Perspectives on Business and Economics Volume 33 | Perspectives on Business and Economics

1-1-2015

Renewable electricity: lighting the way or casting a shadow?

Catherine Withers

RENEWABLE ELECTRICITY: LIGHTING THE WAY OR CASTING A SHADOW?

Catherine Withers

Introduction

Over the past decade, the Portuguese government has sponsored a major investment in renewable and emerging electricity-generation technologies and sold its ownership in electricity companies to private businesses. The mixed results of these two changes have been succinctly chronicled by international news headlines. Commenting on renewable electricity investment begun in 2005, Rosenthal of the New York Times reported, "Portugal Gives Itself a Clean-Energy Makeover." By 2013 that makeover had developed into a success story, and Koronowski of ThinkProgress lauded Portugal's renewable electricity sector with the headline, "Is 70% Renewable Power Possible? Portugal Just Did It for 3 Months." By the next year, however, a headline published by analysts Garcia and colleagues at Fitch Ratings revealed an underlying problem: "Electricity Tariff Deficits Peaking in Spain and Portugal." An electricity tariff deficit is the amount of revenue the government guarantees electricity generators less the amount they earn from selling electricity at the market price; and from 2007 to 2014 the government's debt had accumulated to over €4 billion (Garcia et al.).

The time correlation between high levels of electricity generated from renewable technologies and the revelation of the massive government debt has led critics to question the financial viability of future investments in renewable electricity technologies. In tacit agreement, the Portuguese government has recently reduced subsidies to renewable technologies and has placed a moratorium on the installation of new wind turbines. Although these efforts to curb the costs associated with renewable electricity should help the government reduce its debt, the reduced support for renewable technology may jeopardize the country's ability to meet its assigned goals for renewable energy and efficiency for 2020 and beyond. Furthermore, the subsidization of renewable technology is not the only driving factor underlying the debt ("30 Years…," pp. 107–13). The government also subsidizes a nonrenewable technology called combined heating and power (CHP), guarantees revenue to all generation facilities established prior to 2007 as a result of electricity sector restructuring, and regulates prices.

In this article I explore the evolution of the Portuguese electricity sector in order to determine the extent to which subsidization of renewable electricity-generation technologies, CHP technology, electricity sector restructuring, and price regulation have contributed to the development of the electricity tariff debt. I then consider upcoming changes in the Portuguese electricity system: construction of more than a dozen new hydroelectric dams is already under way, and price regulation is scheduled to be phased out by the end of 2015. I conclude with an assessment of Portugal's electricity sector as a system and prospects for its financial viability.

Electricity System Structure and Development

Physical Structure and Provision

Businesses and households in developed countries have access to a constant supply of electricity that is provided through three physical stages—generation, transmission, and distribution—and a fourth separate business stage called retail (Linden et al., pp. 9, 61). High-voltage electricity is traditionally created at large fossil fuel–burning facilities, nuclear facilities, and hydroelectric dams. In the past two decades, the amount of electricity generated by technologies that harness renewable energy sources (RESs), such as wind turbines and photovoltaic cells, has rapidly increased as these technologies have become more cost effective. When built, a generation facility is classified by its capacity, or the maximum number of megawatts (MW) of electricity it can produce in one hour of operation. However, a facility is rarely run at maximum, so electricity production is measured by the number of hours a facility operates, in MW-hours (MWh). One million MWh comprise one terawatt-hour (TWh); TWh is used to report the electricity consumption of a country. For a renewable facility, such as a hydroelectric dam or wind turbine, the MWh of generation is highly dependent on the weather but is nearly costless to operate, whereas a fossil fuel facility can be utilized at any time but at the price of the coal, oil, or gas on which it runs. To transport electricity to the consumer, the transmission stage is comprised of a network of power lines that carry the high-voltage electricity to substations, where it is converted to the low voltage required in residential and commercial settings. Usable low-voltage electricity is then distributed through neighborhood power lines, which carry the electricity to the final consumer. Payment is coordinated by the retail companies, which compensate the generation, transmission, and distribution companies for the electricity the final consumers use, and then recoup these costs and their own profits by billing those consumers ("Electricity").

Coordination across the separate stages is essential because there is no efficient way to store electricity; so if generators fail to meet real-time consumer demand or if there is a disconnect between any of the stages, a blackout may occur. Therefore, systems vary in terms of the ownership and organization of the four stages. In some systems, a single entity controls all the stages, whereas in other systems separate entities are responsible for each stage. National governments often attempt to streamline coordination among each of the four stages by purchasing the companies at each stage and consolidating them into a single state-run firm. This structure, known as a vertically integrated monopoly (VIM), theoretically solves the coordination problem by allowing electricity to be delivered to consumers through an integrated and contracted supply chain at a price set by the government ("Electricity"). For most European nations, a VIM structure predominantly supplied by fossil fuel generators was the norm throughout much of the twentieth century (Linden et al., p. 9). Portugal maintained such a government-owned VIM electricity system structure until 2000 ("ANNEX II…," p. 5).

