



Energy efficiency and renewable energy systems in Portugal and Brazil

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ABSTRACT

This article presents a review of the energy situation in Brazil and Portugal; two countries which are both characterised by high utilisation of renewable energy sources though with differences between them. The article also introduces contemporary energy research conducted on the two countries and presented at *The 1st International Congress on Energy & Environment* ranging from electricity end-use analyses, electricity production analyses to socio-economic assessment and large-scale energy scenarios.

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1. Bringing together economics and engineering

The 1st International Congress on Energy & Environment organized by the School of Economics and Management, University of Porto (FEP), the Economics and Finance Research Centre, University of Porto (CEF.UP) and the Industrial and Technological Research Centre, University of Minho (CGIT) took place at FEP on 9–10 May 2013.

The congress aimed to bring together leading academic scientists, researchers and scholars from the energy and environmental science community to exchange knowledge, to discuss and to disseminate new ideas towards a low carbon, sustainable future.

The challenge was and is still significant, as both energy and environment transition issues require much more than the simple knowledge of techniques.

Revisiting the technology definition of Müller [1], the concept of technology encompasses four components – technique, knowledge, information and product. Hvelplund [2, 3] has later added the component “profit” and introduced the concept of radical technological change to indicate transitions where two

or more of the components need be changed as discussed in some of his work [4, 5]. A transition towards a low carbon sustainable future is such a case. Hence putting it into the framework of this conference, it also involves processes of technology transfer where economics, social sciences and even politics play decisive roles. Therefore, it became crucial to put together people from diverse scientific backgrounds and establish a coherent, structured, knowledge-based dialogue. During the two days of the congress, very intense discussions allowed for the creation of a multi-disciplinary scientific platform which we hope to strengthen in the future.

2. The energy situation in Portugal and Brazil

The sub-theme of this IJSEPM issue – Energy efficiency and renewable energy systems in Portugal and Brazil - was most welcome by the congress organization. Beyond the close cultural and scientific partnership between Portugal and Brazil, these two countries represent paradigmatic cases of the electricity systems.

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Both rely heavily on renewable energy sources (RES) but the economic and social characteristics of each country are quite different. Energy systems need to be adapted to local circumstances to be optimal – if optimal energy systems exist that is [6] – hence economic and social differences between Portugal and Brazil impact the optimal energy system configurations. Furthermore, energy policies and market organizations differ substantially between the two countries.

From an international perspective, Brazil has a total primary energy supply (TPES) well below the world average whereas Portugal has a TPES above average – see Figure 1. The energy intensity of Brazil is at the world average level while the intensity of Portugal is at half the level due to a less energy-intensive economy. On the other hand, the electrification level of the Portuguese society is far higher than in Brazil and the world on average. Carbon dioxide emissions per TPES are lower than world average in the case of both Portugal and Brazil. This may only be attributed to higher than average RES shares of the two countries. The resulting per capita carbon dioxide emissions for Portugal end up at the world average despite higher than average per capita TPES and electricity demands per capita while emissions per capita in Brazil only are around half the world average.

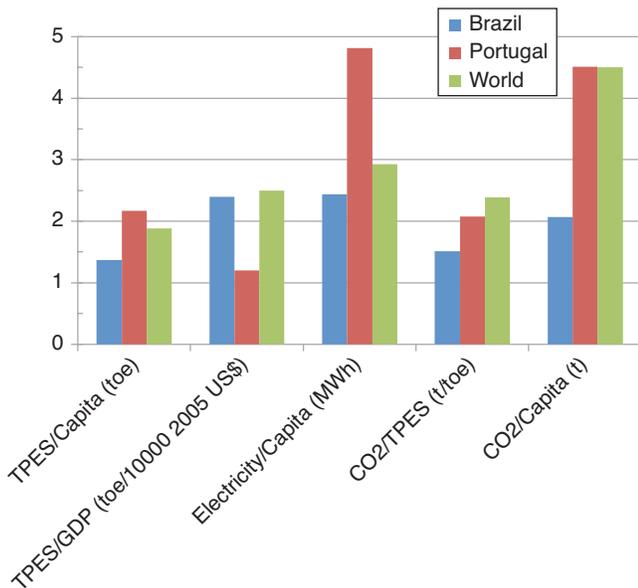


Figure 1: Energy indicators for Brazil, Portugal and world average in 2011. TPES is Total Primary Energy Supply measured in tonnes of oil equivalent (toe). Sources [7, 8].

