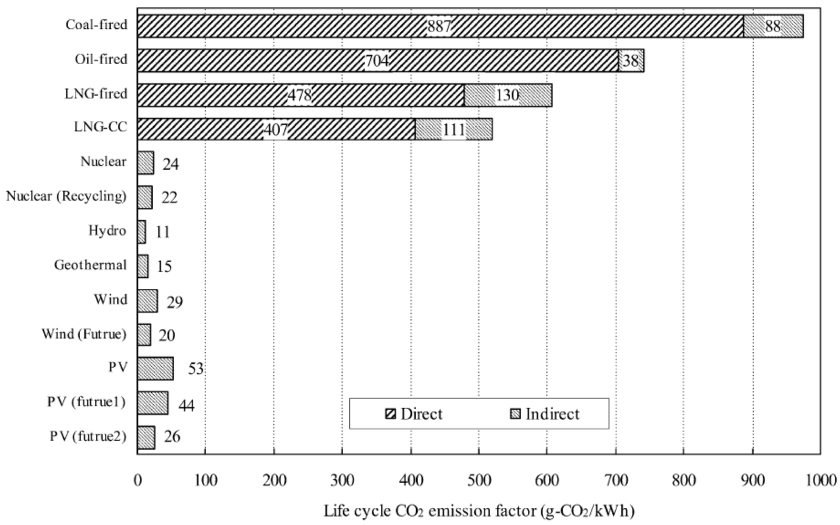
Within the distributed energy networks several power sources may be used. Although thermal generation is the most widespread (P. Díaz, 2011), renewable alternatives are also available and gaining ground not least due to the ease of operation and independence from fuel supply and other operational costs (thus far mostly concentrated on the use of hybrid systems such as wind-photovoltaic and thermal-photovoltaic).

If no storage systems are considered, the energy that is being consumed has to always be equal to the energy being produced at any given moment. This fact is called the load balance and is much easier to achieve when the sheer number of consumers and the power transferred is high, as the inertia of the grid allows for the imbalance produced by an entrance or exit of a consumer.

When considering smaller networks, the fact that the expansion of consumption must always be compensated by an expansion of the production capability brings a very local hassle, as a consequence of the necessary space occupancy, generating feeling of NIMBY- Not In My Back Yard.

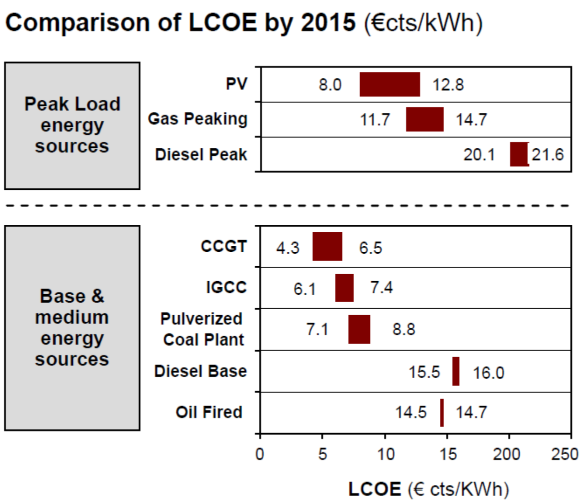
Environment

As mentioned above, due to the operational simplicity and lack of maintenance other than the cleaning of the PV panel, solar power electricity generation has been a major trend. Environmental positive spillovers occur as this technology is free from emissions when in operation, which dilutes the pollution that occurs with the production of the components, making this one of the least polluting technologies, as may be seen in the following figure:



Graph 5 - Life cycle CO2 emission factor per electricity generating technology (Hondo, 2005)

Still, if we take into account the cost of carbon emissions from different technologies, through the concept of Levelized Cost of Energy (LCOE), PV energy generation's cost is still high versus other energy sources, though the gap is expected to shorten over the coming years (see also Graph 28 - LCOE estimate by 2015 and 2020 per energy source (AT Kearney, 2009)).



In scope generation technologies		
Technology	**Fuel type**	**Description**
CCGT	Gas	• Combined cycle gas turbine ; • Base and medium load; • Size: usually 300-600 MW
Gas Peaking	Gas	• Combustion turbine; Peak load; • Size: usually 100-200 MW
IGCC	Coal	• Integrated gasification combined cycle; Base Load; • Size: usually 300-600 MW
Subcr. PC	Coal	• Subcritical pulverized coal plant; Base load; • Size: usually 300-600MW
Oil-Fired	Residual Oil	• Base load; • Size: usually 300-600MW
Diesel Engine	Residual Oil	• Base load(sunbelt countries) and Peak load (developed countries); Size: usually 2.5-20MW

Graph 6 - LCOE estimate by 2015 and 2020 per energy source (AT Kearney, 2009)

Efficiency

In energy production, scale is a factor. As mentioned, the cost per unit of energy produced in centralized power plants is smaller than the distributed alternative. However, when taken into account the distances to the consumer and acknowledging not only the cost of implementation of such a transport and distribution network, but also the energy losses along the way, estimated at around 16% (Empresa de Pesquisa Energética, 2012), the overall distributed production system efficiency can be competitive (Global Network on Energy for Sustainable Development, 2007).

Security

Considering the areas of the globe without current access to electricity one easily correlates these with areas of underdevelopment, war and low-density population. With long transport lines and abandoned substations, transport grids are not only costly infrastructures to build, they are also a low-risk, high-impact infrastructure eligible to be targeted by less satisfied factions of the population.

Without connection to a transport grid, decentralized energy systems allow for the production and consumption to take place in the same area, thereby constituting a tighter and less vulnerable network.

As mentioned before, the limit of decentralized energy production comes when each consumer is his own producer, known as off-grid micro-generation. This allows for the "freedom" from having electricity bills and changing tariffs, as well as being self-reliant in emergency situations, though it usually requires significant investment in energy storage capacity (batteries) to cover periods with insufficient production (like nighttimes for PV systems) and the risk of being left without power given the typical lack of redundancy within these systems. Grid connected systems, on the other hand, enjoy the benefits associated with backup redundancies that are usually built-into such systems, as well as the ability to sell or trade excess energy not consumed locally, though they lack flexibility due to the need to consume within physical proximity of a distribution network.

Data sources and methods used to collect data

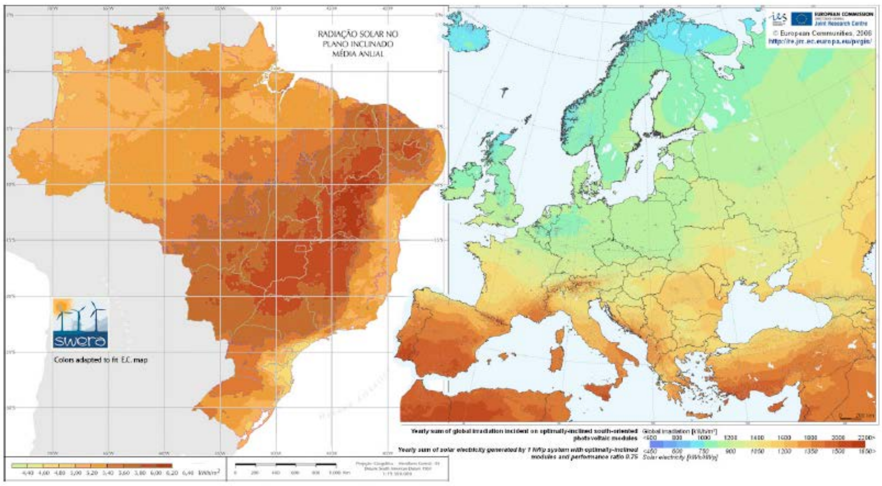
The focus of this section will be to analyze the case of Brazil, where The Lisbon MBA International Lab took place embedded in the São Paulo office of EDP (Energias de Portugal), with a focus on a developing opportunity regarding small distributed capacity (residential-scale projects under 1 MW) which has seen growths of 900 percent over the past five years across G-20 countries, reaching $71.5 billion investments in 2011 (The Pew Charitable Trusts, 2011).

Data sources range from information provided by EDP itself in Portugal and Brazil, to research performed online regarding existing academia databases on the relevant topics, as well as industry, government and NGO's publications on energy and specifically on solar power matters. Also, a qualitative research was conducted through a series of 17 one-to-one interviews, talking with potential household consumers, businesses, construction and energy companies, complemented by an online survey gathering responses from 89 households, 5 businesses and 3 construction companies from the São Paulo area.

Data treatment and analysis: Brazil as case in point

Though Brazil is still considered a developing country in most regards, in what concerns electricity availability to its population it has an electrification rate that reaches 98.3%, leaving "only" 3.3 million people without access to electricity, significantly above the 93.2% average for Latin America or 80.5% world average (International Energy Agency, 2011). This achievement is owed namely to the government program called "Electricity for All", started in 2003 with the aim of providing affordable access to electricity to over 10 million of its citizens, most of which live in rural and underdeveloped areas, having reached by May 2012 over 14.4 million people. Detailed results of this program actually show that of those covered, 80% bought a television and 73% a refrigerator, with 91% stating that their quality of life improved (Ministério de minas e Energia).

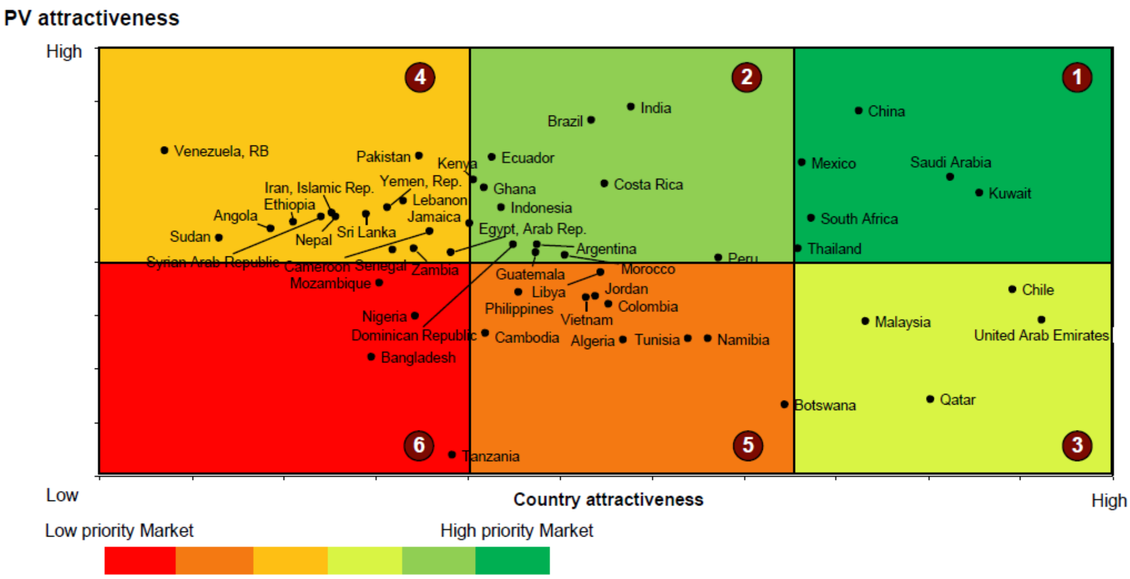
Through Graph 7 - Brazilian annual solar irradiation and Solar Electricity Potential in European Countries, comparing Brazil's and European annual solar irradiation and solar electricity potential, it becomes clear how much potential there is in Brazil for PV technology and how astonishing it is that Germany already boast 24.6GW of PV installed capacity (The Pew Charitable Trusts, 2011) whilst Brazil has under 20MW (Alcântara, 2010).



Graph 7 - Brazilian annual solar irradiation and Solar Electricity Potential in European Countries (Krenzinger, 2011)

Brazil's geography places it in the so called sunbelt area of the globe, between 35º north and 35º south of the equator, an area which makes it especially suitable for photovoltaic energy solutions thanks to the number of hours and intensity of sunlight it gathers.