1973: A Catalyst for Restructuring and Renewables

The 1973 OPEC oil embargo caused a drastic increase in inflation and unemployment in the United States that sent shockwaves through Europe and initiated a global recession. As a US ally, Portugal was one of four additional nations specifically targeted by the embargo and found itself severely impacted due to its lack of indigenous fossil fuel resources ("Milestones…"). This catalyzed European leaders to critically examine fossil fuel intensive industries; their investigations concluded that the security of electricity supply was jeopardized by three ubiquitous issues. The most obvious issue was one of dependence: electricity generation required massive fossil fuel inputs, and most countries relied on less politically stable suppliers, the OPEC nations or Russia. Lacking their own endowment of fossil fuels, a proliferation of renewable electricity-generation facilities was the only way to wean this dependence; hence, a driver for RES investment was born. The second issue was isolation: in the event that one nation was suffering an electricity shortage while its neighbors had a surplus, there was no way for that extra electricity to be transferred to the deficient country. To facilitate this type of transaction, the electricity grids would have to be physically and financially connected. The third issue was the VIM structure, because it inhibited the resolution of the first two issues (Czeberkus, pp. 11–19). Under umbrella ownership, the transmission and distribution stages were contractually obligated to meet all retail requests with the electricity generated by the state facilities. This eliminated residual demand for potential new generation companies, renewable or otherwise. Furthermore, the state-owned systems were constructed to provide electricity for their own country. Thus, with no export market, there was no incentive for investment in interconnection. Dismantling a VIM structure requires three processes: separating ownership of each stage, known as unbundling; selling the state-owned components of the system to private ownership, known as privatization; and facilitating the entrance of more generation and retail companies to enable consumers to choose with whom they do business, known as liberalization. However, dismantling the VIM structure also dismantles the coordination of the integrated supply chain, so an alternative method of coordinating electricity exchange is needed to facilitate seamless provision (Linden et al., pp. 9, 61).

The value of a competitive market and physically connected grids was formally recognized in 1996 when the European Union (EU) issued the first Internal Market Directive. This legislation detailed EU expectations for unbundling, privatization, and liberalization as well as prescribing a framework for the creation of an electricity exchange market to replace the VIM supply chain ("EU Action on Climate"). The envisioned exchange would function as a competitive market in which the laws of supply and demand would dictate electricity sales rather than contracts. In this type of organization, each of the many generation companies lists the quantity and cost of electricity available, while retailers report how much electricity the consumers require. The least expensive electricity is used to meet the reported demand first, followed by the next cheapest, and so on, until the total demand is fulfilled. Thus, the electricity is used in ascending cost order. The price is set by the cost of the last unit of electricity needed to meet the reported demand. Any additional, more expensive capacity that is not needed to meet demand goes unused, and the generator is not compensated. This type of wholesale market functions as an auction between generators and retail companies in which generation companies are incentivized to create electricity as inexpensively as possible so that theirs is used first, resulting in a higher profit margin and lower overall price. The transmission and distribution stages simply serve as a conduit between the two. The presence of many retail companies drives competition because it enables consumers to switch between retailers if one becomes inefficient or tries to charge a higher premium over the wholesale price. Ideally, with competition and financial exchanges, price is minimized and efficiency is maximized (Linden et al., pp. 9–16).