In Brazil, according to the national energy research company Empresa de Pesquisa Energética (EPE), for the period 2013–2023, electricity consumption is projected to grow, on average, 4.3% p.a. which will mean a sharp increase from 514 TWh in 2013 to 782 TWh in 2023 [9]. In the first half of the period between 2013 and 2018, the EPE estimates an average yearly increase of 4.5% [9]. These projections may be compared to projections of Brazil’s Gross Domestic Product (GDP) which is expected to grow 4.1% p.a. until 2018 and then at 4.5% p.a. until 2023 [9]. This means that the future electricity demand increase will follow that of the GDP and even surpass this increase from 2013-2018.

In 2012 RES accounted for 42.4% of the Brazilian energy supply and 84.5% of the electricity supply. Hydroelectricity dominates the electricity matrix – see Figure 2 - representing 69.7% of the total installed capacity in Brazil in 2012 [10] and approximately 74% of the supply in 2011. Brazil’s commitment to other RES started later than in Portugal, and wind energy, for instance, supplies only 0.9% of the total electricity production while biomass supplied a more significant share at 6.8% in 2012 [10]. The remainder of the Brazilian electricity supply is based on fossil fuels or nuclear power.

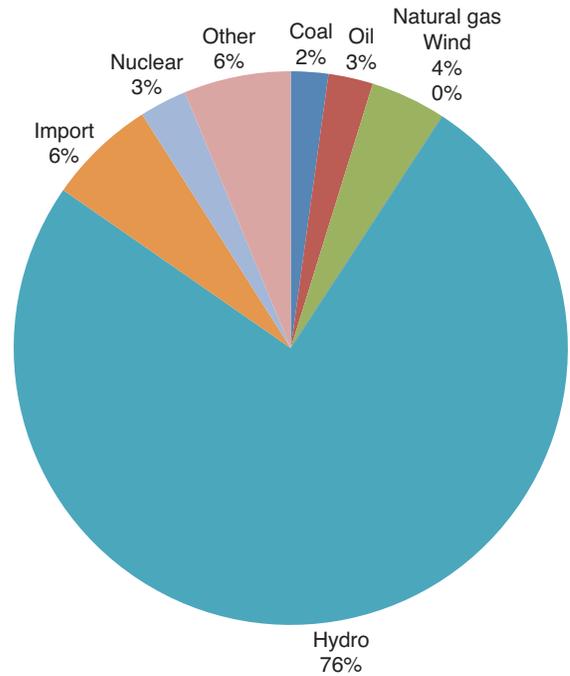


Figure 2: Electricity supply in Brazil in 2011 [8].

A crucial issue in Brazil is how to complement the hydro generation in the most efficient way. There is a strong public and private will to boost wind generation - all the more so since the wind pattern is favourable, being more intense during dry seasons. According to EPE [10] wind power reached 1894 MW at the beginning of 2013 which almost doubled wind share on the national electricity balance.

Outside the electricity sector, Brazil is mainly dependent on fossil fuels, though a large bio energy use accounts for 17.4% of the final demand in transportation and 41.6% within industry in 2011 [8]. This situation occurs in spite of Brazil being a net exporter of oil and oil-derivatives.

Brazil has also an interesting market organization and regulation in order to stimulate private and public companies to build and maintain the country's electricity generation capacity and to ensure security of supply at low tariffs through competitive auctions. There are two parallel markets for electricity trading:

- on the one hand, a regulated contract market for distribution utilities, operated through purchasing auctions;
- on the other hand, a free market for transactions (purchase and sale) of producers, free consumers and traders.

The market organisation also comprises the creation of an electricity reserve for all the electricity traded through contracts and it demands distribution utilities to buy all the energy needed to meet 100% of demand.

In Portugal, the main energy policy goals can be summarized as follows: ensuring the competitiveness of the economy and wellbeing of the citizens supported by energy at affordable costs, promoting energy efficiency of the country and the diversification of the primary energy sources and reduction of the dependency on energy imports [11, 12].

Focusing on the last aim, in the years from 2000 to 2012, the Portuguese energy dependency decreased from approximately 86% to less than 80%, due to the a national RES electricity contribution [12].

