Utilities Policy 31 (2014) 29–35

Contents lists available at ScienceDirect

Utilities Policy

journal homepage: www.elsevier.com/locate/jup

Toward a less natural gas dependent energy mix in Spain: Crowding-out effects of shifting to biomass power generation

María J. Colinet [c], José M. Cansino [a, b, *], José M. González-Limón [a], Manuel Ordóñez [a]

[a] University of Seville, Spain
[b] Universidad Autónoma de Chile, Chile
[c] Andalusian Energy Agency (Andalusian Regional Government), Spain

ARTICLE INFO

Article history:
Received 30 January 2014
Received in revised form
27 July 2014
Accepted 27 July 2014
Available online 30 August 2014

Keywords:
Biomass for electricity generation
Natural gas generation
Combined cycle technology
Input–output framework
Fuel substitution
Renewable energy

ABSTRACT

This paper estimates the impact of a hypothetical change in Spain's energy mix on a number of productive sectors. The change would be brought about by substituting power generation from natural gas with generation from biomass. The total amount of electricity supplied has been calculated to remain constant so that a crowding-out effect would be derived from the displacement of one technology with another. An input–output (IO) framework has been used to estimate the overall economic impact on 26 productive sectors included on Spain's 2007 IO Table. Based on the available literature, the consideration of net impact improves the analysis. The results show that the overall net impact across all productive sectors of this change in the energy mix would be positive and equal to about 0.5% for the period. Higher impacts were measured for the 'Electricity power and Electricity Supply' sector (15.4%) followed by the 'Agriculture, Hunting, Forestry' sector (7.1%). Only the 'Gas generation and Gas supply' sector showed a negative impact (−2.5%), which is consistent with the reduced use of natural gas. The overall calculated total impact for Spain's productive sector was equal to € 8074.95 million at the 2007-equivalent value.

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1. Introduction

To raise the targets established by the European Union (EU) Directive 2009/28/EC, the authorities of Spain approved a document titled 'Plan de Energías Renovables ("Renewable Energy Plan" in Spanish) 2011–2020' (IDAE, 2011). This legal document fixed mandatory deployment targets until 2020 for each renewable energy technology type.

Complying with these mandatory targets will affect Spain's economy; therefore, assessing the economic impact becomes a relevant question. When the impact of the deployment of a particular technology is assessed, the available literature usually assumes that there will be an increase in the total installed capacity (Caldés et al., 2009; Cardenete et al., 2010; Cansino et al., 2013).

However, an alternative assumption that implies no change in the total installed capacity could be more useful. In 2013, the total capacity installed in Spain was 108,148 MW. However, the demand peak was only 39,963 MW (REE, 2013). This means that the total capacity installed was 2.7 times greater than what was necessary to supply the peak. In fact, the experts recommend that the relationship between the available power and the demand peak (known as Demand Coverage Index) be 1.10 (CNE, 2012).

Given that Spain has excess generation capacity, a crowding-out effect implying displacement by new technologies seems more plausible than the assumed increase in total power generation. The displacement is based on substituting Combined Cycle Plants (CCP) for Biomass Plants (BP) and accepts that the total installed capacity remains constant. The choice of the two technologies used in this analysis is explained herein.

First, the literature offers evidence about the positive impact of BP on rural areas (Cardenete et al., 2010). Second, this idea is also consistent with the design of the EU Common Agriculture Policy (CAP, Council Decision 2006/144/EC). Third, the electricity supplied by BP does not depend on weather (sun or wind based technologies) and can be modulated based on the electricity demand (i.e., it is a dispatchable form of energy). BP has a low disruption risk. Section 3 provides greater detail on this point.

In the case of CCP, there are two additional reasons that support our hypothesis. First, the electricity generated by these plants in 2013 accounted for only 9.6% of all electricity generated (REE, 2013). Dismantling and substitution CCPs with BP would not jeopardize overall supply. Second, Spain has no natural gas resources; 99.4%

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* Corresponding author. University of Seville, Spain.
E-mail address: jmcansino@us.es (J.M. Cansino).

http://dx.doi.org/10.1016/j.jup.2014.07.006
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comes from imports (CORES, 2012). Reducing the installed CCP capacity means reducing Spain's dependency on foreign suppliers for this energy source. This also is one of the pillars of the EU energy strategy (European Commission, COM/2000/0769 final).

In the case of BPs working 7000 hours per year (as occurs with CCP replacement), the reduction in natural gas consumption relates to a decrease in imports associated with 11,000,000 MWh, which can be valued at € 290.3 million when considering an import price for natural gas of 26.4 €/MWh (CNE, 2013).