In fact, Brazil has been considered by AT Kearney as having one of the highest degrees of PV competitiveness using the concept of Levelized Cost of Energy (LCOE) and taking into account the size of the electricity market, PV cost competitiveness (irradiation, cost of existing energy sources) and power distribution and transmission losses (AT Kearney, 2009).



Graph 8 - PV attractiveness vs Country attractiveness (AT Kearney, 2009)

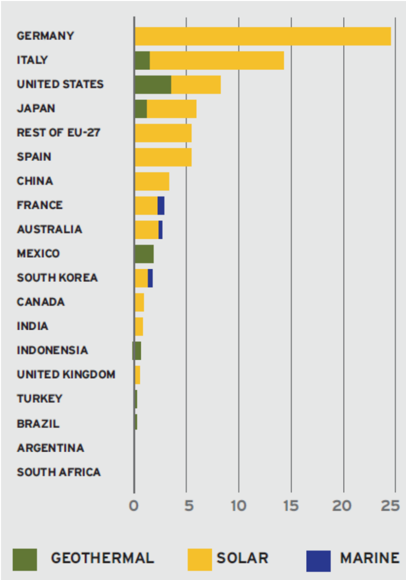
Although technology costs are somewhat standard across different countries given today's global supply chains, Germany is currently the country with the largest installed solar capacity by a significant margin. This development is largely due to its government incentive programs which guarantee feed-in tariffs for up to 20 years, far above current electricity costs, making this a long term investment with very limited risk for investors (the revenue stream is known and government guaranteed from the start).

Country	Tipical cost of solar energy			Electricity energy tariff
	Without incentives	With incentives		
		Governmental	Governmental & Private	
Germany	50	-15	-20	17
Spain	30	25 to 30	-20	7
New Jersey	50	45	11	12
California	35	10 to 15	10 to 15	15
Japan	50	45	20 to 40	21

Graph 9 - Comparison of energy costs from photovoltaic vs standard grid offer (US cents/ kWh) (ROGOL et al apud DA SILVA, 2006)

Brazil boast the world's 8th largest installed capacity for electricity generation in the world with 106 GW and the 7th largest when it comes to alternative sources (geothermal, wind, solar, wave, biomass and residues) (Empresa de Pesquisa Energética, 2012), with 74% its total energy sourced from Hydro sources alone in 2012 (Empresa de Pesquisa Energética, 2011). Also, Brazil comes in 3rd as the country with the largest growth in renewable energy capacity between 2006-2011 (The Pew Charitable Trusts, 2011).

Given its energy matrix, already heavily biased to renewable sources, and the high cost of PV technology, it is thus natural that Brazil offered no government supports for the development of solar power and, up to 2012, the government still had not passed the necessary legislation to allow for individuals and businesses who set up their photovoltaic micro generation (under 100kW) to sell excess energy back to the grid. As such, only a very small number of installations have taken place (around 20MW or 0.02% of the total), mostly to serve off grid locations (not connected to the standard energy grid) to pump water and for rural electrification in Amazonia, in the North and Northeast mostly thanks to a government sponsored program – Programa de Desenvolvimento Energético de Estados e Município (PRODEEM) (Alcântara, 2010).



Graph 10 - G-20 Installed capacity in 2011 (GW) (The Pew Charitable Trusts, 2011)

Country	2010	2011
United States	26.3	15.7
Canada	0.1	0.5
Japan	8.9	1.4
South Korea	10.2	6.3
Germany	8.9	6.2
France	2.1	0
United Kingdom	1.3	1.4
EU 27	3.2	2.6
China	32	12
Brazil	0.2	0
Australia	1.6	0.008
TOTAL	95.4	46.3

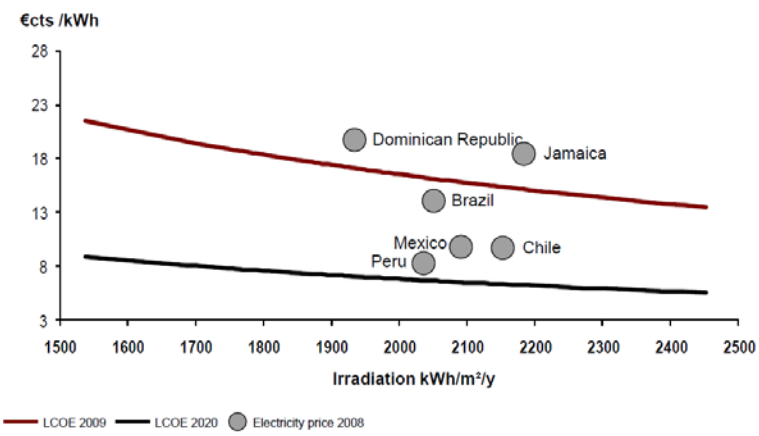
Source: Bloomberg New Energy Finance

Graph 11 - G-20 Clean Energy Stimulus funds spent (Billion USD) (The Pew Charitable Trusts, 2011)

Still, looking ahead, GDP and electricity consumption forecasts point to annual growths above 4% for the next 10 years, taking it from the current 472 TWh to 736TWh by 2021 (+55% vs 2011) (Empresa de Pesquisa Energética, 2011) which continuously raises the issue of how to continue expanding the base electricity generation capability and how to handle its peaks.

Cost vs. existing sources

Despite the fact that PV LCOE is expected to decrease by 40% from 2009 to 2015 and 60% until 2020 (Graph 30 - PV LCOE), its cost is still expected to be higher than other existing energy sources in sunbelt countries, making it interesting to cover peak loads in the grid, but not yet as an alternative to the majority of production.



Graph 12 - PV LCOE vs. household electricity prices (AT Kearney, 2009)

Specifically in Brazil, the same study shows that already in 2009 PV costs were close to reaching parity with existing sources, a threshold which will be surpassed in the short term, concluding that Brazil has the third largest PV potential GWp in this group of countries, with an estimate ranging from 14.3 to 42.8 by 2020.

Why the time for distributed PV micro generation is about to arrive

In April 2012 Brazil's government issued legislation (Resolução Normativa Nº 482, de 17 de Abril de 2012) to be put into effect within one year of its publication, forcing local energy companies to make the necessary technological upgrades to allow individual consumers and businesses to connect to the grid and sell their user generated electricity.

However, unlike other countries in Europe that set up subsidized energy prices (feed-in tariffs), Brazil has set up a net metering policy, under which consumers are only billed for the excess energy they consume from the network once the energy they input is accounted for, though they still need to support a minimum availability fee from their local energy company. Also, the said legislation, in chapter III section IV, opens the possibility for energy credits generated by one consumer to be used by the same consumer in other points of consumption (such as second homes or other business sites), as long as they lie within the same electricity distributor area.

Photovoltaic panels as an investment in Brazil

Looking into the current situation of Brazil in order to determine the potential for distributed photovoltaic micro generation, we first had to compare the current cost of electrical energy supplied by existing infrastructure to the one available from current solar technology.

The base premise was that, as experience from other countries adopting such technology demonstrates, unless the cost of photovoltaic technology is at par or lower versus existing supply, there will be a need for government subsidies or investment guarantees to bridge the gap before ordinary citizens and businesses start adopting them on a large scale.

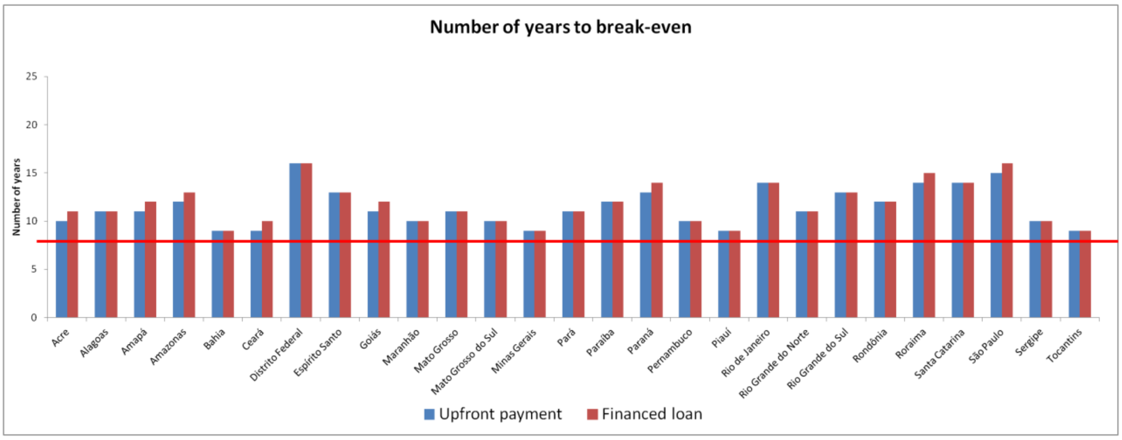
Therefore, a model was built in excel format which allows for the calculation of relevant data regarding an investment of this nature, taking into account the input of relevant variables, namely:

- ✓ Installed panel capacity: 3kWp (supplied by EDP as equivalent to a 4 person household or small business)
- ✓ Cost per Watt (Reais/Wp): 8 (supplied by EDP as reference turn-key cost including panel and installation cost per Wp)
- ✓ Diminishing return of panel efficiency: 3% in the first year, 0.7% in the following years up to the 25 year life expectancy of the panel (supplied by EDP)

- ✓ Yearly maintenance cost: 0.5% of initial investment (supplied by EDP)
- ✓ Loan interest rate: 8% per year (supplied by Brazil's National Development Bank for projects of this nature)
- ✓ Loan maturity: 4 years (average preference from field research)
- ✓ Initial payment: 1.500 Reais (average preference from field research)
- ✓ Discount rate: 4.5% (equivalent to expected inflation rate by EDP)
- ✓ Exchange rate: 2.022 USD/Real (as of August 2012)
- ✓ Yearly increase in electricity tariffs: 4.5% (equivalent to expected inflation rate by EDP)
- ✓ Energy tariffs per state: references supplied by EDP
- ✓ Annual sunlight per state: references supplied by (Tiba, 2000)

A PV installation can be seen as a fairly straight forward investment, with a known negative cash flow at time zero, with the purchase of the equipment itself and the necessary installation costs, and a future stream of positive cash flows as the panels produce electricity which is used for local consumption, thereby saving its expense which would otherwise be incurred upon, plus the income generated from trading with the local power supplier the excess energy which is not used locally.

Therefore, based on the data described before, we were able to calculate, among others, the number of years to reach breakeven on such an investment, per state, for two scenarios: upfront payment and financing via bank loan.



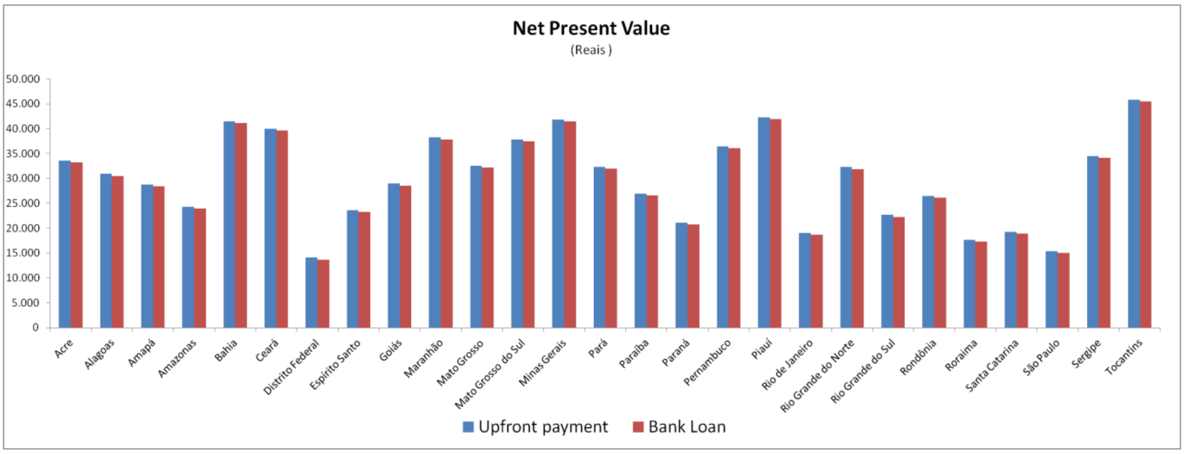
Graph 13- Number of years to break even for average micro PV investment in Brazil

As can be seen from the graph above, there are significant differences between states, mostly due to the differences between the local electricity tariffs that range from 0.36 to 0.63 R$/kWh (a gap of 75%). Naturally, a higher electricity cost will mean that an alternative energy source will pay back sooner, as each unit saved has a higher value to the consumer.

