THE EFFECT OF DISTRIBUTED GENERATION UNDER NEXT ELECTRICITY MANAGEMENT SYSTEMS IN SPANISH ECONOMY

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Abstract

The European Union has shifted significantly toward a more climate friendly and efficient electricity system with the increase of renewable energy sources. Next electricity management systems help to better integrate distributed generation renewable resources, such as photovoltaic as well as small or micro wind or combined heat and power units, in the electricity market. For example, in 2014 the Spanish National Commission for Markets and Competition accounted of 60,000 photovoltaic plants in comparison with 10,000 plants that had been registered for 2006. Moreover, it is expected that distributed generation increases more in Spain as the Action Plan for Renewable Energy 2011-2020 (Spanish Government, 2011) proposes that the installed capacity of micro and small scale hydropower, photovoltaic and micro wind reach 2158 MW, 12356 MW and 300MW till 2020.
By using an Input-Output approach, this paper study the environmental and economic impacts of different energy sources and greenhouse gas emissions in a massive integration of electricity distributed generators under a next electricity management systems. Several scenarios are considered according to different paths of the integration of distributed generators in electricity supply and electricity management strategies.

Economically, the investment in these technologies can originate relevant induced effects in the economy. For example, Micro- wind, Small Hydro and photovoltaic have large economic direct and indirect effects in the Spanish economy in term of output and employment, but the variability of renewable should be considered.

The estimated co-benefits in terms of output and new jobs in the economy are relevant and help to the transformation to not only lower-carbon economy but a prosperous nation.

Keywords: Electricity distributed generation, Virtual Power Plants, input-output analysis.

1 INTRODUCTION

European Union has shifted significantly toward a more decarbonized energy system. In fact, the Europe 2020 Strategy (European Commission, 2010) established three key targets for 2020 as the cut of 20% in greenhouse gas emissions (from 1990 levels), the boost of renewable (RES-E) in final energy consumption to 20% and the improvement in energy efficiency in 20%. The EU framework for climate and energy policies has gone far beyond the levels of these targets and, by 2030 the EU should cut greenhouse gas emissions at least to 40% below 1990 levels and increase the renewable energy and energy efficiency at least 27%. The progressive milestones are in line with the Energy Roadmap 2050 and Roadmap for moving to a competitive low carbon economy in 2050.The UE aims at reducing emissions by 80% by 2050 and enhancing clean technologies and low- or zero-carbon energy.

The electricity markets can be one of the key sectors for boosting the transition to economy more climate-friendly and less energy-consuming. There is not a single solution for decarbonizes the economy, but given the current EU climate strategies, the power generation mix of the electrification of demand and emissions-free generation should be considered (Eurelectric, 2017). Traditionally, distribution companies (DSOs) have planned their networks consistent with peak demand needs in one-directional energy systems from power generation to homes power. But the expansion of renewable points to distributed energy resources (DER) and/or distributed renewable energy sources (DRES). The new power systems waive generate energy locally from solar panel, wind turbines, fuel cells and photovoltaic (PV) systems and all micro-generation technologies in a called decentralised generation system (DG) and connect the energy directly to distribution networks. Extensive research about this topic is carried out around the world. Many countries have approved financial assistance to encourage Electricity generated from renewable sources, RES-E (see Abdmouleh et al 2015 an analysis of different mechanisms and Del Rio and Mir-Artigues 2014, Haas et al 2011 for a review of RES-E support instruments in the EU).