Substituting CCP for BP plants is technologically feasible (as discussed below). The BP technology considered in this study is a mature technology on the market. This substitution implies no risk for the security of the electricity supply. Moreover, the hypothesis is consistent with the objectives for rural development established in the CAP. This change in Spain's electrical mix would contribute to reducing dependency upon foreign energy, as Spain lacks natural gas deposits. In sum, all of the above means that our proposed shift is realistic and feasible.

As mentioned, the authorities of Spain have established mandatory deployment targets for all renewable energy technologies up to the year 2020. Each technology, including biomass, is listed in the document titled 'Plan de Energías Renovables 2011–2020' (PER or Renewable Energy Plan) (IDAE, 2011) with corresponding targets. The target fixed by the PER for biomass power generation using biomass feedstock is an installed capacity of 1350 MW in 2020 (an increase of 817 MW over the amount installed in 2010).

Considering the priority placed on the use of green electricity in Spain's power grid, the fully installed capacity of BP-produced electricity is used in all cases. This technology can be managed in a planned manner if raw materials are available; this differs from other RES technologies that are "variable" and dependent on natural phenomena such as rain, wind or solar radiation (Sovacool, 2009). Because CCP power output can be modulated, in this present study, we consider that the electricity generation levels using CCPs would be reduced to maintain a balance with the added power derived from BP. However, no CCPs would be dismantled.[1]

This paper considers the economic impact of the change in Spain's energy mix associated with compliance with the PER (2011–2020). We estimate the impact on Spain's productive activities when deploying BP instead of CCP to generate a comparable amount of electricity. The analysis contributes to the literature by providing, to our knowledge, the first study that evaluates the net economic impact of shifting to an alternative energy technology. Moreover, our Input–Output (IO) approach constitutes an analytical improvement by considering the crowding-out effect instead of assuming a gross increase in MW installed. These results are interesting not only for researchers but also for utility companies and policy-makers. In fact, this paper speaks directly to the authorities of Spain and the policy agenda with regard to several issues, including energy security.

This paper proceeds as follows. Section 2 explains the IO methodology and Section 3 describes the data used in the analysis. The results and discussion are presented in Section 4, while Section 5 summarizes the main conclusions.

2. Methodology

The IO approach is largely supported by the available literature. The economic impact of Renewable Energy Sources (RES), such as solar energy, has frequently been estimated using IO models. In the US, for example, IO analysis has been used by Cook (1998) and Ciorba et al. (2004), while in Europe, Kulisic et al. (2007), Madlener and Koller (2007), and Allan et al. (2008) developed similar approaches. Caldés et al. (2009), Calzada et al. (2009), and the European Commission (MITRE, 2009) recently used an IO model to estimate the economic impact of RES in Spain.

The basis for the methodology applied herein is the Leontief (1941) model. The starting point is the concept of a technical coefficient, a_{ij}, indicating how the needs (z_{ij}) of sector j relate to the inputs from another sector I per unit of output (x_j) from sector j itself, which is expressed as follows:

$$a_{ij} = \frac{z_{ij}}{x_j} \tag{1}$$

From (1), (2) is obtained:

$$z_{ij} = a_{ij} \cdot x_j \tag{2}$$

On the other hand, the total output of sector j is the sum of intermediate consumption for the entire sector (n) of this sector's economy makers (z_{ij}) and products that are destined to final demand (f_j). Thus, the production of sector j can be expressed as:

$$x_j = z_{j1} + z_{j2} + \ldots + z_{jj} + \ldots + z_{jn} + f_j \tag{3}$$

The production of the remaining sectors follows a similar pattern. The production of each of the n sectors is defined by the following expression:

$$\begin{aligned} x_1 &= z_{11} + z_{12} + \ldots + z_{1j} + \ldots + z_{1n} + f_1 \\ x_2 &= z_{21} + z_{22} + \ldots + z_{2j} + \ldots + z_{2n} + f_2 \\ &\ldots \ \ldots \ \ldots \ \ldots \ \ldots \ \ldots \\ x_j &= z_{j1} + z_{j2} + \ldots + z_{jj} + \ldots + z_{jn} + f_j \\ &\ldots \ \ldots \ \ldots \ \ldots \ \ldots \ \ldots \\ x_j &= z_{j1} + z_{j2} + \ldots + z_{jj} + \ldots + z_{jn} + f_j \end{aligned} \tag{4}$$