The other variable that distinguishes states is the number of sunlight hours they get per year: in this case, the gap between the lowest (Santa Catarina) and the highest (Rio Grande do Norte) is 30%.

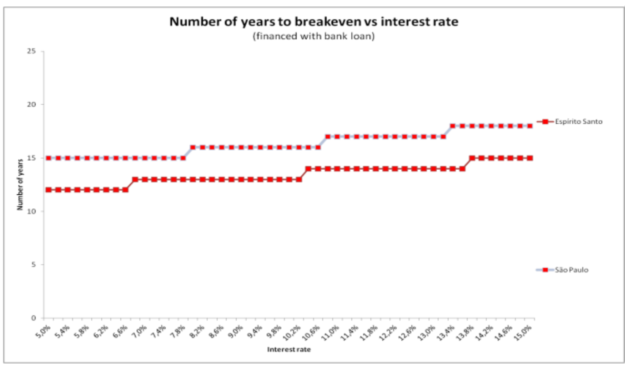
All variables combined, the number of years to reach breakeven for a household of 4 people ranges from 9 years (Tocantins, Piauí, Minas Gerais, Ceará, Bahia) to 16 years (Distrito Federal, São Paulo), which is interesting if we put into context that in Europe average households only adopted such technologies when the number of years to break even went below 8 (marked by the red line across Graph 13), and our own research indicated that in Brazil consumers have a much shorter term view of their investments, taking into consideration only those that range up to 4 years to reach break even.

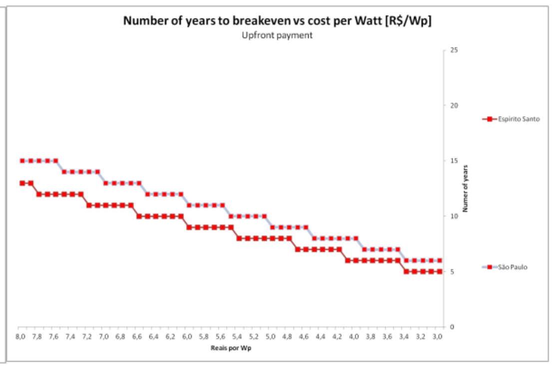
Still, given the 25 year life expectancy for the panels, for the simulation at hand this means that even without considering government subsidies this would be a profitable investment with a Net Present Value ranging from 13.000 to 46.000 Reais for an initial investment of 24.000 Reais (Internal Rate of Return from 9% to 20%).



Graph 14 - Net Present Value for average micro PV investment in Brazil

One further analysis done via the said model was a sensitivity analysis of the number of years to breakeven related with variations of the interest rate and cost of the technology.





Graph 15 - Number of years to breakeven vs interest rate for average micro PV investment in Brazil

Graph 16 - Number of years to breakeven vs cost per Watt for average micro PV investment in Brazil

As can be seen from Graph 15 - Number of years to breakeven vs interest rate, the variation of interest rates does not have a significant impact in the number of year to breakeven: São Paulo, for example, goes from 15 years at 5% to 18 years at 15% (see *Graph 33 - Number of years to breakeven vs interest rate* for detail on the remaining states).

On the other hand, Graph 16 - Number of years to breakeven vs cost per Watt shows that as technology costs decrease, the impact in the number of years to breakeven reduces more significantly, thanks to the reduction of the required investment (assuming that panel output remains at par with current technology). Still, taking into account that in most installations the panel cost represents half of the total cost (the rest being construction work and other electrical materials), this means that at today's prices, even if the panel were free the cost per watt would still be at 4 Reais, meaning for São Paulo a breakeven of 8 years, still too high for its adoption (see *Graph 34 - Number of years to breakeven vs cost per watt with upfront payment* for detail on the remaining states).

Overall, this analysis allowed us to demonstrate the significant differences consumers will be facing across different Brazilian states, indicating that the current differences in energy tariffs lead to a distortion in the expected adoption rate of this technology. Also, we come to the conclusion that at this time, as an investment opportunity, photovoltaic micro generation still has some way to go before being considered as interesting, given its long period to breakeven when compared to other countries, in the absence of government incentives. In fact, by late 2012 president Dilma Rousseff announced plans to reduce the current electricity tariffs by as much as 28% starting in 2013 (Revista Exame, 2013), which would significantly increase the expected number of years to breakeven and thus delay even further the adoption of PV solutions.

The alternative

As described before, Brazil poses an interesting challenge for distributed PV micro generation: on one hand, its electricity demand is increasing and its geography placement in the globe gives it a significant solar exposure, but on the other hand the recently passed legislation refrains from giving the sort of government subsidies that projects of this nature have thrived on in other world economies, making its cost too high for most.

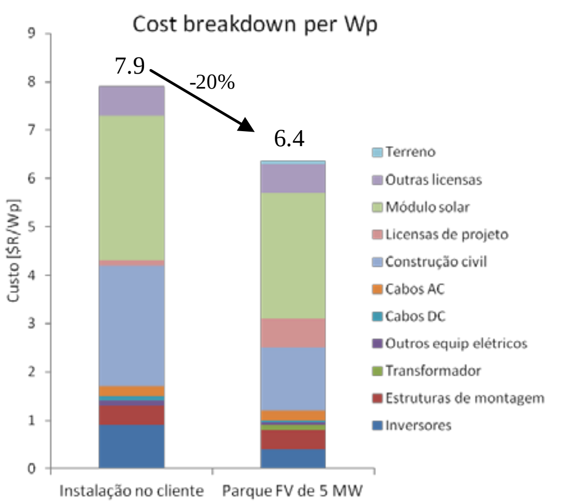
Still, the before mentioned chapter III section IV of the Resolução Normativa Nº 482, de 17 de Abril de 2012 has in effect, in our view, opened a significant loophole. One characteristic of micro generation is that its intended purpose is for installations to occur on a very small scale at a residential level, which by definition means that there are significant on-costs derived from a "capillary" system (from installation to maintenance, any intervention requires that technicians go to each individual site which can be dispersed over a wide area). However, if energy producers may produce electricity in one home and benefit from excess credits at another home, it should be possible to develop a solar farm, where multiple consumers would be owners of parcels, using the generated credits at their homes.

Such a solution would enable significant advantages, such as:

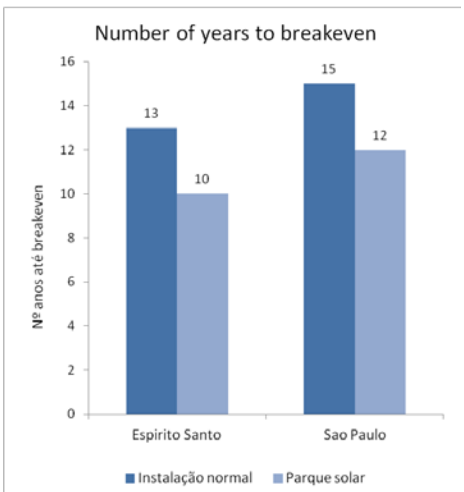
- ✓ Eliminate space constraints in urban areas densely populated by multiple stories buildings and high-rises (which naturally limit the available physical space for panel installation and generate significant shaded areas from buildings blocking each other's sunlight exposure);
- ✓ Reduce costs by taking advantage of scale economies (installation, maintenance, security);
- ✓ Enable the use of simple solar concentrators which enhance even further the panels output;
- ✓ Enable owners to acquire PV solutions without the hassle of construction work that goes into mounting the panels on the roof;
- ✓ Enable owners to change house without needing to leave behind their PV installation, or even to resell their panels halfway through its lifespan;
- ✓ Makes sense from a grid point of view as it still reduces the amount of energy loss through transport.

However, one must not forget that the legislation requires the production and consumption points to lie within the area attributed to each electricity distributor (there are 64 different ones across Brazil), somewhat limiting this alternative's potential, namely if one were to consider the set up of a solar farm in the interior rural areas of Brazil, where the land is less expensive and the sunlight strongest, only to then use the credits in an urban area like São Paulo.

Still, one must not ignore that this was surely not the intended purpose of this section in the legislation, so before going ahead with investments on this basis one should clarify with the regulator that one may do so in order to avoid the issuance of complementary legislation closing such a loophole.



Graph 17 - Cost breakdown of standard PV vs solar farm



Graph 18 - Years to breakeven of standard PV vs solar farm

Overall, this alternative could take around 3 years off of the period to reach breakeven, which is not only significant by itself, it could also make the difference to the first company that explores it gaining a first mover advantage, a huge benefit in a country with this much potential and no upfront prime contender to take the lead in this area.

Even if from the outside this solar farm would look just like those in other countries, in order to comply with the said legislation each panel(s) would have to have separate meters and ownership so that one could trace the production credit to attribute to their owners. In actual fact this would mean a significant change in approach: companies would be selling a service (the co-ownership, set up and maintenance of the panels) instead of a product (the panel and installation at the buyers home).

Business model to launch PV solutions in Brazil

Product vs. Service

The first issue at hand upon the set up of a business to market PV solutions in Brazil would be to determine what would be sold: a product (panels, installation and maintenance) or a service (to provide a discounted energy bill).

Given our findings, the best option seems to be the latter, since the solar farm allows for cost savings that can be passed on to the consumer, making this service appealing a few years in advance of the more traditional solution, as well as carrying many other advantages as stated before.

Regarding panel sourcing, in today's global market, considering Brazil's typically high import duties versus its limited internal production capacity, there would be little alternative to their import from Chinese manufacturers (see Graph 22 - Regional PV cell shipments).

Consumer segmentation

From our research, we concluded that there were 4 major consumer segments that could be targeted to effectively introduce this technology in Brazil, distinguished by their different purchase drivers: AA Households (earning over 15.000 Reais/ month), Other households (A, B, C), Construction companies and Businesses. Surely, within each group there should be identified sub-segments in order to properly determine a route to market, but on the whole their underlying purchase drivers will be the same.

The key attributes found to be of most relevance across all segments in the purchase of PV systems were:

- ✓ <u>Investment</u>: PV systems can be viewed as a simple investment with cash flows coming from the initial investment and future savings from grid sourced energy;
- ✓ <u>Real estate valorization</u>: A house fitted with a PV system will tend to be worth more than a similar one without, given its grid energy cost saving potential;
- ✓ <u>Environment</u>: PV systems are able to produce electricity with lower $CO2$ emissions, thereby helping the environment for the same level of energy output;
- ✓ <u>Image</u>: PV systems tend to be big in size, and their placement in one's home is usually visible from the outside. This attribute refers to how important it is for the purchaser to be seen as someone who cares for the environment, or as an early adopter of new technologies, by others.

	Households		Construction companies	Businesses
	AA	Others		
Investment		xx		xx
Real estate valorization			xx	
Environment	xx	x		
Image	xx		x	x

Legend: xx – main purchase driver
x – secondary purchase driver

Graph 19 - PV system purchase driver in Brazil

AA Households

This target's main objective when purchasing a PV system is related with reducing the environmental impact of their consumption. In fact, from our interviews we found that even at today's cost this is an interesting option for this target, given their low price sensitivity.