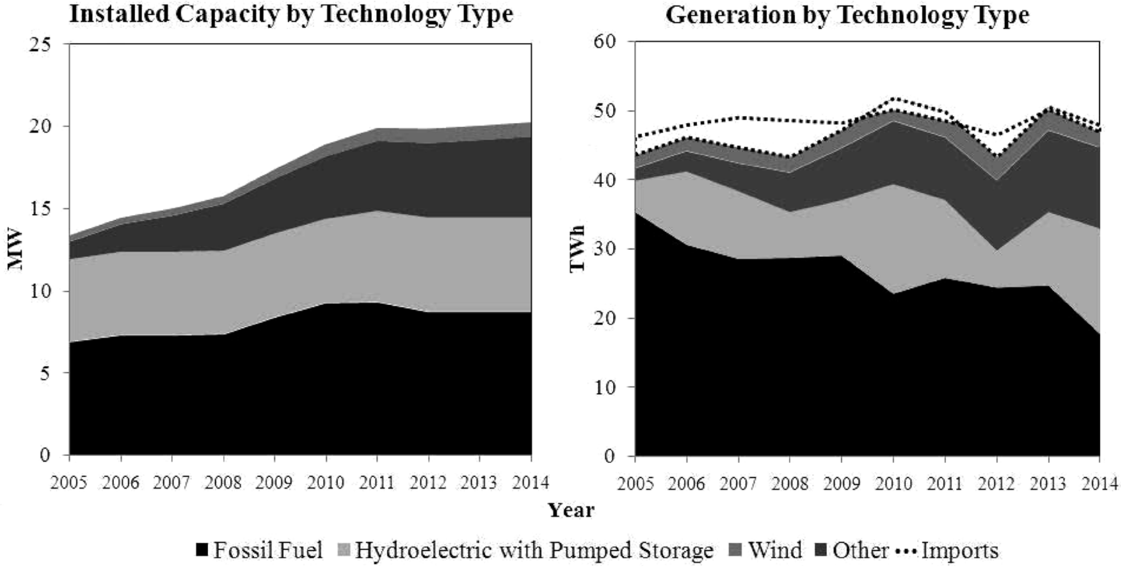
Investing in RES was declared an EU priority in 2001, and a legally binding commitment was made in 2008 when the European Commission passed the first unilateral emissions reduction and renewable technology commitment in the world, known as the EU 2020 Climate and Energy Package. The 2020 Package specified that EU nations increase the amount of energy derived from RES to 20 percent and improve their efficiency of energy use by 20 percent by the year 2020, along with several other goals. The 2020 Package also updated the structure and connectivity directives with more stringent requirements. To reach the EU-wide 20 percent RES goal, each member nation was assigned a unique RES percentage target, relative to its economic strength and endowed renewable potential. This placed Portugal in a contradictory situation: the country's GDP per capita ranks in the bottom half of the EU, but its endowed physical geography of strong rivers and a windswept interior make it rich in the natural resources that enable RES success. The latter was deemed more significant, and Portugal was tasked with generating 31 percent of its total energy consumption from RES, which ranked in the top quarter of all EU nations. Energy consumption is classified by the purpose for which it is used: electricity, heating and cooling, or transportation; and EU nations autonomously determine an RES target for each of the three categories. A majority of nations planned to fulfill most of their RES target by increasing the use of RESs in electricity production. Portugal proposed to achieve its 31 percent overall RES in energy target by generating 60 percent of electricity from RES (RES-E), increasing RES in heating and cooling (RES-H&C) to 30 percent, and gaining the remaining 10 percent from RES in transportation (Rosenthal).

The Portuguese Scenario

Until 1993 the Portuguese electricity sector was structured as a completely government-owned VIM, under the name Energias de Portugal (EDP); and electricity was generated via 4,307 MW of fossil fuel capacity and 4,174 MW of hydroelectric capacity, respectively contributing 69 percent and 28 percent of the 38.5 TWh demanded with negligible imports (International Energy Agency [IEA]; "ANNEX II…," pp. 15–16). Thus, the EU Internal Market Directive of 1996 and RES Directive of 2001 required fundamental changes in the Portuguese electricity sector. However, as one of the nations targeted by the OPEC oil embargo, the Portuguese government was acutely aware of the need for reform; so it issued its own national directives in advance of the two EU Directives. In terms of RES-E, Portugal began to offer a group of technologies, called the "special regime," a feed-in tariff (FiT), or guaranteed payment for each MWh of electricity generated, in 1988 ("30 Years…," p. 107). In terms of market restructuring, unbundling and privatization began in 1993, when EDP allowed the foreign company International Power (IP) to buy two new fossil fuel generation facilities. Generation was fully unbundled from transmission by 2000, but a fully functional wholesale market did not come to fruition until 2007. This gap forced the Portuguese government to guarantee revenue to all of EDP's and IP's facilities established prior to 2007 ("ANNEX II…," pp. 1–3, 14). Renewable proliferation was more successful than liberalization; and by the end of 2013 the electricity sector had four main generation companies and ten main retail companies (Council of European Energy Regulators [CEER], pp. 51–52). Electricity was generated via 7,388 MW of fossil fuel capacity and 10,302 MW of renewable technology, which respectively accounted for 33 percent and 63 percent of the 49.1 TWh demanded that year, with less than two percent of electricity imported from Spain (IEA). Portugal has surpassed its 2020 RES goal, and this evolution of RES-E is displayed in Figure 1, with installed capacity of each technology type in MW displayed in the left panel and the actual amount of electricity generated by each technology type in TWh displayed in the right panel.