Substituting each z_{ij} by $a_{ij} \cdot x_j$ gives:

$$\begin{aligned} x_1 &= a_{11} \cdot x_1 + a_{12} \cdot x_2 + \ldots + a_{1j} \cdot x_j + \ldots + a_{1n} \cdot x_n + f_1 \\ x_2 &= a_{21} \cdot x_1 + a_{22} \cdot x_2 + \ldots + a_{2j} \cdot x_j + \ldots + a_{2n} \cdot x_n + f_2 \\ &\ldots \ \ldots \ \ldots \ \ldots \ \ldots \ \ldots \\ x_j &= a_{j1} \cdot x_1 + a_{j2} \cdot x_2 + \ldots + a_{jj} \cdot x_j + \ldots + a_{jn} \cdot x_n + f_j \\ &\ldots \ \ldots \ \ldots \ \ldots \ \ldots \ \ldots \\ x_n &= a_{n1} \cdot x_1 + a_{n2} \cdot x_2 + \ldots + a_{nj} \cdot x_j + \ldots + a_{nn} \cdot x_n + f_n \end{aligned} \tag{5}$$

Solving f_i, one obtains:

$$\begin{aligned} &(1 - a_{11}) \cdot x_1 - a_{12} \cdot x_2 - \ldots - a_{1j} \cdot x_j - \ldots - a_{1n} \cdot x_n = f_1 \\ &-a_{21} \cdot x_1 + (1 - a_{22}) \cdot x_2 - \ldots - a_{2j} \cdot x_j - \ldots - a_{2n} \cdot x_n = f_2 \\ &\ldots \ \ldots \ \ldots \ \ldots \ \ldots \ \ldots \\ &-a_{j1} \cdot x_1 - a_{j2} \cdot x_2 - \ldots + (1 - a_{jj}) \cdot x_j - \ldots - a_{jn} \cdot x_n = f_j \\ &\ldots \ \ldots \ \ldots \ \ldots \ \ldots \ \ldots \\ &-a_{n1} \cdot x_1 - a_{n2} \cdot x_2 - \ldots - a_{nj} \cdot x_j - \ldots + (1 - a_{nn}) \cdot x_n = f_n \end{aligned} \tag{6}$$

The expression (6) can be shown in this matrix formula:

$$(I - A) \cdot x = f \tag{7}$$

where I is the identity matrix of order $n \times n$, A is a matrix of order $n \times n$ for the technical coefficients, x is a column vector of order $n \times 1$ for the production of each sector, and f is the column vector of order $n \times 1$ of the final demand of each sector.

If we pre-multiply the two terms in (7) by $(I-A)^{-1}$, we obtain:

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[1] In 2012, Spain had 51 CCPs with an installed capacity of 25,269 MW (this accounted for 25.22% of the total national installed capacity); 50.734 GWh (19.2% of the total) were generated, which is a utilization ratio of 25.1% of the CCPs' production capacity. By 2010, this had increased to 31.9%. The functioning electricity system has a rated capacity of 2007.75 hours per year. In 2012, the operations stood at 1579.46 hours per year (See REE, 2011 and 2012).

$$x = (I - A)^{-1} \cdot f \tag{8}$$

Equation (8) is the fundamental equation of the Leontief model; it shows that the production of each sector depends on the final demand and on the so-called Leontief inverse matrix. From (8), one can determine any variation that economic activities undergo in response to changes in the final demand; for example, variations associated with altering the technologies used to generate electricity.

This methodology also permits the impact of a change in the magnitude for any of the considered economic activities to be calculated. For this case, the impact associated with a larger biomass power generation sector can be calculated. Introducing a larger-scale biomass electricity sub-sector must, by definition, result in changes to input requirements and supplies to the rest of the electricity sector. This methodology allows us to compare the benchmark (pre-shock on vector f) with the final stage output following the shock caused by the crowding-out effect associated with the new BP.

This impact produces a double effect. The first effect is due to the fact that the investment in new BP creates a shock in the final demand, thus affecting the sector's output. This impact is calculated using (8). The second effect is associated with the fact that the new BPs have different input needs than the CCPs they displace. In other words, the operation and maintenance costs (O&M) of the technologies are different. This causes a change in the matrix for inter-sectarian transactions that will also have an impact on the output of the sector. This variation in sector output can be calculated using a different method than those proposed by Miller and Blair (2009).