Second in their priority is its contribution to their image: people in this target tend to value the perception others have of them and their choices, hence a PV solution is seen as something that will help their perception as environmentally responsible people.

Other Households

For the remaining households, the most important feature of a PV system is its profile as an investment, with the concern for the environment coming in second place, only to be considered if as an investment it makes sense.

Actually, as an investment, we found that average consumers were only willing to consider purchasing such a solution should the breakeven period be reached within 4 years of the initial investment, regardless of its 25 year lifespan and positive NPV profile. This we found to be related with a cultural focus on the short term, much more so than in Europe where a more medium to long term view is held.

Construction Companies

For construction companies there are two perspectives: the main one is the extent to which a PV system adds value to the properties they build, in the sense that a house equipped with a solar panel will be worth more than one without. From this point of view, the focus is placed on how much buyers will be willing to spend on top, not on how much the panel will actually yield: if a panel costs 25.000

Reais but the construction company is able to charge over 25.000 Reais on top for its house, then its payback is immediate, and hence PV system adoption may make sense even at today's cost.

The second perspective is the image impact it apports to the company as a whole and how much that can add value to its properties: if a given construction company is seen as environmentally responsible thanks to its use (in its construction sites or even in its headquarters) of PV systems, then it is likelier to be able to charge a premium on its developments, and hence gather the payback from its investment not only from the energy savings it generates, but also from the additional value it can charge.

Businesses

For businesses as a whole, the first priority to consider when evaluating a PV system is its profile as an investment, much like other households, but also its impact on the business brand image and how it can be translated into additional value to be charged to their customers, as described before regarding construction companies.

Other interesting findings from our research were the facts that most interviewees overestimate the degree of pollution from Brazil's energy matrix (considering it as more pollutive than world average) and that almost a third of them overestimate the current cost of PV technology, which should be taken into account when determining the best approach in terms of communication for the marketing strategy of such products and services.

Partnerships

Since Brazil is such a large country and this technology is so insipient, partnerships would need to be established in order to efficiently gain critical mass, namely with:

- ✓ Technical schools: the company would potentially subsidize these schools, contributing with knowledge and experience in exchange for access to the technical staff who would in the future become the installers for their technology;
- ✓ Energy service companies / Installers: the company would bring additional products for these partners to market and they would provide the necessary geographical coverage of their existing commercial network;
- ✓ Banks / Insurance companies: the company would bring in new products for banks and insurance companies to cross-sell, facilitating at the same time the adoption of their offer by making them more accessible via financing alternatives to up-front investments.

Market Access

When considering how to access the market, decisions regarding three variables would need to be taken: Field Network (to develop one from scratch or use existing ones); Geographical delimitations (hand out exclusive dealership areas or not) and Exclusivity (require that our brand be exclusive within a dealer or not).

Field Network	**Own**	+	better control, knowledge integration, quality guarantee
		-	lower flexibility, higher cost, longer to reach geographical coverage, lower commercial aggressiveness
	Third-party	+	local knowledge, flexibility, capilarity
		-	lower control, difficult knowledge integration
Geographical delimitation	**Open**	+	local knowledge, flexibility, capilarity
		-	lower control, difficult knowledge integration, conflicts from area overlaps
	Limited	+	better control and accountability
		-	lower flexibility, lower geographical coverage, lower ramp up time
Exclusivity	**Exclusive**	+	better brand control and service quality consistency
		-	more difficult to implement, lower margin
	Non Exclusive	+	faster speed of implementation
		-	lower commercial aggressiveness, larger margin

Graph 20 - Advantages and disadvantages from Market Access decisions

A decision on these variables would need to take into account the existing conditions of the company about to undertake this endeavor, but *per se*, a third-party network with limited geographical coverage in a non-exclusive partnership would seem to be the best alternative for a fast ramp up in order to gain critical mass.

Still, these are but a few considerations on the decisions that would need to be taken, as a deeper strategic and financial analysis taking into account the specificities of the company considering to enter such a market would need to be done.

Nonetheless, one should note that the commercialization of these types of products and services is not limited by legislation to existing energy companies. In fact, consumer opinion of existing energy companies is so poor (probably due to their ailing infrastructure) that they should consider thoroughly whether to launch this new offer under their own brand or to make the investment and create a new one altogether.

Conclusions

Regardless of the directionality of causality between GDP growth and energy consumption, it is fair to say that the two are positively correlated and have enabled the exponential development of mankind, both in population numbers and in quality of life.

With the development of technology we have seen time and again how prevalent and widespread solutions can become obsolete within a few years leading to complete paradigm shifts (from telegraph to land line telephone to mobile phone to web phone; from huge mainframe computers to desktops, to laptops to tablets and smart phones).

As such it is no wonder that one can look to the future with a hopeful notion of continuing development and additional energy needs and question whether the solutions from the past, namely in terms of electricity production, will hold in the next few years or will be made redundant as so many before them.

At a time when energy related pollution is reaching the top of the political agenda and the costs with expanding the existing energy producing infrastructure seem all the more difficult to manage, it is hard to continue ignoring the solar option's potential, especially when its costs have fallen so sharply even in the absence of a sizeable worldwide demand.

Micro generation PV solutions may not be the only answer to the world's electricity needs, but from the research conducted they surely seem to be eligible to start by complementing existing grids with benefits for the distributor (managing demand peaks and reducing losses in energy transportation), the user (through credits or subsidized feed-in tariffs that lead to NPV positive investments), the government (reduced investment needs in the local infrastructure) and the environment (with lower CO_2 emissions).

The case of Brazil is an interesting one: it has a huge landmass geographically placed in the sunbelt area of the globe; it already boasts one of the "greenest" energy production matrix in the world, heavily based on hydro solutions; despite its "developing nation" status, and poverty headcount ratio still above 10% of its population (World Bank, 2009), it has an almost universal electricity grid coverage; its energy needs will almost double in the coming years and finally, it has just taken the first steps to allow for distributed PV solutions to take off with the passing of necessary legislation in 2012.

However, a closer analysis revealed significant differences in electricity tariffs across its states, a legislation that falls short of those in other countries by introducing a net metering system (versus a feed-in tariff one), a government that may be about to undermine it by subsidizing regular energy tariffs in an effort to boost the economy and a propensity among potential investors (households and businesses) to only consider projects with very short breakeven periods (under 4 years), regardless of their average lifespan (of 25 years in the case of PV).

In the face of breakeven periods ranging from 9 to 16 years for the average household, it seems unlikely that distributed PV micro generation projects will take off in Brazil in the short term. Only after this period falls to around 4 or 5 years is it expectable to see a massification as that witnessed in other countries such as Germany.

Still, the first opportunity for companies to exploit this market seems to be through the loophole in the Brazilian legislation, written to allow consumers with multiple consumption points to generate their own electricity and get credits for the amount injected into the grid to use them in other points of consumption, such as second homes. This may allow for some form of solar farms to be developed, combining the panels of different owners, allowing for up to 20% cost reduction and a 3 year drop in the number of years to breakeven, among other significant advantages.

For Brazil, I expect that it could be another 5 to 10 years before PV distributed micro generation takes off: production costs and panel output will still need to reduce and improve in order to compete with the existing hydro based infrastructure. For once, this is a case of a developing country which is not particularly worried about the environmental impact of its energy consumption, not because its priority is GDP growth even if at the expense of CO_2 emissions, but because it is already using a large majority of "green" energy sources.

Overall I believe that the continuing development of solar technology will make its role in the energy matrix of countries, especially those in the sunbelt area, all the more relevant. Also, given the growing concerns and costs associated with today's centralized energy systems, I am sure that distributed electricity generation will reach massification levels in the coming years, especially those based on renewable energy sources such as solar and wind, in a path that will render fossil fuels based plants obsolete.

Main limitations

As discussed before, the main conclusions regarding the potential for distributed PV solutions in Brazil lie on premises regarding not only its geographical location and sunlight exposure, but also the current electricity tariffs practiced across its states and technology costs.

Whilst one can be fairly confident that the variables associated with the number of hours of sunlight per state and its radiation intensity will remain constant in the foreseeable future, the remaining variables may be less predictable and hence make these investments riskier than stated:

- ✓ Changes in government policy regarding:
    - Electricity tariffs – if president Dilma's plan to lower tariffs goes ahead as announced, interest in this technology from an investment point of view will be greatly diminished as its NPV will decrease;
    - Subsidies to electricity generation – if the government considers that PV solutions may decrease the need to invest in the standard grid thanks to its contribution to complement demand peaks, it could follow other countries and adopt a feed-in tariff model increasing the NPV of such projects;
    - Import duties – Brazil is known for its tendency to levy heavy import duties in an effort to develop its internal production capabilities. Changes in these policies may have strong impacts in these types of investments which still rely on the import of several key components;
- ✓ Technology cost – PV solutions have seen their cost decrease significantly over the years, especially after Chinese manufacturers started their mass production. This trend is expected to continue as per Graph 43 - PV cost evolution forecast, but it may be made redundant by other technologies in the coming years
- ✓ Interest rates, exchange rates and inflation – although not directly related with these investments, these macroeconomic variables play a key role in determining any project's NPV and as such are an additional and external source of risk.

Also, due to time and budget limitations, the qualitative research's main objective was to determine an approach which could be undertaken at a larger scale, should EDP decide to advance with this type of offer in Brazil, so its results can only be read as proof of concept and not as an accurate representation of Brazil's consumers as a whole. Finally, the focus of this research was to identify the relevant consumer segments to target, leaving the analysis of their size, profitability, etc. out of scope, though these areas would surely need to be covered in order to build a proper business case.

Personal Note

This project had its origins in the International Lab of The Lisbon MBA at EDP's office in São Paulo, Brazil. Taking into account that my previous academic background in Business Management and 10 year career in Fast Moving Consumers Goods Sales and Marketing roles in some of the world's largest multinational companies present in Portugal had never touched any matter concerning the energy market or Brazil's economy, this was an opportunity to develop work completely outside my comfort zone an learn about a new reality.

In order to tackle the challenges posed by EDP, I had not only to research the energy market at a global level in order to benchmark the Brazil case and shape my conclusions and recommendations in light of other more advanced countries' experience, but also to go as deep as possible in the understanding of the Brazilian reality, very different from a market size, development stage and investment priorities to the more familiar European setting.

Personally, the highlights of this project were the time spent in São Paulo, which allowed for close contact with EDP's Brazilian office staff and knowledge, and the fact that we were able to go beyond the initial scope of the project and come up with an innovative solution that exploits a loophole in the Brazilian legislation, enabling the company that first realizes it to have a first mover advantage that could very well be the deciding factor as to who will win the solar PV race in Brazil.

Finally, the opportunity to work alongside our Brazilian colleagues from the INSPER MBA and be advised by Professor Leticia Costa from INSPER and Professor Ricardo Reis from Católica Lisbon School of Business & Economics also revealed essential for the understanding of this business environment.