As discussed previously, RES-E success was concurrent with delays in market reform, and both of these factors contributed to the development of a €4 billion tariff debt. This tariff debt has accumulated from successive years of tariff deficit, which occurs when there is a shortfall between the revenue that electricity generators are guaranteed less the amount that

Figure 1
Evolution of Electricity Installation and Generation



Source: International Energy Agency; Garcia et al.; Peña et al.

they receive. The Portuguese electricity sector has functioned as an idealized wholesale market since 2007 in that retailers pay the generators the wholesale price for the quantity of electricity they need. The market deviates from the ideal in that retailers are also obligated to pay generators any guaranteed revenue, the aforementioned FiT and revenue guarantee, to which they are entitled. As a result, the wholesale price of electricity may not reflect the price retailers pay many of the generators. Retail companies, in theory, recoup all of this cost by billing customers, but there is a limit to how much Portuguese retailers can charge for electricity. This price cap is set by the Energy System Regulatory Authority, which was established to oversee the restructuring process and prohibit electricity retailers from charging unfair prices. When this cap is binding, that is, when the price cap does not fully cover the wholesale price plus the entitled revenue, retailers are only able to buy electricity from generators at a loss, so instead they choose to exit the market. To guarantee electricity provision, the Portuguese government requires the former VIM retail company, EDP Serviço Universal (EDP-SU), to purchase electricity from the generators and supply it to consumers even when the price cap is binding. EDP-SU is supposed to remain financially solvent because the Portuguese government has pledged to reimburse the retailer for any losses by increasing the price cap the following year (Linden et al., pp. 9–11, 30–31).

During 2007–2014, the price cap did become binding, but the Portuguese government refused to raise prices because the Portuguese economy was in a severe recession. As a poorer EU nation, electricity costs represent a higher share of average household income than in other EU countries; and with skyrocketing unemployment and faltering growth, the Portuguese government refused to further burden its citizens with a higher price for the basic necessity of electricity. The result was the growing tariff deficit in each year that was driven by the guaranteed revenues from FiTs and by the pre-2007 generators (Linden et al., pp. 30–31). In the following sections, I explore the motivation for the guaranteed revenues and the degree to which each has contributed to the debt.

Special Regime Subsidies: The Double-edged Sword of Success

Portugal planned to meet its lofty 2020 targets of 60 percent RES-E, 30 percent RES-H&C, and a 20 percent increase in efficiency primarily with a proliferation of wind turbines and CHP facilities. These two technologies are classified as the "special regime," which benefits owners by guaranteeing that the electricity these facilities produce will be purchased at all times irrespective of demand at a predetermined, above-market price, the FiT. Large hydroelectric dams are a renewable source of electricity generation but are not included in the special regime because they are cost-competitive with fossil fuel facilities ("30 Years…," pp. 111–13). Wind and CHP are the most relevant technologies in terms of the yearly tariff deficit because the other special regime technologies (e.g., biofuels, photovoltaic cells, and tidal power) account for less than ten percent of electricity generation (IEA).

Relative to the other special regime technologies, wind turbines are the closest to being cost competitive with fossil fuel facilities. Therefore, in addition to offering a FiT in 1988, the Portuguese government created several grant programs to further incentivize investors. From 2005 to 2014, the FiT was approximately €74 per MWh to €104 per MWh and guaranteed that all electricity generated would be purchased at that price for the first 15 years of facility operation. With average wholesale prices for electricity for the same timeframe about €50 per MWh, the Portuguese government was obligated to pay turbine owners €25 to €55 ("30 Years…," pp. 107–11).

According to the initial 15-year subsidy scheme, since the first wind-driven electricity-generation facility was completed in 1992, its FiT was guaranteed until 2006. After this year the turbine owners would receive the wholesale market price only if their generation cost ranked low enough in the ascending cost order. However, updates to the compensation scheme included extensions to the FiTs for older wind facilities, such that the first will not expire until 2020 (Peña et al., p. 354). Under this generous and stable regulatory environment, installed wind power more than doubled from 2,150 MW in 2007 to 4,742 MW in 2014, which currently provides nearly one-quarter of the electricity generation (IEA). While this jump in installed capacity was the goal, the government liabilities to wind turbine owners also roughly doubled, and the extension of the FiT to the earliest wind turbine owners further added to these liabilities ("30 Years…," p. 107).