The methodology used to assess this second effect follows a three-step process. The basic methodology for this calculation is found in the expression (4), because substituting one technology for another will spark changes in inter sectoral transactions. The first step implies that some needs increase when new BPs come into force. At the same time, other power sector needs decrease as CCP power generation is reduced. Thus, the net power sector needs are provided by:

$$z^f_{i,6} = z^0_{i,6} + z_{i,BP} - z_{i,CCP} \tag{9}$$

where, $z^f_{i,6}$ is the electricity sector's final needs (sector 6 in Table 4) as a function of the remaining production activities; $z^0_{i,6}$ represents the initial needs of this sector; $z_{i,BP}$, represents the input needs of new BPs; $z_{i,CCP}$ represents CCPs needs that now decrease as a consequence of the decreased power generation using this technology.

The second step introduces data from (9) into an IO Table. With the IO Table, the total resources must match the total employed by each production activity. Therefore, the monetary value of the energy provided by the new biomass sector supplies other productive sectors; the final demand must equal the value of the total resources required for their production. Consequently, it is necessary to reduce input requirements proportionally to the reduction of total sector resources.

After this adjustment, because the new input needs and the total resources employed by the various production activities are not equal, it is necessary to calibrate the former as a third step in the process. Since we know the total sector input needs, these are taken as the total resources. So, respecting the technical coefficients, the new totals are calculated in relation to these coefficients. This can be done as follows:

$$z'_{ij} = a_{ij} \cdot x'_j \tag{10}$$

Where z'_{ij} represents the new intermediate needs of each sector; x'_j, is the new total resources; and, a_{ij} represents the technical coefficients. These coefficients remain unchanged with the exception of the technical coefficient for the electricity sector, which changes when one technology displaces another.

Comparing the final production with the initial production allows us to calculate the impact associated with the change in the input needs.

3. Data

To assess the economic impact of changing Spain's energy mix, two cost types must be taken into account. These are BP investment and O&M costs for the implementing this technology. CCP O&M costs are also necessary. This section provides a breakdown of these costs according to the 26 sectors considered.

3.1. Biomass and combined cycle plant data

Data for the BP investment and O&M costs for both CCP and BP were obtained from questionnaire-based information from companies belonging to these sectors in Spain. The reliability of the information was confirmed by the Andalusian Energy Agency technical staff.

For the purpose of this research, one type of BP and one type of CCP were considered, with both plants using technologies that are sufficiently developed to be considered representative of standard practice (see below). The construction period for this type of plant is about one year, with approximately a 20-year working lifetime. The standard business hypothesis has been calculated for the 2011–2020 period.

CCP technology is based on a gas turbine and the subsequent use of waste heat passing through a steam cycle (Kehlhofer et al., 2009). The gas turbine combustion heat uses compressed air from a compressor coupled to the turbine itself (Brayton cycle), with expansion of gases in the turbine producing energy converted into electrical energy with an alternator. Natural gas is the primary fuel used. The gases from turbine reach temperatures well over 600 °C; a recovery boiler uses these gases to produce steam which, in turn, can be used to drive a steam turbine to produce energy that is converted into electrical energy (Rankine Cycle). The type of CCP envisaged for the scenario in this study corresponds to a 800 MW capacity.

The BP technology used is based on a classical thermodynamic Rankine cycle with a combustion boiler, steam turbine, extraction and air condensation. The boiler pipes and natural water circulation include a super-heater, evaporator and economizer bank (Van Loo and Koppejan, 2008). “Orujillo” (the pomace or residual pulp) derived from olive oil production) is the biomass fuel used. This product is burned in the boiler to produce high pressure, superheated steam that feeds the turbine, where it expands and produces electrical energy by driving an alternator connected to the turbine shaft. The BP type considered for this research corresponds to a 25 MW capacity. The use of pomace as a raw material does not involve secondary issues such as indirect land use changes associated with the use of certain biofuels.[2]

Total new installed capacity for BPs demands 5 million tons of biomass to operate at full capacity (500 ktep). Only in southern Spain (Andalusian region) are 3958 ktep per year available. 38.6% of this amount (1526 ktep per year) comes from olive oil production residue (Colinet and Lobo, 2013).

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[2] For a recent publication concerning indirect land use change, see Popp et al. (2012).

Tables 1 and 2 show the investment and O&M costs associated with the implementation of BP.

The main economic activity benefiting from the implementation of a BP is seen in the 'Metallic product' sector, which receives 32.7% of the total spending on investment. The 'Construction' (15.5%) sector also benefits significantly, along with 'Metallurgy' (14.7%).