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Appendix

U.S. Average Levelized Costs (2010 $/megawatthour) for Plants Entering Service in 2017

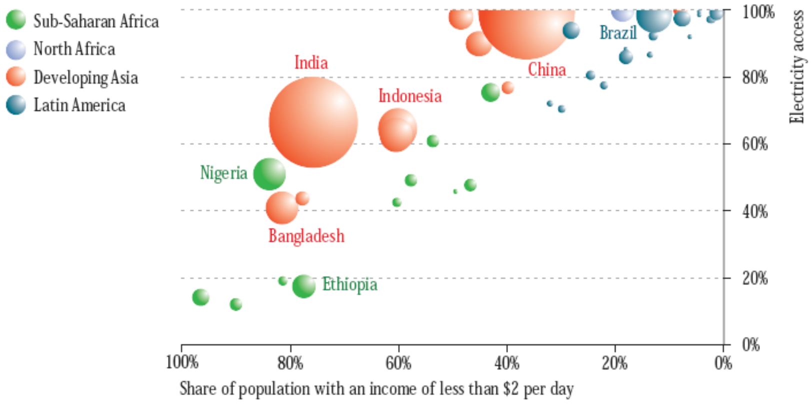
Plant Type	Capacity Factor (%)	Levelized Capital Cost	Fixed O&M	Variable O&M (including fuel)	Transmission Investment	Total System Levelized Cost
Dispatchable Technologies						
Conventional Coal	85	64.9	4.0	27.5	1.2	97.7
Advanced Coal	85	74.1	6.6	29.1	1.2	110.9
Advanced Coal with CCS	85	91.8	9.3	36.4	1.2	138.8
Natural Gas-fired						
Conventional Combined Cycle	87	17.2	1.9	45.8	1.2	66.1
Advanced Combined Cycle	87	17.5	1.9	42.4	1.2	63.1
Advanced CC with CCS	87	34.3	4.0	50.6	1.2	90.1
Conventional Combustion Turbine	30	45.3	2.7	76.4	3.6	127.9
Advanced Combustion Turbine	30	31.0	2.6	64.7	3.6	101.8
Advanced Nuclear	90	87.5	11.3	11.6	1.1	111.4
Geothermal	91	75.1	11.9	9.6	1.5	98.2
Biomass	83	56.0	13.8	44.3	1.3	115.4
Non-Dispatchable Technologies						
Wind	33	82.5	9.8	0.0	3.8	96.0
Solar PV[1]	25	140.7	7.7	0.0	4.3	152.7
Solar Thermal	20	195.6	40.1	0.0	6.3	242.0
Hydro[2]	53	76.9	4.0	6.0	2.1	88.9

[1]Costs are expressed in terms of net AC power available to the grid for the installed capacity.

[2]As modeled, hydro is assumed to have seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.

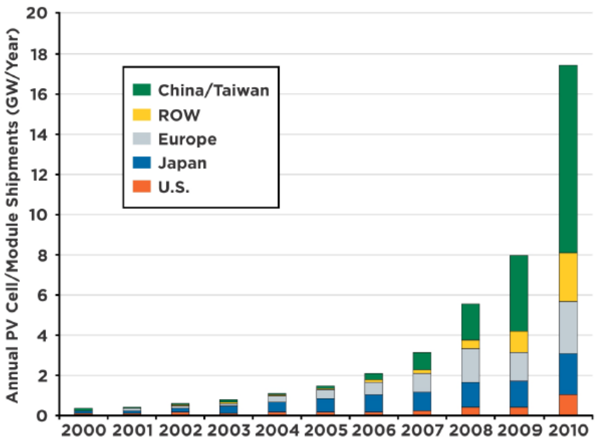
Note: These results do not include targeted tax credits such as the production or investment tax credit available for some technologies, which could significantly affect the levelized cost estimate. For example,new solar thermal and PV plants are eligible to receive a 30-percent investment tax credit on capital expenditures if placed in service before the end of 2016, and 10 percent thereafter. New wind, geothermal, biomass, hydroelectric, and landfill gas plants are eligible to receive either: (1) a $22 per MWh ($11 per MWh for technologies other than wind, geothermal and closed-loop biomass) inflation-adjusted production tax credit over the plant's first ten years of service or (2) a 30-percent investment tax credit, if placed in service before the end of 2013 (or 2012, for wind only).

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2012*, June 2012, DOE/EIA-0383(2012).

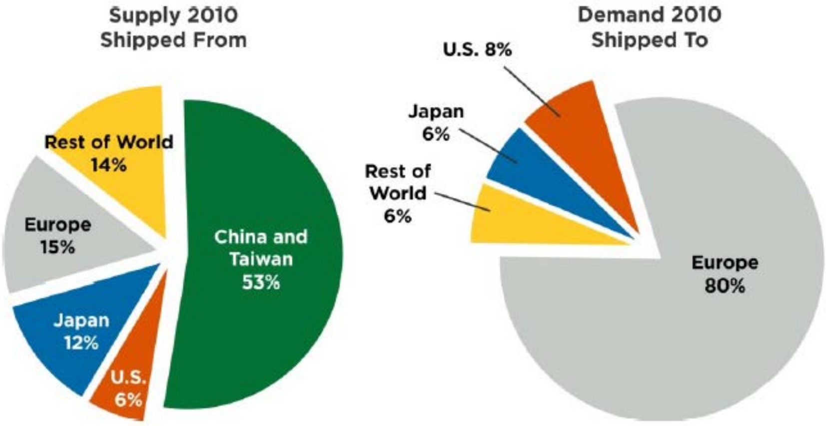


Note: The size of the bubble is proportional to population.
Sources: Electrification rate: www.worldenergyoutlook.org; and poverty rate: http://data.worldbank.org/indicator/SI.POV.2DAY.

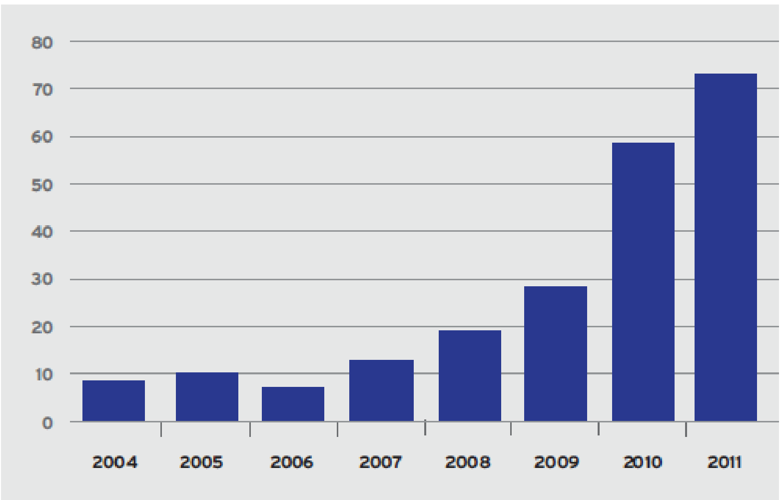
Graph 21 - Electricity access vs Income



Graph 22 - Regional PV cell shipments (National Renewable Energy Laboratory, 2012)



Graph 23 - Global supply and demand for PV (National Renewable Energy Laboratory, 2012)



Graph 24 - G-20 Investment in small distributed solar capacity (Billion USD) (The Pew Charitable Trusts, 2011)

Classe	2010	2011	Δ%
Residencial	107.215	112.232	4,7
Industrial	179.478	183.953	2,5
Comercial	69.170	73.647	6,5
Outras	59.414	61.010	2,7
Total	**415.277**	**430.842**	**3,7**

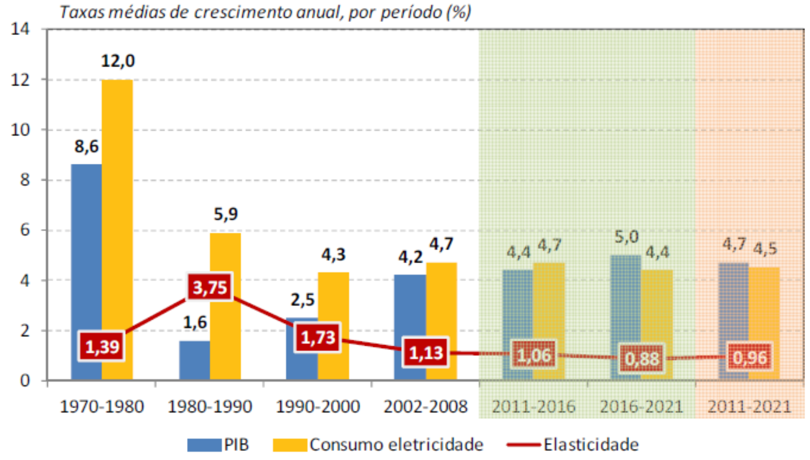
Nota: Estimativa preliminar para 2011.

Graph 25 - Brazil's energy consumption GWh (Empresa de Pesquisa Energética, 2011)

Ano	Consumo (TWh)	PIB (10^9 R$ 2010)	Intensidade (kWh/R$ 2010)
2011	472	3.804	0,124
2016	593	4.717	0,126
2021	736	6.021	0,122
Período	**Consumo (Δ% a.a.)**	**PIB (Δ% a.a.)**	**Elasticidade**
2011-2016	4,7	4,4	1,06
2016-2021	4,4	5,0	0,88
2011-2021	**4,5**	**4,7**	**0,96**

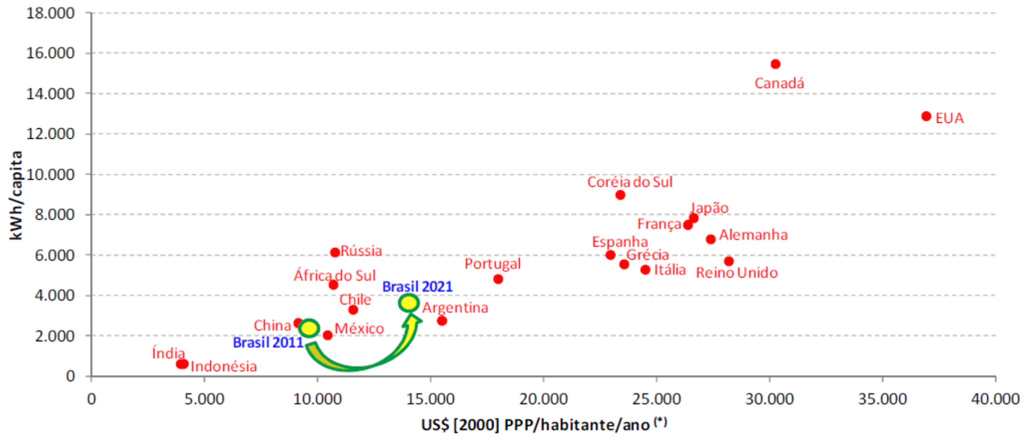
Notas: (i) O consumo de energia elétrica inclui autoprodução; (ii) Para 2011, consideradas estimativas preliminares do PIB e do consumo de energia elétrica.

Gráfico 18. Evolução da elasticidade-renda do consumo de eletricidade (*)



(*) Inclui autoprodução.

Graph 26 - Brazil energy consumption forecast (Empresa de Pesquisa Energética, 2011)



(*) PIB per capita referenciado a US$ [2000] PPP (*Power Purchase Parity*). Os dados são relativos ao ano de 2009 para todos os países com exceção do Brasil.

Nota: considera o consumo total de eletricidade, incluindo a autoprodução.

Fonte: IEA, 2011: *Key World Energy Statistics* 2011. Elaboração EPE.

