Energy for Sustainable Development 29 (2015) 47–56

Contents lists available at ScienceDirect

Energy for Sustainable Development

Economical–environmental impact of subsidised renewable energy sources for electricity (RES-E) in the Spanish system

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ARTICLE INFO

Article history:
Received 24 June 2014
Revised 26 August 2015
Accepted 10 September 2015
Available online 18 October 2015

Keywords:
RES-E
Cost–benefit analysis
Greenhouse and hazardous gas emissions
Merit order effect
Fossil fuel supply problems

ABSTRACT

In 2012, Spain obtained 68.5 TWh of its electricity (25% of the total) from renewable energy sources excluding large hydroelectric power (RES-E). Subsidies, through feed-in-tariffs, for various forms of RES-E ranged from 40.2 €/MWh to 321.1 €/MWh and totaled 6.1 billion E, an amount that has motivated substantial criticism. This paper examines the effects of RES-E on the market price of electricity considering the merit order effect in Spain's power auction system. The M5P algorithm developed by Quinlan (1992) is used to calculate changes in the settling price in daily power auctions. Also, the value of emissions of CO_2, NO_x, and SO_x avoided through RES-E is calculated. They are valued at $10/t, $478/t, and $1460/t, respectively. Results of the analysis show that, in 2012, RES-E caused an estimated 3.1 B€ savings in electricity expenditures due to market effects and a 0.7 B€ saving in emission costs. When subtracted from the total subsidy a net cost of RES-E of 2.3 B€ is derived. Wind, biomass, and small hydroelectric had negative net costs (i.e., net benefits) while photovoltaic and solar-thermal power had net costs. Alternative scenarios in which the production of gas-fired and coal-fired electric power are individually curtailed by 30% in comparison to the baseline scenario, while RES-E is held at the 2012 level, yielded a net cost decrease of about 300 M€ for gas curtailment and a net cost increase of about 300 M€ for coal curtailment.

Introduction

Despite the progress made in social awareness of global warming and pollution, the world is still far from reaching a change of trend to reverse the situation (the level of carbon dioxide in the air in May 2013 reached as high as 400.03 ppm — NOAA, 2014). However, Spain has finally realised that dependence on fossil fuels can no longer be prolonged and renewable energies are becoming stronger over time within the global generation mix. RES-E excluding large hydroelectric (referred as RES-E from now on) in Spain increased from 15.4 TWh in 2002 to 68.5 TWh ten years later (see Table 1), accounting for almost 25.0% of the total generation in 2012 (REE, 2003, 2013a,b). Nevertheless, not all the renewable alternatives offer the same degree of sustainability and technological maturity.

Spanish electricity system

As commanded from European Community, a free market for the Spanish electric system, i.e., a wholesale electricity auction, was settled. Three different institutions were dedicated to make it possible. OMI-POLO ESPAÑOL, S.A. (OMIE) controls the market from an economical side, settling supply and demand. Red Eléctrica de España, S.A. (REE) was established to control the new market from a technical side, ensuring that electricity reaches final consumers. Finally, CNE (Comisión Nacional de la Energía), as a third party, is dedicated to ensure effective competiveness and market transparency.

The core of the wholesale market (known as *pool*) is the daily auction where most wholesale electricity is bought and sold. All generation facilities not affected by bilateral contracts (of power supply) are required to submit offers for the daily market. In the Spanish electricity system, RES-E has the right to a subsidy known as feed-in-tariff because it belongs to the Special Regime[3] of power generation and therefore

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[3] Term that includes the facilities that use sources or resources of renewable energies, wastes, and co-generation. It was stated by Royal Decree 2818/1998, that stated a specific regulation of energy production by adjusting to the regulations of Law 54/97. This support scheme offsets the gap between the costs of generation with these clean technologies and traditional power generation plants as well as it ensures that RES-E will be matched in the wholesale electricity auction.

http://dx.doi.org/10.1016/j.esd.2015.09.002
0973-0826/

Table 1
Electricity generation by source in 2002, 2008 and 2012 (REE, 2003, 2013a,b).

Electricity generation [TWh]	2002	2008	2012
Special regimen	34.1	68.0	102.2
Wind power	8.7	31.8	48.1
Photovoltaic power	0.0	2.4	7.8
Biomass power	1.7	2.7	4.7
Solar–thermal power	0.0	0.0	3.4
Small hydroelectric power	3.8	4.6	4.6
Non-renewable thermal power	20.0	26.6	33.4
Ordinary regimen	177.9	212.0	166.3
Nuclear	63.0	59.0	61.5
Coal	78.8	46.3	54.7
Oil	21.8	2.4	0.0
NGCC		91.3	38.6
Large hydroelectric power	22.6	21.4	19.5
Generation consumption	−8.3	−8.3	−7.9
Total	212.0	280.0	268.5

present their electricity sale bids to zero price in order to be matched in the auction. From this point on, the rest of the facilities (covered by Ordinary Regime Scheme) enter into the auction. Nuclear, NGCC, coal-fired and large hydroelectric facilities bid their production, increasing prices step by step, until demand is served. Since the auction is a marginal auction type, the matched price of the latest MWh needed to cover demand sets the market-clearing price for the wholesale electricity *pool*.