In an effort to immediately offset the tariff debt, the Portuguese government made a further amendment to the FiT scheme in 2013. Wind park owners were able to maintain the current FiT arrangement or to select one of two options: pay the government $6,700 (approximately €5,400) per MW installed for eight years and in return receive an extension of the FiT for five years, or pay the government $7,500 (approximately €6,000) per MW installed for eight years and receive an extension of the FiT for seven years (Peña et al., p. 354). If the oldest park participates in one of the extension options, the FiT and purchase guarantee could last until 2026, which is nearly a decade longer than the initial scheme specified. Although both of these options provide the government with a yearly influx of extra revenue with which to repay EDP-SU, in return the government must provide a longer period of FiT payments to the generators themselves, which is a driving factor of the current debt. In fact, analysis in 2014 by Peña and colleagues concluded that this new scheme will increase the tariff debt due to the longer FiT period. Peña and colleagues also found that wind facilities can be cost-competitive with fossil fuel facilities after just seven years of FiT subsidy. If the FiT scheme for wind turbines were reduced to seven years rather than the current range of 15 to 24 years, the level of wind subsidy payments would be greatly reduced. In support of the conclusions of Peña and colleagues, a study by Portugal's Secretary of State for Energy suggests that wind generators have been significantly over-subsidized, perhaps up to 20 percent of the tariff deficit in any year ("Rents…," p. 55).

The second of the two significant special regime technologies, CHP, is used to produce heat in commercial settings but also increases the efficiency of energy use by harnessing the waste heat to generate electricity. Both fossil fuels and renewables can be used as the initial energy source for CHP facilities, and in Portugal roughly 80 percent of CHP facilities use natural gas. Despite this reliance on fossil fuels, the Portuguese government and EU policymakers wanted to promote CHP because it contributed to the RESs and efficiency goals. It was also hoped that investment and proliferation of CHP would lead to cost-reducing innovations. The subsidy scheme did succeed in promoting the proliferation of CHP facilities: FiTs paid to CHP plants were approximately €25 per MWh to €50 per MWh above market price, and generation from all CHP facilities increased from five percent of total electricity demand in 2000 to 14 percent in 2014. With a comparable premium to wind turbines, combined heat and power facilities also require a large government subsidy, but the cost of CHP facilities has not fallen much. With this lack of progress, the EU as a whole repealed the directive to promote the technology; and the Portuguese government cut subsidies to CHP facilities in late 2012 ("Final Cogeneration…," pp. 5–11).

Initial promotion of wind and combined heat and power facilities was effective at stimulating installation; however, it is clear that both technologies were over-subsidized, leaving the government with an expensive and growing liability. The Secretary of State for Energy estimates that payments to wind turbines and CHP facilities comprised approximately 37 percent of the tariff debt accrued by 2011, with the former contributing about 19 percent and the latter about 18 percent ("Rents…," pp. 13–14). These cost estimates illustrate the dual nature of subsidy programs: the more successful they are, the more expensive they become, particularly when the subsidy is overly generous. Clearly both the subsidies for wind turbines and combined heat and power facilities have significantly contributed to the tariff debt, but the remaining 60 percent of the debt accrued by 2011 has a different cause ("Rents…," p. 17).

The Consequences of Piecemeal Unbundling

The Internal Market Directive to restructure the government-owned VIM was intended to eliminate government involvement, but the process of moving to a competitive system was not nearly as smooth as policymakers envisioned. Therefore, government intervention was necessary to complete the process. EDP officially unbundled its ownership and legal control of transmission from the generation and retail stages in 2000 through the creation of an independent transmission company, Redes Energéticas Nacionais. In the idealized framework, a wholesale market through which generators and retailers trade electricity would be created simultaneously. However, creation of the wholesale market was delayed for seven years. In the interim the two generation companies, IP and the newly unbundled EDP, established a purchase power agreement (PPA) with the transmission company for each generation facility. These contracts guaranteed a level of revenue for each facility in exchange for immediate delivery of any amount of electricity that the retail company, EDP-SU, required. The PPAs covered a total of seven fossil fuel facilities with 4,630 MW of capacity and 26 hydroelectric facilities with 4,095 MW of capacity and effectively allowed the system to function as a VIM ("PPAs…," p. 1–2, 4–6). This arrangement satisfied both companies, because it protected the generation companies, EDP and IP, from demand or price fluctuations and allowed the retail company, EDP-SU, to more easily guarantee consumers a constant supply of electricity without internal negotiation or a market. In order to fully launch the wholesale market, these contracts had to be dismantled so that less expensive but uncontracted generators would be compensated for their electricity rather than being crowded out by the contracted companies. The generation companies were reluctant to renegotiate their contracts because a highly competitive market auction for electricity would return a lower profit than the amount which their current PPAs entitled them. Thus, the Portuguese government needed to create new contracts which could both guarantee the companies the same revenue and force them to compete on price as part of the wholesale market ("ANNEX II …," pp. 9–14).