Because BP uses a raw material, the main economic activity benefiting from the operation of a BP is the 'Agriculture, Hunting, Forestry' sector, which absorbs 77.8% of the total O&M expenses (Cardenete et al., 2010; Soliño, 2010; Soliño et al., 2012). Spending on 'Financial Intermediation' represents 14.7%. Table 3 shows the O&M costs associated with a CCP.

The O&M costs for a CCP are much less than those of a BP, representing only 18.9% of the cost per MW installed in BP. In the case of a CCP, the economic activities most directly related to O&M costs are financial services (38.4%) and 'Gas generation, gas and supply' (36.5%).

In accordance with our assumption, when 1 MW of BP-derived electricity is placed on the electricity grid, 1 MW of CCP is crowded-out. This directly affects the O&M costs of each technology. In the case of BP, O&M costs increase, while those for CCP decrease.

The explanation for the elevated importance of financial service expenditures for both plant types is that the demand for electricity is generally assured, which reduces investment risk. Consequently, in a non-credit crunch scenario, leverage is high. Due to the assumption that the installed CCP will continue operating but at a lower intensity, dismantling costs are irrelevant for this research.

3.2. Spanish economic data

IO Tables have served as the basis for an ample number of economic impact analyses. However, the publication of these tables by most statistical agencies is not usually offered on an annual basis. Therefore, for this paper, a symmetrical IO table for Spain was constructed (using a variety of procedures) from the supply and use tables with the basic IO Framework prices in Spain for 2007. The reason why the 2007 IO Table was chosen rather than the most recent for 2009 is that the origin and destination tables for 2007 present a biased electric sector with regard to the gas sector. This is better suited to the objective of this article. We have chosen the D model (Eqn. (7)) (Eurostat, 2008), which considers a fixed structure for product sales in which each product has its own sales structure irrespective of the productive activity generated.[3] Furthermore, it requires a relatively simple mechanical procedure with these tables being closer to national statistics and not appearing as negatives in the IO Table.

Table 1
Investment cost of BP power generation (Euros/MW).

Agriculture, hunting, forestry	
Fishing and aquaculture	
Energy extracts	
Other extracts	
Coke, refined petroleum and nuclear fuel	
Electricity power and electricity supply	18,904.4
Gas generation and gas supply	8493
Water generation and water supply	
Food, beverages and tobacco	
Textiles and textile products, leather and footwear	
Wood and products of wood and cork	
Chemicals and chemical products	48,517.2
Construction materials	94,697.4
Metallurgy	183,987.6
Metallic products	407,069
Machinery, Nec	123,288.6
Vehicles	6286.6
Other forms of transport	7152
Other manufacturing	89,090
Construction	193,881.8
Commerce	
Hotels and restaurants	
Transport and communications	14,134.6
Financial intermediation	49,604.2
Other retail trade	
Services not oriented to sales	
Total	1,245,106.6

Source: Own elaboration.

Table 2
O&M costs of BP power generation (Euros/MW).

Agriculture, hunting, forestry	3,870,484.1
Fishing and aquaculture	
Energy extracts	
Other extracts	
Coke, refined petroleum and nuclear fuel	
Electricity power and electricity supply	
Gas generation and gas supply	
Water generation and water supply	
Food, beverages and tobacco	
Textiles and textile products, leather and footwear	
Wood and products of wood and cork	
Chemicals and chemical products	93,051.4
Construction materials	18,610.3
Metallurgy	
Metallic products	55,830.9
Machinery, Nec	
Vehicles	
Other forms of transport	
Other manufacturing	87,734.2
Construction	55,830.9
Commerce	
Hotels and restaurants	
Transport and communications	55,830.9
Financial intermediation	732,176.1
Other retail trade	
Services not oriented to sales	
Total	4,969,548.6

Source: Own elaboration.

An IO Table contains rows and columns to represent economic sectors and productive activities, respectively. The 75 productive activities appearing in the source and destination tables for Spain have been categorized according to the 26 sectors considered in this article (Table 4).

4. Results and discussion

From the data contained in Tables 1–3, the IO analysis provides results showing the crowding-out effect of CCP by BP. On the one hand, the impact originates in the shock in demand associated with the necessary investment for the construction of the BP. On the other hand, the net variation of the O&M (positive variation due to the start-up of the BP and negative variation due to the reduction of the CCP activity) causes an economic effect, which induces change in the input needs of the electric sector, modifying the transaction matrix.