Graph 27- Electricity consumption vs GDP (Empresa de Pesquisa Energética, 2011)

LCOE definition

- ✓ Cumulated system costs divided by cumulated energy produced over the lifetime of the system
- ✓ Costs are levelized in real terms (i.e. adjusted to remove the impact of inflation)
- ✓ Result is a cost per kWh (€/kWh)

$$LCOE(€/kWh) = \frac{Capex + PV(Fuel + O\&M + CO2)}{PV(EP)}$$

– Capex: Capital expenditures

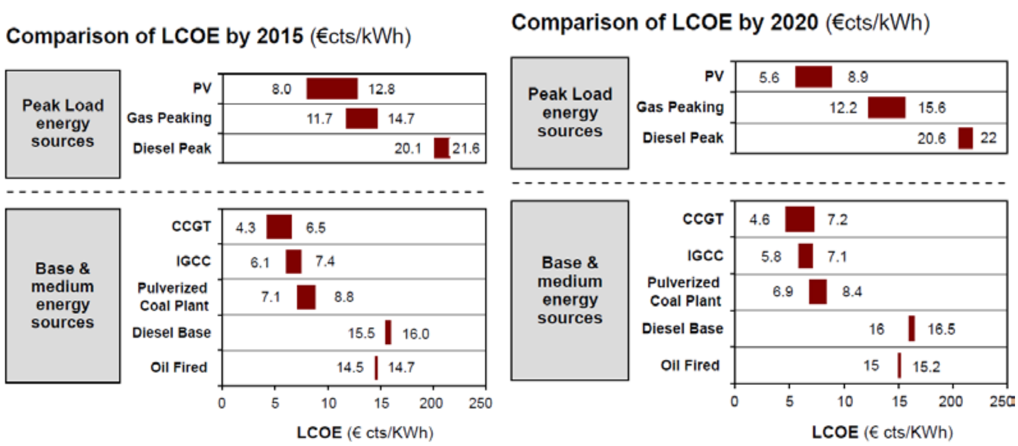
– Fuel: Fuel cost

– O&M: Operations & Maintenance cost

– CO2: Cost of CO2 emission

– EP: Electricity production

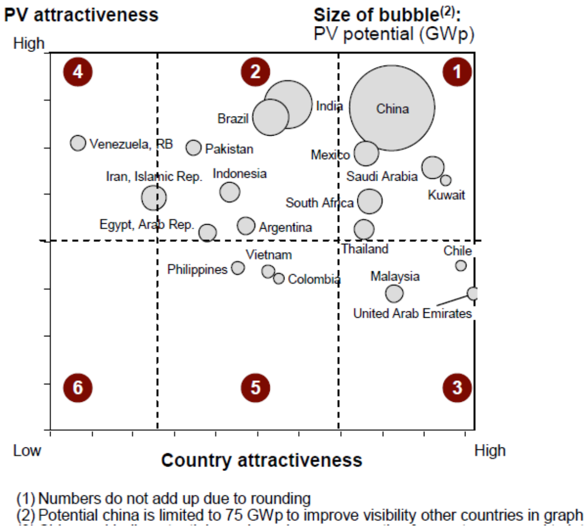
– PV: Present Value



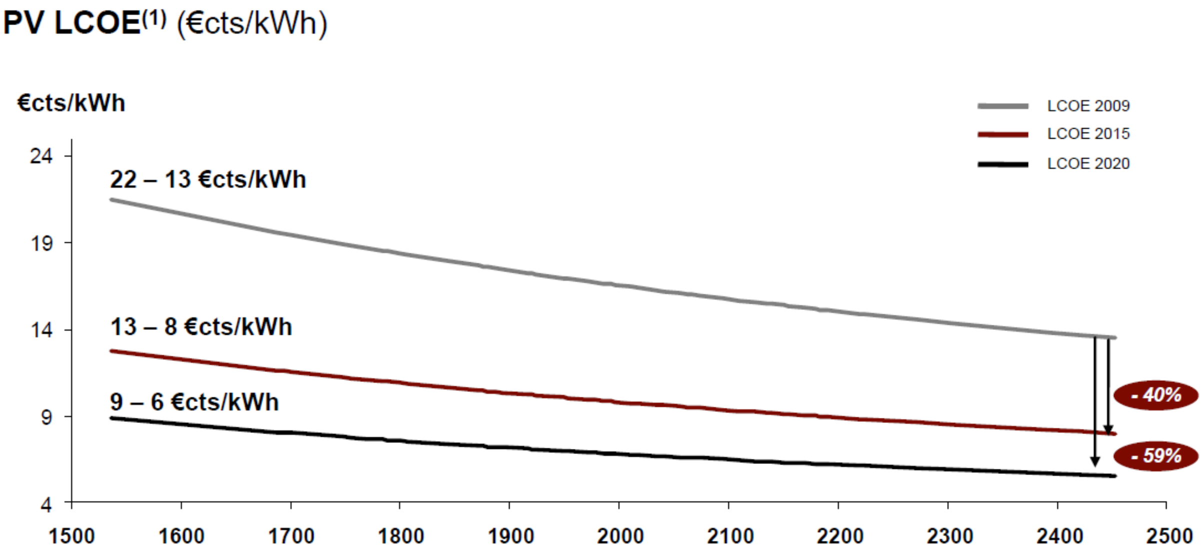
In scope generation technologies

Technology	Fuel type	Description
CCGT	Gas	• Combined cycle gas turbine ; • Base and medium load; • Size: usually 300-600 MW
Gas Peaking	Gas	• Combustion turbine; Peak load; • Size: usually 100-200 MW
IGCC	Coal	• Integrated gasification combined cycle; Base Load; • Size: usually 300-600 MW
Subcr. PC	Coal	• Subcritical pulverized coal plant; Base load; • Size: usually 300-600MW
Oil-Fired	Residual Oil	• Base load; • Size: usually 300-600MW
Diesel Engine	Residual Oil	• Base load(sunbelt countries) and Peak load (developed countries); Size: usually 2.5-20MW

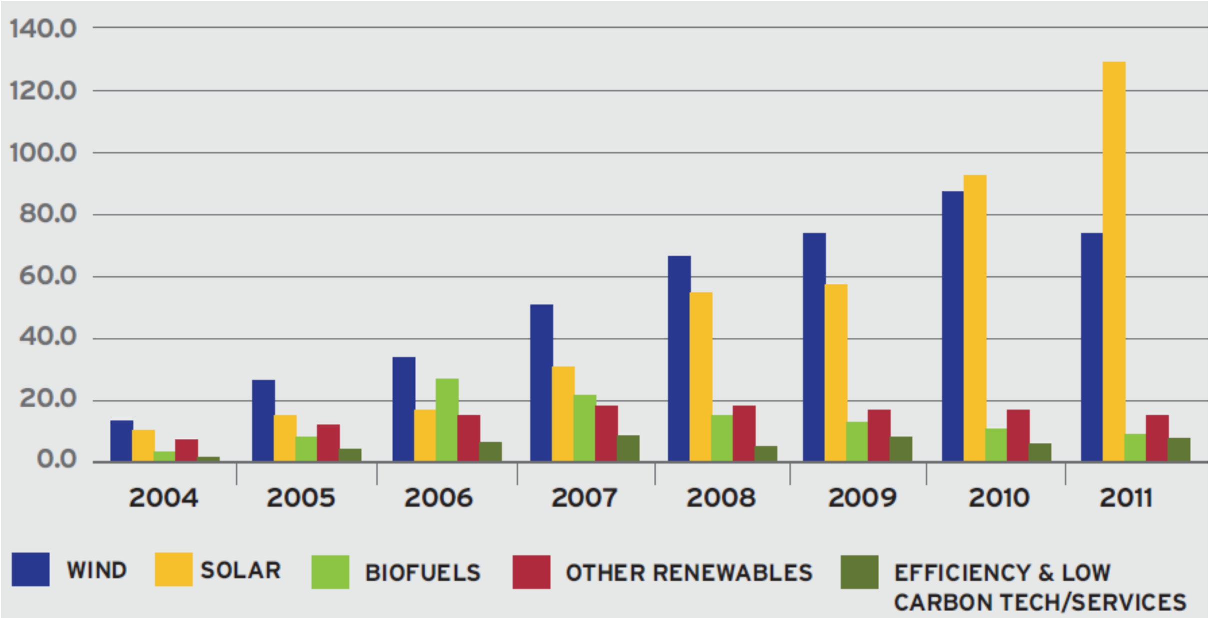
Graph 28 - LCOE estimate by 2015 and 2020 per energy source (AT Kearney, 2009)



Graph 29 - PV development potential for top 20 countries (AT Kearney, 2009)



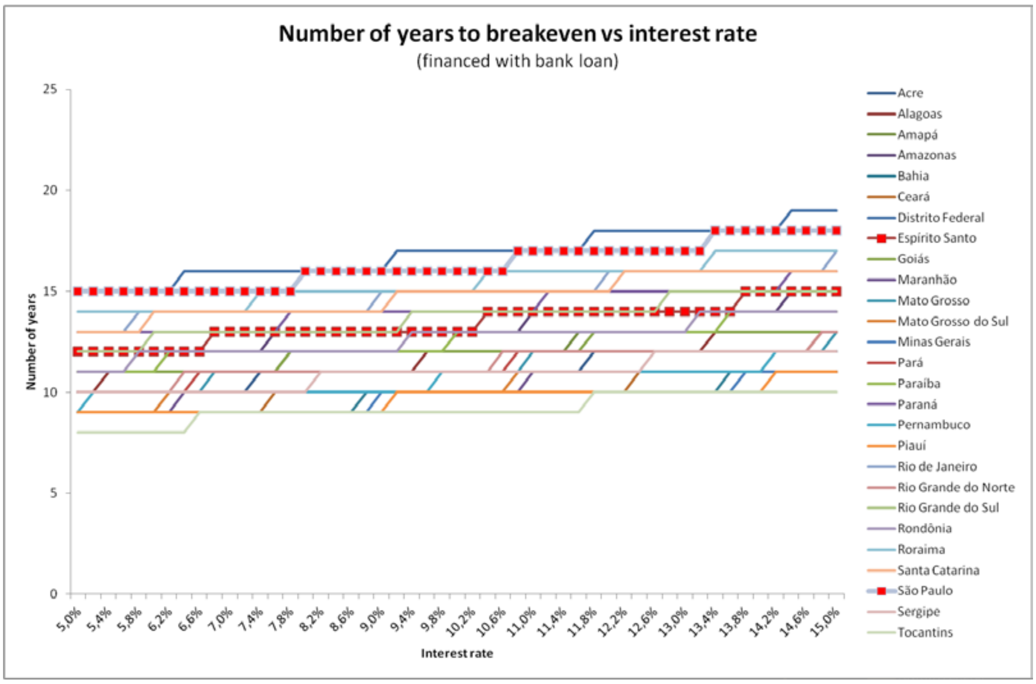
Graph 30 - PV LCOE (AT Kearney, 2009)



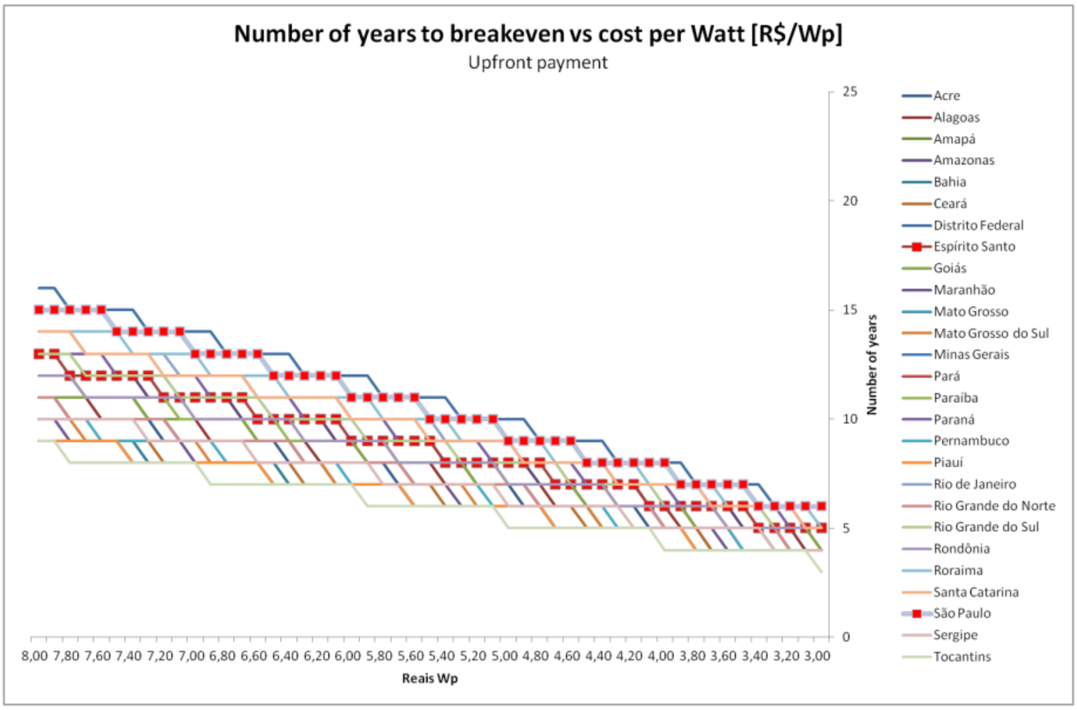
Graph 31 - G-20 countries investment by technology (Billion USD) (The Pew Charitable Trusts, 2011)