The solution for the EDP facilities was to renegotiate the PPA contracts, called Costs for the Maintenance of Contractual Equilibrium (CMEC). The PPA contracts with IP were also adjusted but retained the label of PPA. These new contracts force generation companies to sell their electricity on the auction market, but the Portuguese government guarantees that each facility receives a certain revenue level. Thus, the renegotiations were successful in creating an electricity auction because the electricity generated by the EDP and IP facilities will not be purchased if lower cost electricity is available. However, the persistence of the revenue guarantee allows the companies to maintain volume-risk protection: if the CMEC or adjusted PPA facility's electricity is not needed to meet demand, the facility is still paid the contractual revenue. In this sense, the auction is artificial and the volume-risk protection arrangement causes the government debt to grow rapidly when there is no market revenue to help offset the revenue guarantee ("ANNEX II …," pp. 12–18).

Exact amounts of contractual revenue payments are obscured in the facility income statements; however, the CEMC and adjusted PPA contracts do explicitly guarantee the companies a return of 8.5 percent, while the current market return is under five percent ("Rents…," p. 7). More specifically, the Portuguese Secretary for Energy stated that more than half of the 2011 €1.486 billion electricity deficit resulted from the CMEC payments to EDP. Liabilities from the adjusted PPAs with the IP companies were much smaller, contributing less than seven percent of the deficit incurred that year. These percentages can be generalized for each year in which a tariff deficit was incurred. Elimination of these guaranteed revenues is crucial because unlike the "special regime" payments, they do not enhance the sector or drive technological progress. Instead, guaranteed revenue payments serve only as unnecessary compensation for the pre-2007 EDP and IP generation facilities that must be paid for by taxpayers ("Rents…," p. 14).

A System of Problems

Subsidizing wind and combined heat and power facilities, renegotiating the PPAs, and protecting consumers with a price ceiling were all necessary changes to enable Portugal to reach its 2020 goals, which it essentially achieved as of 2014. However, although each of these changes corrected a specific problem, together they have created a paradoxical system in which the desired success of subsidized technologies perpetuates the growth of tariff debt. Critics are correct in their assertion that subsidizing wind turbines is expensive, but an increase in low-cost renewable electricity-generation facilities also exerts downward pressure on prices. While lower prices are generally favorable for consumers, the contractual revenue guarantees, through the CMEC and adjusted PPAs, cause the government's liabilities to increase when the price of electricity decreases. Yearly tariff deficits are projected to occur until 2017, but further changes to the system may help lessen the amount. CMEC will gradually expire by 2027, and recent renegotiations should save the government €205 million by that year. Reductions in the FiTs to CHP subsidies are projected to save the government €1 billion from 2012 to 2025, and cuts to wind subsidies are projected to save €151 million ("Final…," p. 10). However, the future cost cannot be fully eliminated because both special regime technologies and CMEC and adjusted PPA facilities are still entitled to some level of subsidy. By the end of 2015, the full cost of electricity will be passed on to consumers because the Energy System Regulatory Authority's ability to set a price ceiling will be fully eliminated ("Electricity"). The Portuguese government believes these changes will enable it to pay off the tariff debt by 2020, but independent EU experts do not believe this will be achieved until 2030 (Linden et al., p. 31). Portugal is on track to meet its 2020 goals; but it is clear that lower subsidies to new technologies, not guaranteeing revenue to the pre-2007 EDP and IP generation facilities, and more coordination in the unbundling process could have enabled the sector to achieve this success without incurring as much of the €4 billion debt.

Forthcoming Changes: Hydroelectric Expansion and Interconnection

The EU has not formally committed to an RES goal for 2030, but it has set a target of increasing overall use of RESs from 20 percent to 27 percent and increasing the amount of electricity available to neighboring nations from 10 percent to 15 percent. If Portugal's augmented burden increases accordingly, it will need to gain about 38 percent of its energy from RES, and the country has announced tentative plans to meet that target by increasing the amount of RES-Es to upwards of 60 percent ("EU Action on Climate"). Achieving this higher target is likely despite the halted expansion of subsidized RES-E technologies because construction of new hydroelectric installed capacity is in progress. If all of the planned hydroelectric facilities are completed, Portugal will be able to produce more electricity than it will need, and the increase in interconnection requirement will be the key for Portugal to become an exporter (Melo, p. 3).