The shock pattern could be considered as follows. Characteristics of O&M costs for renewable technologies (such as biomass) help explain why most European Union Member States have introduced measures to promote green electricity (Cansino et al., 2010). The most widespread promotional measure is the feed-in tariff scheme. This scheme has actually been suspended in Spain

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[3] That is to say, certain goods may be manufactured by different productive activities.

Table 3
O&M costs of CCP power generation (Euros/MW).

	1 MW
Agriculture, hunting, forestry	
Fishing and aquaculture	
Energy extracts	
Other extracts	
Coke, refined petroleum and nuclear fuel	
Electricity power and electricity supply	88,536.00
Gas generation and gas supply	343,728.00
Water generation and water supply	
Food, beverages and tobacco	
Textiles and textile products, leather and footwear	
Wood and products of wood and cork	
Chemicals and chemical products	36,911.70
Construction materials	7382.34
Metallurgy	
Metallic products	22,147.02
Machinery, Nec	
Vehicles	
Other forms of transport	
Other manufacturing	34,802.46
Construction	22,147.02
Commerce	
Hotels and restaurants	
Transport and communications	22,147.02
Financial intermediation	361,617.48
Other retail trade	
Services not oriented to sales	
Total	939,419.0

Source: Own elaboration.

since the Royal Decree 1/1202 (RD 1/2012) came into force to reduce public spending, but it is expected to once again take effect in 2017 (Hernández, 2012). For this reason, our research considers a temporary investment pattern for the 817 MW of additional BP-produced power.[4]

Approximately one year is needed to build and put the BP into operation; therefore, annually, for the 2017–2019 period, one third of the total target (272 MW) could be implemented. The pattern used enables the PER (2011–2020) target to be reached by the 2020 deadline.

These results are shown separately in Tables 5 and 6. Table 5 shows the annual, investment spending impact for 2017, which will be repeated in 2018 and 2019. Table 6 shows the impact caused by the new input needs, due to the use of BP instead of CCP.

The demand shock associated with the investment required to install the BP is positive for all economic activities. Moreover, the total growth of economic activities for the years 2017–2019 is equivalent to 0.03%. Economic sectors with the greatest impact were those of ‘Other manufacturing’, ‘Machinery’ and ‘Energy extracts’, with each of these activities being closely linked to investment projects such as the one considered. The total impact on Spain's economy[5] is € 1387.22 million at the 2007-equivalent value.

Crowding-out provokes a positive total effect on economic activities when input needs vary due to the substitution of BPs for CCPs. As presented in Tables 2 and 3, not all economic activities show a positive effect.

Crowding-out causes a logical and negative effect on ‘Gas generation and Gas supply’ due to the decreased use of natural gas.

Table 4
IOT 07 productive activity structure and correspondence with the branches of the IO framework for Spain 2007.

ITO07	Activities
1. Agriculture, hunting, forestry	1, 2
2. Fishing and aquaculture	3
3. Energy extracts	4, 5
4. Remaining extracts	6, 7
5. Coke, refined petroleum and nuclear fuel	8
6. Electricity power and electricity supply	9
7. Gas generation and gas supply	10
8. Water generation and water supply	11
9. Food, beverages and tobacco	12–16
10. Textiles and textile products, leather and footwear	17–19
11. Wood and products of wood and cork	20
12. Chemicals and chemical products	23, 24
13. Construction materials	25, 27, 28
14. Metallurgy	29
15. Metallic products	30
16. Machinery, Nec	31–35
17. Vehicles	36
18. Other forms of transport	37
19. Other manufacturing	21, 22, 26, 38, 39
20. Construction	40
21. Commerce	41–43
22. Hotels and restaurants	44, 45
23. Transport and communications	46–52
24. Financial intermediation	53–55
25. Remaining retail trade	56–60, 62, 64, 67, 69, 71, 74
26. Services not oriented to sales	61, 63, 65, 66, 68, 70, 72, 73, 75

Source: Own elaboration.

When the additional BP power is placed onto the electricity grid (817 MW by 2020), the overall effect on the economic activity of this sector is equal to a reduction of the 2007-equivalent value by 2.5%.

Table 5
Impacts associated with investment costs of new BP (in millions of Euros).