The Portuguese electricity system is characterized by an increasing reliance on a diversified portfolio of RES and other technologies (See Figure 3) and a declining trend of the growth rate of the electricity consumption. The renewable share of the electricity production increased significantly over the last years - from 21.4% in 1999 to 56.2% in 2013 [13]. In the first quarter of 2013, RES supplied 70% of the electricity demand due

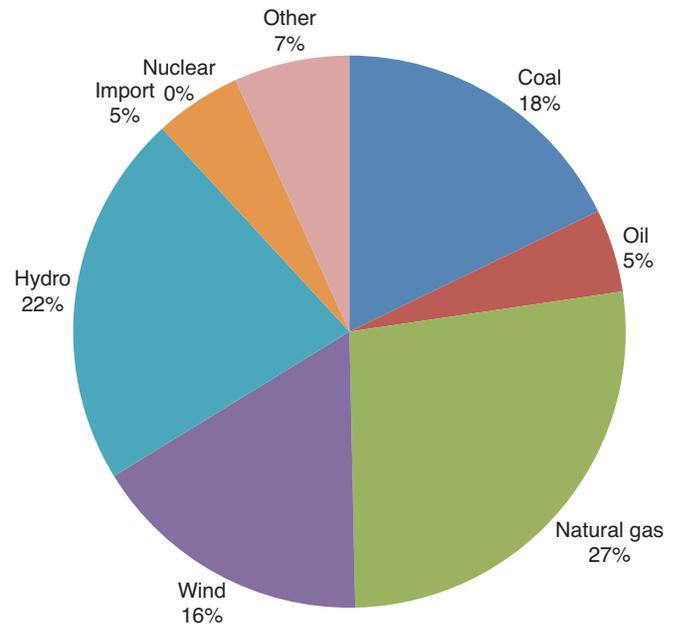


Figure 3: Electricity supply in Portugal in 2011. Source [7].

to favourable weather conditions - increased wind and water flow - as well as lower demand. Support mechanisms largely contributed to this increase, and were justified by the need to reduce the external dependence of the country and greenhouse gas emissions.

Portugal benefits from favourable climatic and natural conditions, allowing for taking advantage of hydro, wind and solar potentials to produce electricity. The large wind-swept coastal area creates additional perspectives for obtaining off-shore energy. Notwithstanding, the contribution of these technologies to electricity generation is expected to be limited in the next years, mainly because of the still required technological developments and large capital costs, although they are recognized in the National Renewable Energy Action Plan (NREAP), published in April 2013, as important resources for exploration in the future.

The RES sector also benefits from a very favourable social environment with most of the population being very favourable to these investments even when projects are located in their municipality [14].

In terms of organisation, the Portuguese electricity market is organized as a single market and the European Union's Third Energy Package from 2009 has been fully adopted with the ownership unbundling of transmission. The market is characterised by:

- generation and trading as well as management of organized markets are open to competition, subject to licenses and approval procedures.
- Transmission and distribution activities are regulated and subject to public concessions.

Both Brazil and Portugal are quite dependent on renewable generation, although there are serious social and environmental concerns of the impact of very large hydro plants in Brazil and both countries are thus vulnerable towards hydrological patterns.

While Brazil has an increasing population and electricity consumption projections indicate a significant future growth rate, Portugal has a decreasing population and a limited electricity demand growth. Between 2012 and 2013 electricity demand grew only about 0.2% in Portugal.

In Brazil, the renewal and expansion of the electricity grid is one of the most urgent tasks as service quality measured in terms of supply interruption is still low; this is not the case of Portugal. Portugal's geographical position and the strong interconnections to Spain (more than 2 GW) enables Portugal to exchange with Spain – however the interconnection capacity between the Iberian Peninsula and the rest of Europe remains quite limited, standing at only 1400 MW. This is the most important challenge to development of RES in Portugal and Spain – particularly if the 800 MW connection to Morocco will be used as an import channel for Europe.

Last but not least, Brazil has not yet created a wind cluster while Portugal is already exporting goods, engineering and know-how of hydro and wind generation.

3. Electricity end use assessment

Planning the electricity infrastructure and curbing demand increases are both parts of sustainable development within the electricity sector, however planners and engineers often face the challenge of lack of information in particularly developing countries or economies in transition. Projections are also important for economically more developed nations to ensure adequate and sustainable energy systems.