In 2007 the government announced the Portuguese National Program for Dams with High Hydropower Potential, which proposed construction of ten new dams to increase installed hydroelectric capacity from 5,000 MW in 2014 to 7,000 MW. This plan to increase installed capacity was motivated by an EU-wide assessment that identified Portugal as having over 50 percent untapped hydroelectric generation potential. The Portuguese government also gave EDP approval to build two additional dams and to expand six others. The exact figures of installed MW capacity at each facility will not be finalized until construction is complete; but with the additional EDP facilities, the total hydroelectric installed capacity is projected to exceed 9,000 MW. In total, 4,000 MW of new hydroelectric capacity could be installed; 3,000 MW of this total are planned to have pumped storage capability, a key factor discussed later. Nearly doubling hydro capacity should enable Portugal to meet the predicted 2030 EU RES goals; however, it is conceivable that not all of this potential will be realized because there are serious doubts about the facilities' environmental impact and productivity (Melo, p. 3).

Estimates of the amount of electricity that the new 4,000 MW of installed hydroelectric dams could generate vary widely between the government reports, the investing firms, and critics; but a simple analysis of the past five years can be used to forecast a reasonable estimate. The year 2012 was one of the driest years in Portugal, whereas 2010 was one of the wettest, so these can be used as the minimum and maximum expected generation levels from the existing 5,000 MW of installed capacity. The corresponding generation amounts were 5,824 gigawatt-hours (GWh) and 14,869 GWh, or approximately one to three times the installed capacity amount in GWh. These estimates imply that if all the EDP facilities are built such that installed capacity increases to 9,000 MW, the generation level will likely be between 10,000 GWh and 27,000 GWh. That level of generation would account for 20 to 50 percent of 2014 electricity consumption (CEER, p. 50). Such a wide range clearly illustrates the risk of relying on nature-driven sources for electricity supply. This dam-building policy initiative is another example of what could be a major success if it comes to fruition as idealized but could become a costly liability if not.

The System as the Solution

The Portuguese government's subsidization of wind turbines and commission of new dams are both expensive investments in RES-E and highly weather dependent; but together the two technologies can offset each other's weakness by improving reliability and decreasing system costs. Hydroelectric dam outputs are susceptible to fluctuation due to dry years or summers, whereas electricity generation via wind turbines is subject to daily fluctuations because it is generally windier at night than during the day. Demand for electricity is much higher during the day; but because electricity cannot be stored, the electricity generated by wind turbines at night sometimes goes unused. This is a major loss for consumers because they do not fully benefit from the low-cost electricity and, under the Portuguese subsidy scheme, wind turbine owners are still compensated. One solution that harnesses this extra electricity entails redirecting it off-peak at night to hydroelectric dams that have pumping capability in order to bring water that has already flowed downstream through the turbines back to the reservoir upstream of the dam. The pumping process is particularly helpful in dry years or seasons when water flow from upstream is limited and is useful in general as the water in this reservoir can then be released whenever electricity is needed. However, the efficiency of the process is diminished because it uses some of the generated electricity to run the pump. By using off-peak wind-generated electricity, the total amount of electricity that the hydroelectric plant is able to put back into the system is increased; and wind-generated electricity is better utilized. To fully power the pumping, one MW of hydroelectric capacity needs approximately 3.5 MW of wind capacity. As of 2014, it is estimated that 3,000 MW of the future 9,000 MW will have pumping capabilities, and wind capacity is roughly 5,000 MW. Therefore, the ratio of hydroelectric pumping capacity to wind capacity is only 1 MW:1.67 MW, which implies an excess of hydroelectric capacity (Melo, p. 4).

Critics of the massive hydroelectric expansion argue that the optimal ratio would be met, rather than unnecessarily surpassed, if only the proposed updates and additions were pursued. These critics further argue that the environmental degradation that the new dams will cause far outweighs the benefit of additional electricity-generation capability (Melo, p. 5). To some degree these arguments are correct; however, increased hydroelectric capacity, even without pumping capacity or wind support, remains a highly productive and renewable energy–based addition to the electricity-generation system. Given the current moratorium on new wind installation, the ultimate completion of these new dams, which are scheduled to open after 2020, is essential to Portugal's ability to meet its 2030 obligations. Furthermore, Portugal has been a net importer of electricity from Spain. The new dams and additions will allow Portugal to fully meet its own electricity needs as well as provide excess capacity to export. This will benefit Portugal as well as the EU by moving closer to its fossil-fuel independent and interconnected ideal.