State	Yearly usage [hrs]	Electricity tariff [R$/kWh]	Number of years to break even: Upfront payment	Number of years to break even: Bank loan
Acre	1.501	0,59	10	11
Alagoas	1.762	0,48	11	11
Amapá	1.676	0,49	11	12
Amazonas	1.559	0,48	12	13
Bahia	1.707	0,59	9	9
Ceará	1.871	0,53	9	10
Distrito Federal	1.675	0,36	16	16
Espírito Santo	1.537	0,48	13	13
Goiás	1.685	0,49	11	12
Maranhão	1.698	0,56	10	10
Mato Grosso	1.665	0,52	11	11
Mato Grosso do Sul	1.698	0,56	10	10
Minas Gerais	1.637	0,62	9	9
Pará	1.658	0,52	11	11
Paraíba	1.847	0,43	12	12
Paraná	1.553	0,45	13	14
Pernambuco	1.818	0,51	10	10
Piauí	1.834	0,55	9	9
Rio de Janeiro	1.518	0,44	14	14
Rio Grande do Norte	1.879	0,46	11	11
Rio Grande do Sul	1.542	0,47	13	13
Rondônia	1.581	0,49	12	12
Roraima	1.681	0,39	14	15
Santa Catarina	1.441	0,47	14	14
São Paulo	1.586	0,39	15	16
Sergipe	1.799	0,50	10	10
Tocantins	1.688	0,63	9	9

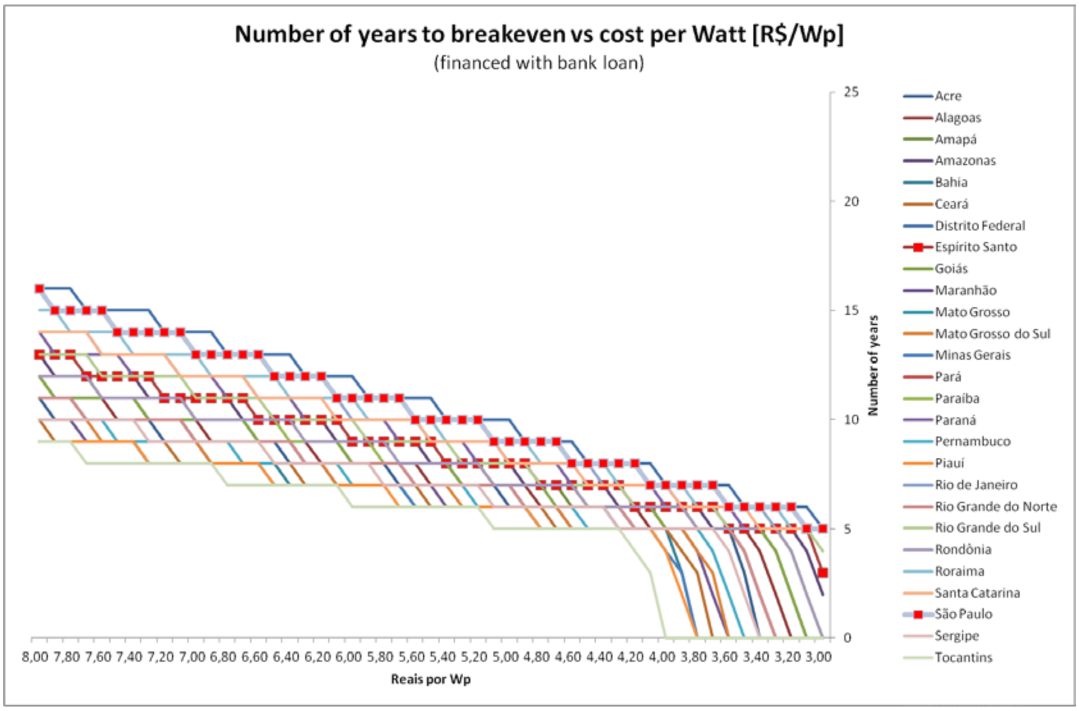
Graph 32 – Brazil: yearly usage and electricity tariffs per state (EDP)



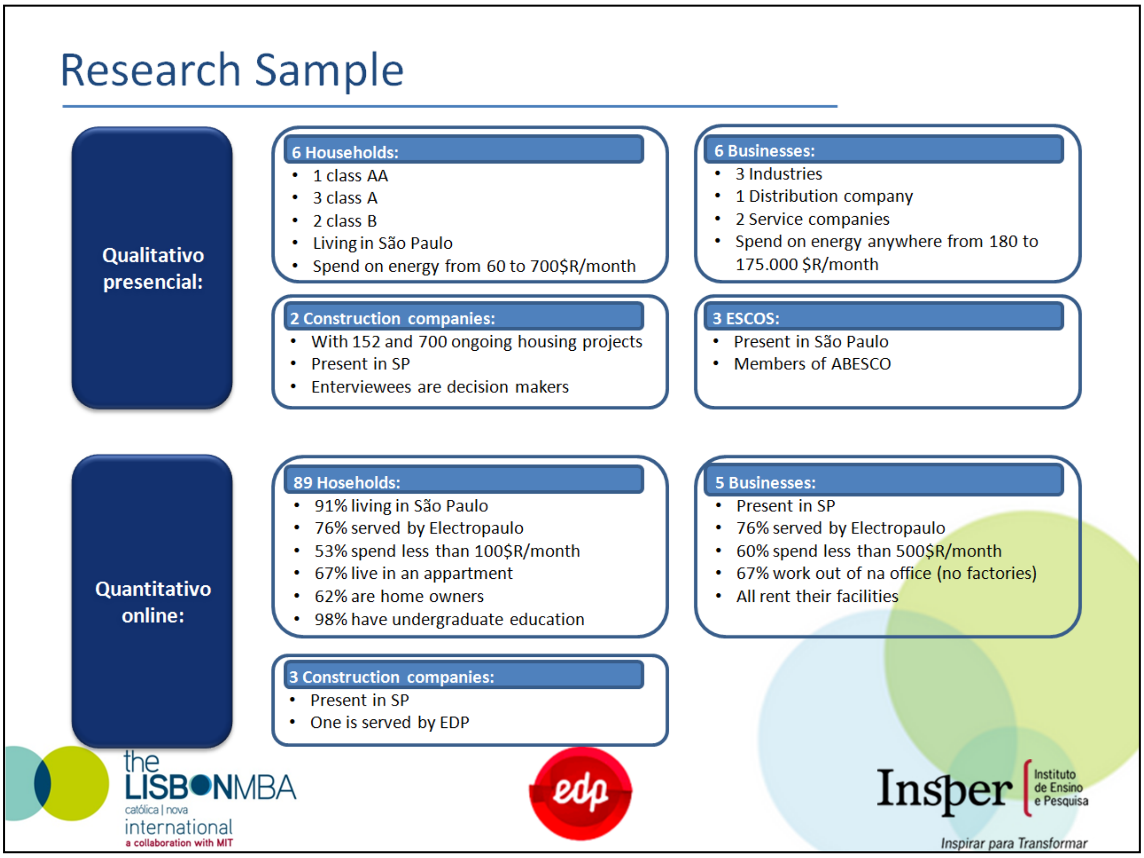
Graph 33 - Number of years to breakeven vs interest rate



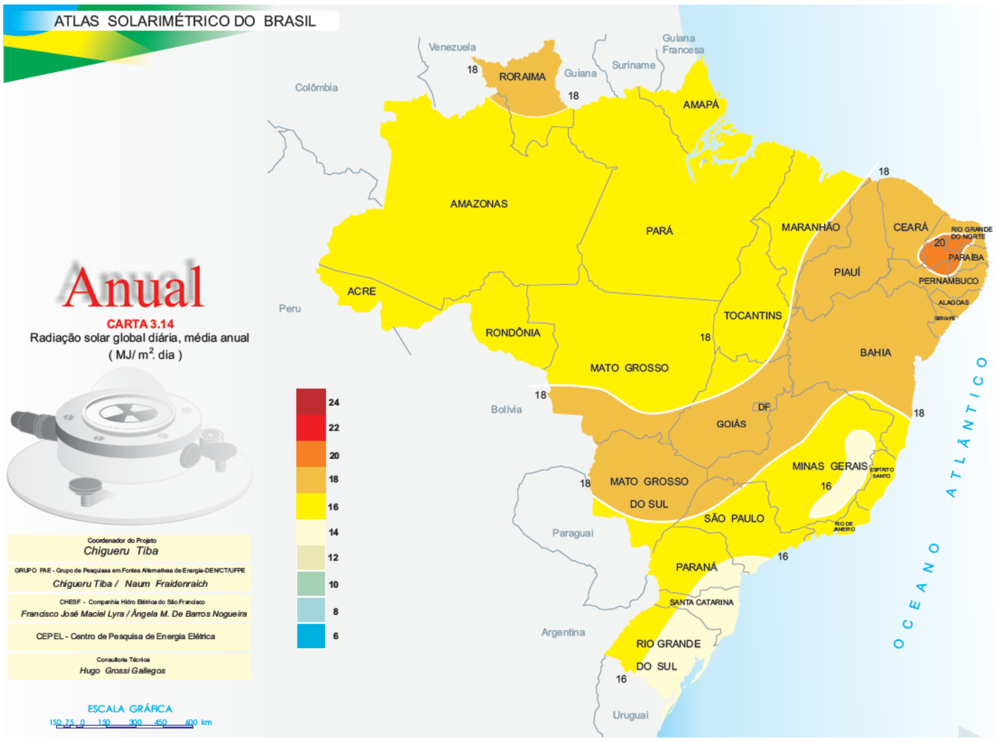
Graph 34 - Number of years to breakeven vs cost per watt with upfront payment



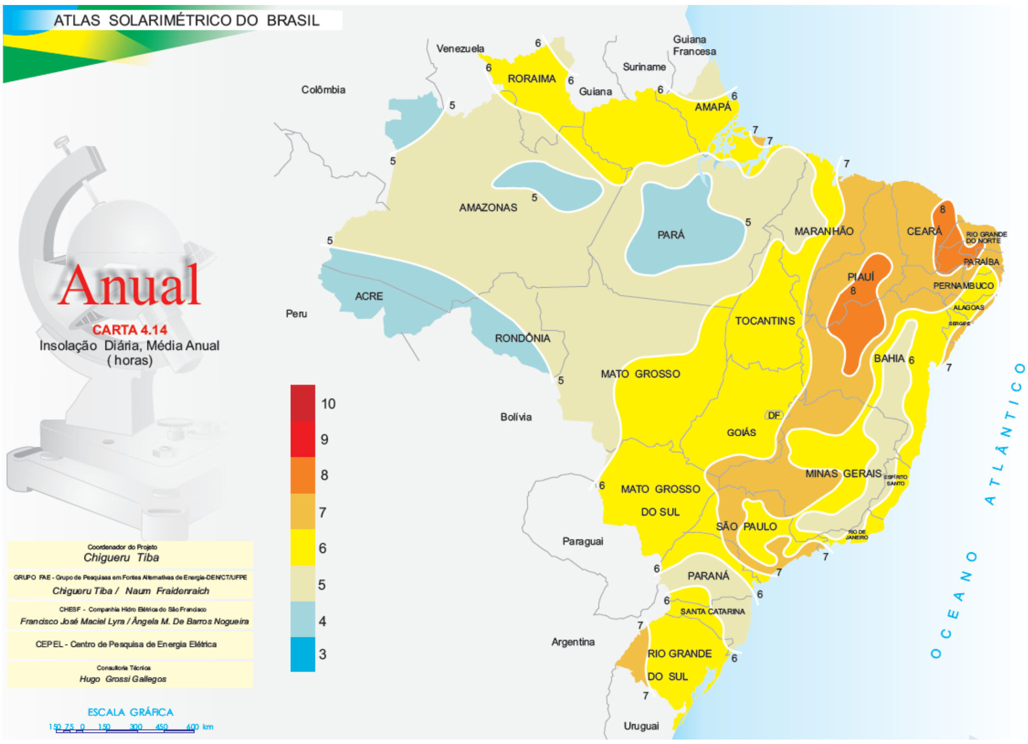
Graph 35 - Number of years to breakeven vs cost per watt financed by bank loan