Silva et al [15] have addressed the issue of electricity end-use monitoring and savings in low-income families in Brazil coming to the conclusion that electric showers account for between 33.5% and 40.3% of the electricity consumption. Refrigerators come second with shares in the 27–33% range. These results are interesting as they

suggest an uneven demand profile. Where refrigerators are automatically controlled – though influenced by usage - and has a demand relatively evenly distributed over the diurnal cycle, electric showers in Brazil typically use up to 8 kW [15] with a use pattern much influenced by behaviour. With the significant power, the use is very relevant to address with peak shaving in mind. This applies to the individual dwellings and for the system at large as there is a certain degree of synchronisation of the demand. As Silva et al also point out, public programmes in Brazil encourage the replacement of electric showers by solar heaters which would entail both economic benefits for consumers as well as system benefits in terms of peak load shaving.

Gonçalves & Domingos [16] bring the electricity demand discussion up to the level of urban systems with a view to investigating the electricity demand in cities as a function of city growth. Based on a power function approach, they investigate a number of Portuguese cities, finding however that the correlation between electricity demand and population growth rather follows a linear growth profile than a power function. Within individual sectors however, there was a correlation that might be captured by scaling laws based on power functions.

4. Feasibility of electricity production

Cogeneration of heat and power (CHP) is one method of increasing the energy efficiency of the energy system though the exploitation of the cooling heat from power production. Traditionally, CHP has found its primary utility in cold or temperate countries like Denmark and Germany[17–21] or in industrial applications where heat demands have been covered by CHP units rather than boilers thus bringing power generation to the site of heat demands.

Ferreira et al [22] present a non-linear optimisation model of CHP applications in buildings in Portugal. Based on case studies of micro gas turbines, they conclude that there is a large potential for small-scale applications of CHP in Portugal to produce space heating and domestic hot water (DHW). Profitability is sensitive to input parameters though, and of particular attention is the valuation of carbon dioxide emission reductions. Internalization of external costs increase profitability considerably and in fact also result in system designs with higher electricity efficiencies and thus higher electricity outputs for the same in-house heat demand.

Cunha & Ferreira [23] investigate another component in renewable energy systems – hydro power with a particular attention to small-scale hydro plants (SHS) in Portugal. Based on an investment appraisal, they conduct sensitivity analyses in order to identify the most important factors affecting the feasibility of SHP. Investigating the SHP under both fixed feed-in tariff system and under market conditions, they find that while the SHP system is feasible under the former, it is not economically feasible under the latter under Portuguese conditions. Of other influential factors is the interest rate.

5. Large-scale energy systems and socio-economic assessment

Electricity consumption is traditionally increasing at a more rapid pace than other energy demands, and this situation is likely to continue in the future. In high-RES scenarios, demands are often expected being shifted to electricity – e.g. for heating and transportation [24–26] – due to lack of storable RES and ample opportunities for producing electricity from wind power, solar cells, wave power etc. in the future. A transition towards increased use of RES combined with improved end-use energy efficiency will also have socio-economic impacts since the investments will be channelled for local power and energy generation and energy efficiency rather than for international purchasing of fossil fuels. Improved balance of trade for most present net-importers of energy will thus be an effect of such a transition.

Brito & Sousa [27] investigate the global electricity system with a view to forecasting demand increases towards the year 2100. In the course, they develop two scenarios - *Current Energy Mix Scenario* and *Electricity as Main Energy Source Scenario*. The latter is developed taken into consideration that RES-technologies often produce electricity directly as opposed to fuels. Projections based on econometrics, historical data and energy/electricity intensities suggest that electricity demand will increase by a factor 3.5-5 compared to today with the Current Energy Mix or up to 9–14 times the current level with electricity as the main energy source.

Oliveira et al [28] investigate the socio-economic impacts of energy efficiency programmes. Specifically, they investigate the employment generation from insulating houses – roofs and walls – as well as from replacing window glazing or substituting window

frames in Portugal. Based on an Input-Output matrix, they assess direct, indirect and induced job creation and job destruction. Apart from the large generation of employment, it is interesting observing that direct job creation is a little minority compared to indirect and induced job creation.

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