	Initial output	272 MW	
		Final output	Variation (%)
Agriculture, hunting, forestry	44,435.0	44,436.5	0.0034
Fishing and aquaculture	3025.0	3025.0	0.0011
Energy extracts	1374.0	1375.0	0.0711
Remaining extracts	5321.0	5324.7	0.0698
Coke, refined petroleum and nuclear fuel	34,419.0	34,422.4	0.0097
Electricity power and electricity supply	40,051.0	40,070.4	0.0485
Gas generation and gas supply	11,166.0	11,173.4	0.0659
Water generation and water supply	6216.0	6216.7	0.0108
Food, beverages and tobacco	93,503.0	93,504.7	0.0018
Textiles and textile products, leather and footwear	21,987.0	21,988.4	0.0065
Wood and products of wood and cork	11,300.0	11,304.3	0.0384
Chemicals and chemical products	67,589.0	67,617.1	0.0416
Construction materials	34,159.0	34,196.4	0.1094
Metallurgy	40,544.0	40,631.8	0.2166
Metallic products	47,631.0	47,766.9	0.2853
Machinery, Nec	64,765.0	64,810.4	0.0701
Vehicles	62,654.0	62,657.4	0.0054
Other forms of transport	13,753.0	13,755.7	0.0198
Other manufacturing	62,778.0	62,826.3	0.0769
Construction	323,774.0	323,861.4	0.0270
Commerce	180,165.0	180,183.5	0.0103
Hotels and restaurants	117,011.0	117,012.7	0.0014
Transport and communications	154,511.0	154,547.4	0.0236
Financial intermediation	78,373.0	78,399.3	0.0336
Remaining retail trade	351,131.0	351,165.6	0.0099
Services not oriented to sales	199,833.0	199,834.6	0.0008
Total	2,071,468.0	2,072,107.9	0.0309

Source: Own elaboration.

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[4] The approval of the new Law for the Electricity Sector 24/2013 could change the temporary investment patterns taken for granted in this article. The new Law foresees specific retribution for certain renewable power plants. Nevertheless, the Law fails to clarify what those characteristics may be.

[5] Based on to Santamaría (2012) and Weitzman (2011), a discount rate equal to 3% is applied.

Table 6
Impact associated with net O&M cost variations (in millions of Euros).

	Initial output	272 MW		545 MW		817 MW	
		Final output	Variation (%)	Final output	Variation (%)	Final output	Variation (%)
Agriculture, hunting, forestry	44,435.0	45,489.1	2.4	46,543.1	4.7	47,597.2	7.1
Fishing and aquaculture	3025.0	3025.0	0.0	3025.0	0.0	3025.0	0.0
Energy extracts	1374.0	1374.0	0.0	1374.0	0.0	1374.0	0.0
Remaining extracts	5321.0	5321.0	0.0	5321.0	0.0	5321.0	0.0
Coke, refined petroleum and nuclear fuel	34,419.0	34,419.0	0.0	34,419.0	0.0	34,419.0	0.0
Electricity power and electricity supply	40,051.0	42,111.6	5.1	44,172.2	10.3	46,232.8	15.4
Gas generation and gas supply	11,166.0	11,072.4	−0.8	10,978.8	−1.7	10,885.2	−2.5
Water generation and water supply	6216.0	6216.0	0.0	6216.0	0.0	6216.0	0.0
Food, beverages and tobacco	93,503.0	93,503.0	0.0	93,503.0	0.0	93,503.0	0.0
Textiles and textile products, leather and footwear	21,987.0	21,987.0	0.0	21,987.0	0.0	21,987.0	0.0
Wood and products of wood and cork	11,300.0	11,300.0	0.0	11,300.0	0.0	11,300.0	0.0
Chemicals and chemical products	67,589.0	67,604.3	0.0	67,619.6	0.0	67,634.9	0.1
Construction materials	34,159.0	34,162.1	0.0	34,165.1	0.0	34,168.2	0.0
Metallurgy	40,544.0	40,544.0	0.0	40,544.0	0.0	40,544.0	0.0
Metallic products	47,631.0	47,640.2	0.0	47,649.3	0.0	47,658.5	0.1
Machinery, Nec	64,765.0	64,765.0	0.0	64,765.0	0.0	64,765.0	0.0
Vehicles	62,654.0	62,654.0	0.0	62,654.0	0.0	62,654.0	0.0
Other forms of transport	13,753.0	13,753.0	0.0	13,753.0	0.0	13,753.0	0.0
Other manufacturing	62,778.0	62,792.4	0.0	62,806.8	0.0	62,821.2	0.1
Construction	323,774.0	323,783.2	0.0	323,792.3	0.0	323,801.5	0.0
Commerce	180,165.0	180,165.0	0.0	180,165.0	0.0	180,165.0	0.0
Hotels and restaurants	117,011.0	117,011.0	0.0	117,011.0	0.0	117,011.0	0.0
Transport and communications	154,511.0	154,520.2	0.0	154,529.3	0.0	154,538.5	0.0
Financial intermediation	78,373.0	78,473.9	0.1	78,574.8	0.3	78,675.7	0.4
Remaining retail trade	351,131.0	351,131.0	0.0	351,131.0	0.0	351,131.0	0.0
Services not oriented to sales	199,833.0	199,833.0	0.0	199,833.0	0.0	199,833.0	0.0
Total	**2,071,468.0**	**2,074,650.2**	**0.2**	**2,077,832.5**	**0.3**	**2,081,014.7**	**0.5**

Source: Own elaboration.