Conclusion

Since 2005, Portugal's electricity sector has been drastically restructured and augmented with renewable generation technologies, which, in 2014, made the country an RES-E and market reform trailblazer but that also have left it mired in debt. Although some of this debt is a consequence of renewable subsidies, the liabilities to former PPA holders are larger, do not improve the sector in any way, and benefit the private companies at the taxpayers' expense. For Portugal's electricity sector to achieve financial solvency, it is essential that the former PPA payments are fully eliminated and that the proliferation of renewable technology, with lower subsidies, is allowed to continue. The new system of dams will enable Portugal not only to meet future RES-E requirements but also to surpass them and potentially profit from exporting excess electricity. Portugal faces a significant challenge in eliminating unnecessary payments in the electricity sector; but because the debt is a function of non-renewable factors and its elimination is feasible, Portugal's electricity system is a beacon of proof that electricity systems with RES-E are both possible and affordable if created correctly.

REFERENCES

"30 Years of Policies for Wind Energy: Lessons from 12 Wind Energy Markets." International Renewable Energy Agency and Global Wind Energy Council. 2012. www.irena.org/DocumentDownloads/Publications/IRENA_GWEC_WindReport_Full.pdf. Accessed December 5, 2015.

"ANNEX II: Liberalising the Portuguese Energy Markets." Portuguese Competition Authority. 2006. www.concorrencia.pt/SiteCollectionDocuments/Noticias_e_Eventos/Intervencoes_Publicas/ANNEXII_290807b.pdf. Accessed June 10, 2015.

Council of European Energy Regulators (CEER). "2013 Annual Report to the European Commission: Portugal." July 2014.

Czeberkus, Malgorzata Alicja. "Renewable Energy Sources: EU Policy and Law in Light of Integration." Thesis at School of Social Sciences Aðalheiður Jóhannsdóttir. May 2013. hdl.handle.net/1946/14692. Accessed November 29, 2014.

"Electricity." Entidade Reguladora dos Serviços Energéticos (ERSE). 2009. www.erse.pt/eng/electricity/Activities/Paginas/default.aspx. Accessed November 19, 2014.

"EU Action on Climate." European Commission. 2014.

"Final Cogeneration Roadmap: Portugal." Cogeneration Observatory and Dissemination Europe. July 2014. www.code2-project.eu/wp-content/uploads/CODE2-D5-1-Roadmap-Portugal-Dec14.pdf. Accessed May 12, 2014.

Garcia, Juan, Angel Jimenez, Pilar Auguets, and Mark Brown. "Electricity Tariff Deficits Peaking in Spain and Portugal." Fitch Ratings. September 25, 2014. www.fitchratings.com/fitchwirearticle/Electricity-Tariff-Deficits?pr_id=882074. Accessed October 4, 2014.

International Energy Agency (IEA). U.S. Energy Information Administration. www.eia.gov. Accessed March 12, 2014.

Koronowski, Ryan. "Is 70 Percent Renewable Power Possible? Portugal Just Did It for 3 Months." Climate Progress. April 14, 2013. thinkprogress.org/climate/2013/04/14/1858811/is-70-renewable-power-possible-portugal-just-did-it-for-3-months/. Accessed October 4, 2014.

Linden, Asa J., Fotios Kalantzis, Emmanuelle Maincent, and Jerzy Pienkowski. "Electricity Tariff Deficit: Temporary or Permanent Problem in the EU?" EU Economic Papers 534. October 2014. Accessed February 10, 2015.

Melo, João J. "Not sustainable: The Sad Business of Portuguese New Dams." Position Paper Presented at the International Association for Impact Assessment Conference, June 2012.

"Milestones: 1969–1976." U.S. Department of State Office of the Historian. October 31, 2013. history.state.gov/milestones/1969-1976/oil-embargo. Accessed November 29, 2014.

Peña, Ivonne, Azevedo Inês Lima, and Luis Ferreira. "Economic Analysis of the Profitability of Existing Wind Parks in Portugal." Energy Economics. Vol. 45, Issue C, 2014, pp. 353–63.

"PPAs/CMECs Legislation Package." Energias de Portugal Report. February 16, 2014.

"Rents in the Electricity Generation Sector." Governo de Portugal Secretary of State for Energy. January 1, 2012. es.scribd.com/doc/91417095/Rents-in-the-electricity-generation-sector#scribd. Accessed May 15, 2015.

Rosenthal, Elisabeth. "Portugal Gives Itself a Clean-Energy Makeover." New York Times. August 9, 2010. www.nytimes.com/2010/08/10/science/earth/10portugal.html. Accessed October 4, 2014.