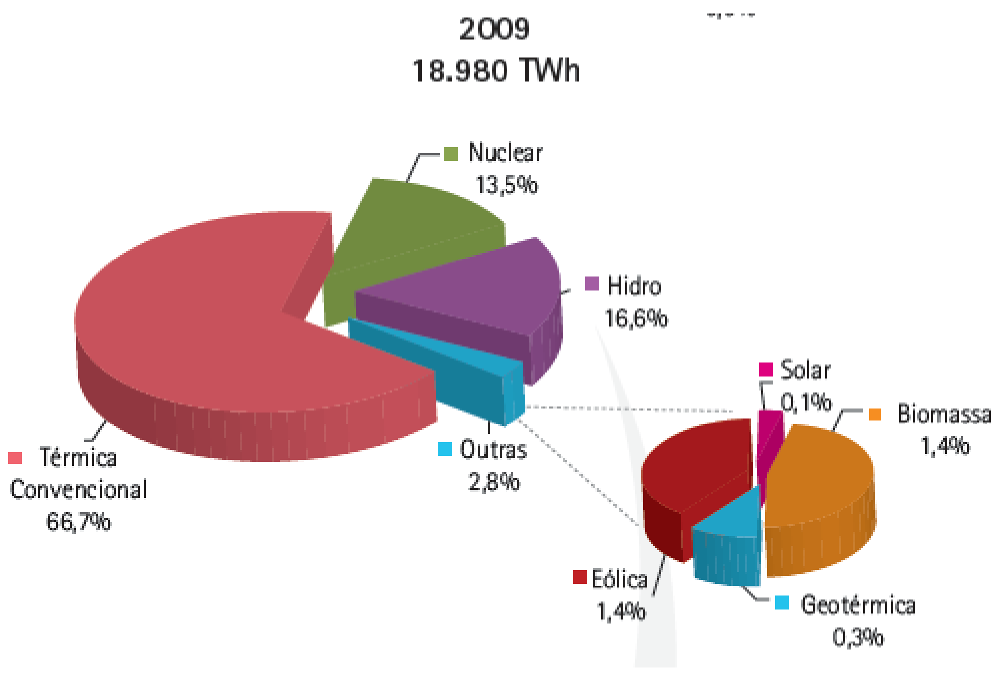
Graph 36 - Research sample characterization



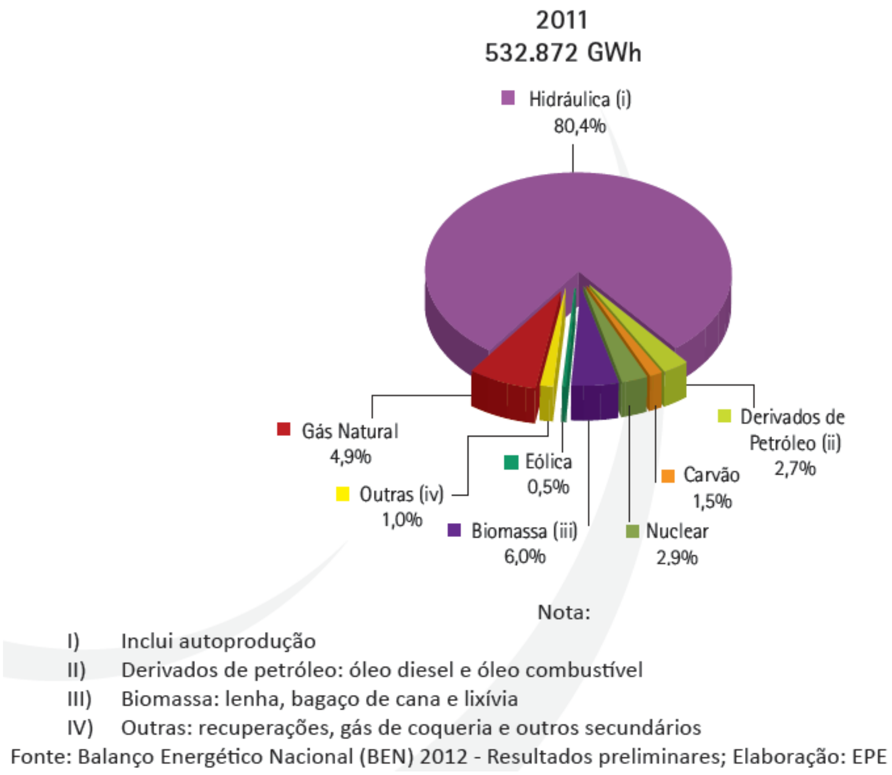
Graph 37 - Average daily sunlight radiation (Tiba, 2000)



Graph 38 - Average number of hours of sunlight per day (Tiba, 2000)



Graph 39 - Worldwide electricity energy sources (Empresa de Pesquisa Energética, 2012)

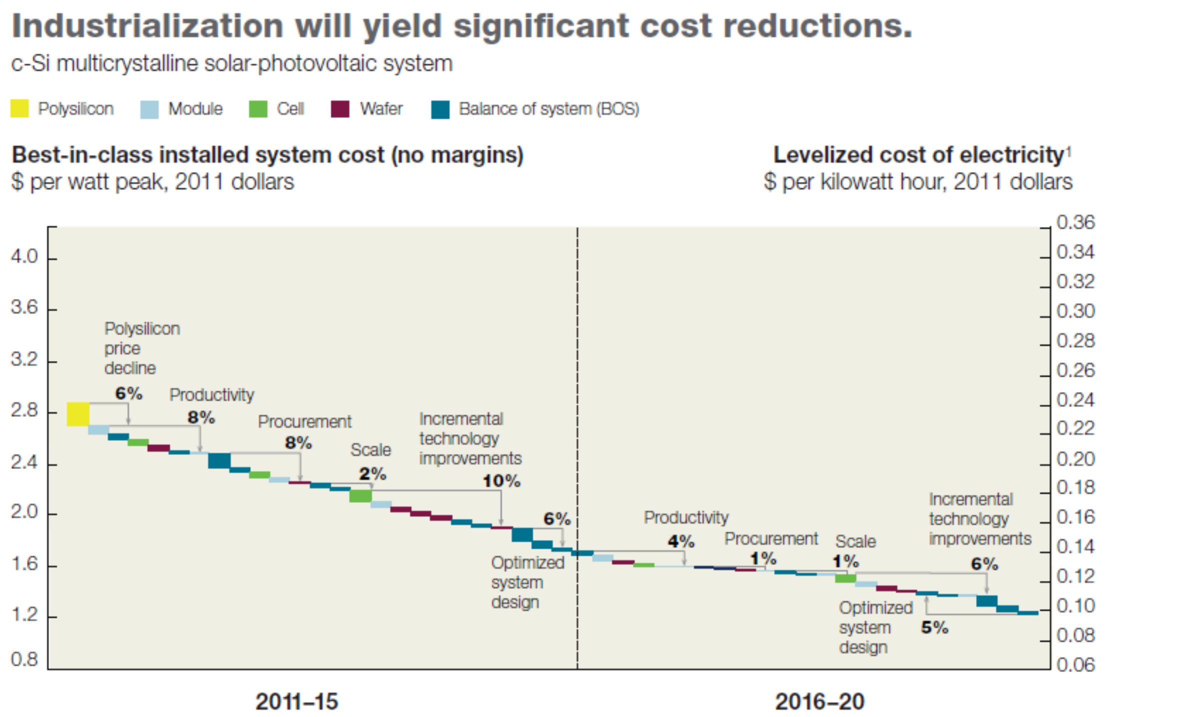


Graph 40 - Brazil's Electricity generation sources (Empresa de Pesquisa Energética, 2012)

Graph 41 - Brazil's Energy consumption (Empresa de Pesquisa Energética, 2012)

	2007	2008	2009	2010	2011	Δ% (2011/10)	Part. % 2011)
Brasil	*377.030*	*388.472*	*384.306*	*415.683*	*433.034*	*4,2*	*100,0*
Residencial	89.885	94.746	100.776	107.215	111.971	4,4	25,9
Industrial	174.369	175.834	161.799	179.478	183.576	2,3	42,4
Comercial	58.647	61.813	65.255	69.170	73.482	6,2	17,0
Rural	17.269	17.941	17.304	18.906	21.027	11,2	4,9
Poder público	11.178	11.585	12.176	12.817	13.222	3,2	3,1
Iluminação pública	11.083	11.429	11.782	12.051	12.478	3,5	2,9
Serviço público	12.441	12.853	12.898	13.589	13.983	2,9	3,2
Próprio	2.158	2.270	2.319	2.456	3.295	34,2	0,8

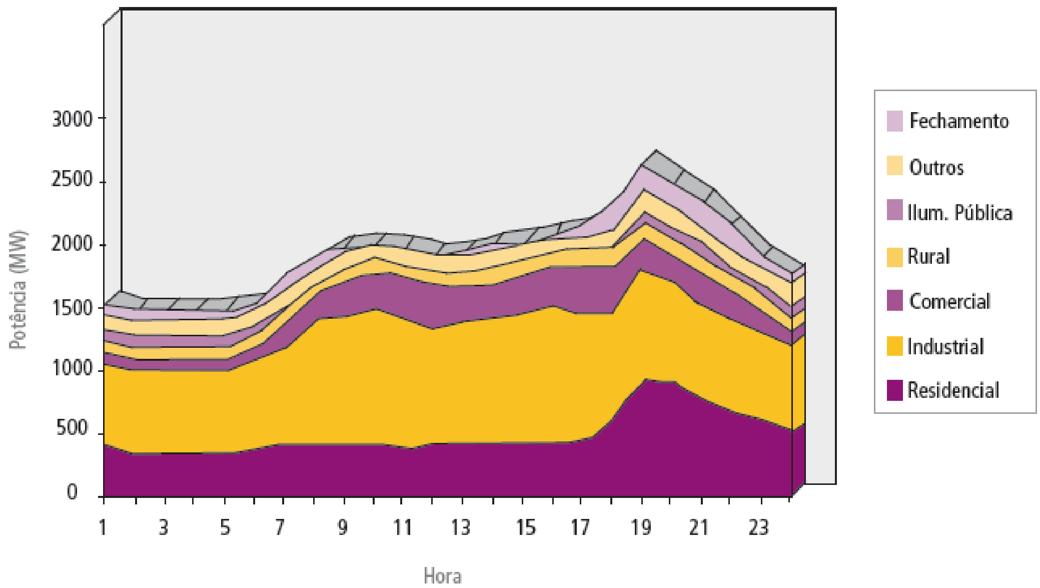
Graph 42 - Brazil's consumption per user type (Empresa de Pesquisa Energética, 2012)



[1]Levelized cost of energy; assumptions: 7% weighted average cost of capital, annual operations and maintenance equivalent to 1% of system cost, 0.9% degradation per year, constant 2011 dollars, 15% margin at module level (engineering, procurement, and construction margin included in BOS costs).

Source: Industry experts; Photon; GTM Research; National Renewable Energy Laboratory; US Energy Information Administration; Enerdata; press search; company Web sites; McKinsey analysis

Graph 43 - PV cost evolution forecast



Graph 44 - Brazil's electricity demand curve through the day (PEREIRA, 2004)