On the other hand, crowding-out provokes a positive effect on ‘Agriculture, Hunting, Forestry,’ which is also logical due to the raw materials used by the new BPs. When the full 817 MW of new BP-derived power is available, the overall effect on the economic activity of this sector is equal to an increase of 7.1% above the 2007-equivalent value.

The main effect on economic activities caused by crowding-out is on ‘Electricity power and Electricity Supply,’ which is due to the higher costs of the electricity generated by BP technology, as shown on Table 2.

When the economic activities of all sectors are considered together, the total net variation resulting from the addition of 817 MW of new BP-derived power to the electricity grid is equal to 0.5%. This equates to a total impact on Spain's economy of € 6697.73 million at the 2007-equivalent value. Logically, the net impact is less than the gross estimated impact based on similar analyses, as indicated in the study by Cardenete et al. (2010).

The possible impact on electricity prices is an important issue. Currently, in Spain only 40% of the consumer electricity price is market based. The rest of the price is determined under the Public Authorities (Law 24/2013). The relevant market is the Iberian one (Spain and Portugal). On this market, the share of the electricity generated from biomass is only 0.07% (Spanish Ministry of Industry (2013)). The cost of a feed-in tariff system is financed through private debt, supported by sovereign guarantee, and without any kind of impact on electricity prices (FADE, 2014). For the forthcoming years, the most likely pattern for this price is not dissimilar from previous years; therefore, we assume that there will be no relevant impact on electricity demand or output based on prices.

5. Conclusions

The economic impact due to the deployment of new energy technologies can be assessed by using an IO framework. However, most of the available literature focuses on gross rather than net impacts. Net economic impacts clearly are relevant when policy-makers consider mandating a change the energy mix.

In this paper, we carried out an analysis within an IO framework by estimating the economic crowding-out effect associated with the displacement of CCPs by BPs. Our results were significantly enhanced by considering net impact. Within this improved methodological context, our major finding is that the economic crowding-out effect is positive and equal to about 0.5% of total output for the period when the net variation of O&M costs on demand are considered. The greatest growth is seen in the economic sector for ‘Electricity Power and Electricity Supply’ (15.4%), followed by the ‘Agriculture, Hunting, Forestry’ sector at 7.1%. Only ‘Gas generation and Gas supply’ suffered a negative economic impact (−2.5%), reflecting the fuel shift.

By taking into account the joint impacts from investment costs associated with new BPs and the net variation of O&M costs, the overall effect on Spain's productive sector is equal to € 8074.95 million at the 2007-equivalent value. This amount should be considered a maximum because the inclusion of any governmental compensation payments to CCP owners has not yet been considered. For example, we have not accounted for possible payments to maintain the CCPs that might resume production if an increase in electricity demand cannot be met by other technologies.

Our results are relevant for policy-makers because they can inform decisions about the energy mix. The results show that a hypothetical but feasible substitution of CCP by BP would contribute to attaining two national objectives. First, reducing natural gas usage in power generation diminishes Spain's dependence on foreign supplies. Second, the positive impact on the agricultural sector is consistent with the objective for rural development, which is one of the pillars of the Common Agricultural Policy. The results are also relevant for the utilities involved, whether BP or CCP owners.

Although the methodology applied in this work is based on the IO approach using IO tables, it follows a fixed-coefficient technology and therefore, it is likely to be valid only for short-term scenarios. As such, the results presented herein have a higher predictive value for short periods of time, no more distant than the 2020 horizon. Predicting a longer-term scenario would require a different approach involving a dynamic general equilibrium or recursive model.

Acknowledgements

The authors acknowledge financial support received from the Cátedra de Economía de la Energía y del Medio Ambiente (Department for Energy Economy and the Environment) at the University of Seville-Fundación Roger Torné. The second, third and fourth authors also acknowledge financial support from SEJ 132 project of the Andalusian Regional Government. The second author acknowledges support from Universidad Autónoma de Chile, Chile. The standard disclaimer applies.

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