RES-E scheme — continuous regulatory changes

The context of promotion of the special regime has varied significantly in recent times due to two main reasons:

- In 2007 the Spanish government deeply decided to promote RES-E by increasing the subsidies and not establishing a power capacity limit for its deployment along the time. That supposed a very high cost for the electric system in a very short time.
- Once the government realised that the subsidies were out of control, decided to start applying measures to reduce cost. So, from 2008 on several new regulations were (some of them retroactively) promulgated and the RES-E were pointed out as expensive and the reason of the Spanish electric system deficit.

In following paragraphs, the regulatory changes summarized above are presented in detail:

Royal Decree 661/2007 appears after the approval of the PER (Renewable Energies Plan) 2005–2010 whose objective was to cover 12.1% of the total energy demand of Spain and the 30.3% of the total power consumption with renewable sources for the year 2010. The subsidies of the special regime generation are significantly increased in order to promote RES-E in Spain. No limit for installed annual power t is determined allowing a RES-E boom in the Spanish electric system.

Royal Decree 1578/2008 appears due to the need of controlling the excessive growth underwent by photovoltaic energy after the Royal Decree 661/2007. It fits the bonuses to the price fall experienced by solar panels and determines an exhaustive control of the maximum annual power to be installed.

Royal Decree 1565/2010 establishes urgent measures to correct the tariff deficit of the energy sector, modifying certain aspects of the Law 54/1997 of the Energy Sector, among which stand out the limit of equivalent hours with right to subsidy is introduced for photovoltaic facilities based on its technology and climate zone.

Royal Decree 1/2012 suppressed the incentivizing economic regimes for certain special regime facilities, imposing therefore a moratorium on new facilities.

Royal Decree-Law 2/2013 obliged renewable energy facilities to follow a regulated tariff (so that the possibility of market price plus a bonus was no longer available).

Royal Decree-Law 9/2013 suppressed the bonuses to renewable energies as such are and in exchange a "reasonable" profitability is guaranteed for a period of 25 years (from 2001 to 2026), equivalent to a 7.5%.

All these last measures are focused on reducing the cost of promoting the development of RES-E in the Spanish power system pointed out as expensive and the main reason for the deficit of the electric system.

Effect of RES-E

However, RES-E also has indirect economic impacts on the system. Since bilateral contracts are out of the pool and production from RES-E is always matched in it, there is less electricity demand to be covered by the Ordinary Regime, hence depressing the price they have to offer to be matched in the *pool*, and therefore the final matched price of the auction. It may happen that the savings derived from a lower settling price were greater than the subsidies received by the technologies covered under the Special Regime. This is known as the Merit Order Effect.

Furthermore, renewable energies lead to health, environment and climate benefits as they displace conventional thermal power plants from the generation mix, thus reducing the emissions of pollutant gases such as:

- hazardous air pollutants known or suspected to cause cancer or other serious health effects or adverse environmental effects (this includes SO_2, NO_x, etc.);
- greenhouse gases which absorb part of the infrared radiation emitted by the Earth's surface when heated by the sun, thus increasing the atmospheric temperature.

Literature review

Direct (feed-in tariff) and indirect (merit order effect) economic impacts

The economic influence of the RES-E, accounting for both the direct (feed-in tariff) and indirect (merit order effect) influences, has brought the attention of the scientific community as long as the deployment of these technologies on the generation mix has become relevant. Sensfuß et al. (2008) analysed the impact of subsidised renewable electricity generation on the electricity market in Germany. The central aspect analysed is the impact of renewable electricity generation on spot market prices. The results generated by an agent-based simulation platform indicate that the merit order of renewable energies (specifically wind power) in the *pool* made the price of electricity drop by €7.83/MWh. Also for Germany, Weigt (2009) stated that wind power is profitable to the system in economic terms.

Forrest and MacGill (2013) determine that the merit order effect of wind power in the Australian system caused a drop in energy prices of $8.05/MWh for South Australia and $2.73/MWh for Victoria. Also for the Australian case, McConnell et al (2013) analysed the hypothetical introduction of 5 GW of photovoltaic energy into the generation mix, estimating a saving of $628 million and $1200 million for 2009 and 2010 respectively. Those cures represent 8.6% and 12% of the value traded for those years respectively.

For the specific case of the Spanish electricity *pool*, Sáenz de Miera et al. (2008) indicate that wind power generation caused a decrease in the wholesale electricity price of €7.08/MWh in 2005, €4.75/MWh in