In Spain, RES-E already composes 37,8% of Spain´s gross electricity generation and the installed power of electrical energy production activities related with wind and solar has boost 131% and 320% in 2014 with respect 2005 (European Commission, 2017). In 2014, 90% of 60,000 photovoltaic plants are connected to the electrical distribution grid in comparison with 10,000 plants that had been registered for 2006 (Álvarez and Castro 2014). Furthermore, it is anticipated that more than half of the installed electric generation capacity will be renewable-energy based in 2020 in Spain (Dietrich et al 2015). Spanish Action Plan for Renewable Energy 2011-2020 (Spanish Government, 2011) raises the installed capacity of small hydropower, photovoltaic or micro wind to 2158 MW, 12356 MW and 300MW till 2020, respectively.It is noticed that, the rising of renewable plants increased the support cost, becoming an unsustainable long-term policy. For this reason, Spain fixed the abolition of the renewable promotion mechanism (Spanish Government, 2013) and the Royal Decree 413/2014 (Spanish Government 2014) regulates in Spain the activity of production of electric energy from renewable energy sources, cogeneration and waste and establishes a new support scheme for these sources. It replaces the feed-in tariff, and links the collection of additional payments to what RES-E producers receive in the electricity market at a reasonable return. Thus, after RES-E become non-supported generation it is most exposed to electricity market and raises a number of challenges related to its integration in wholesale exchange market: (i) Under marginal cost pricing in competitive electricity markets the offer of RES-E reduces electricity price market-, turning renewable plants in less profitable. Moreover (ii) RES-E production is variable and very difficult to predict –as it is determined by weather conditions-, increasing RES-E owners´ imbalance costs due to the forecast error.

In this context, RES-E has to find new solutions to increase its economic viability and reduce its risks of unavailability and imbalance generation. One solution is to allow RES to participate in other electricity markets as in the provision of ancillary services -voltage and frequency regulation- (the current Spanish Royal Decree 413/2014, Government of Spain 2014, allows the participation of RES plants-with power equal or higher 5MW- in voltage regulation). Another solution is to combine RES-E plants of different technologies (wind and solar) or with a dispatchable power plants (fueled-based technologies) under the concept of Virtual Power Plant (VPP). Virtual Power Plant is a flexible aggregation of a portfolio of distributed generation resources (DERs) that operate them as a unified unit similar to a transmission-connected generator on the energy markets. As VPP is a multi-technology generation entity, the aggregation of non-renewable DERs with renewable DERs (photovoltaic, small wind and combined heat and power plants) could reduce the imbalance costs and increase a reliable electricity supply compared to stand-alone renewable DERs units (Zapata et al 2014 evaluates the ability of a VPP to reduce the imbalance error of renewable generators). Despite the increasing research on VPP -many experts and researchers are currently working on simulation and modeling, the optimization of power quality, power management and stability control of generation units and systems (see Dietrich et al 2015 and Nosratabadi et al 2017 for a comprehensive review of existing research)- the analysis about the effect of the massive integration of electricity distributed generators under next electricity management systems is still scarce. In this context, this article studies the effect of the expansion of electricity generated from renewable sources- RES-E in a massive integration of electricity distributed generators under a next electricity management systems in Spain. In fact, small hydropower (plants with installed capacity of less than 10MW), photovoltaic or micro wind (plants with installed capacity of less than 100 kW) are the distributed generation resources considered in the present study. The input-output methodology is used to study the environmental and economic impacts by integrating the economic and technical relations observed in the production system. Input-output framework has been applied to the study of the electricity sector as a whole in Spain (Álcántara et al. 2010, Ramos and Moreno 2013, among others). Nevertheless, the electricity sector is composed of heterogeneous groups of energy technologies with very different technical characteristics. The multiplier effects analysis of electricity sector according to the production technologies are is still limited in the Spanish area (Cámara et al 2011, Ramos et al. 2013). Under IO scope, an impact analysis of the VPPs development is proposed in this work. The start-up of a set of generators involves a direct impact in aggregated demand associated to input contracting for construction and operation and then induced effects. The input-output model makes possible to detail trade-off between alternative technologies and their impacts on economic growth.

This paper is divided into four more sections. Firstly, disaggregation of Spanish electricity sector in Spanish input-output table is detailed; secondly a brief reference to the impact methodology is exposed. Finally, within a medium long-term market horizon, the obtained results provide useful information to virtual power plant to inform about the different impact of coalition of DERs. The main concluding remarks complete the paper.

2. DISAGGREGATION OF SPANISH ELECTRICITY SECTOR

The level of sector aggregation of an IO table is key in the evaluation of economic impact on the environment, especially if the environmentally sensitive sectors are aggregated. The Spanish input-output table includes the Electricity, gas, steam and air conditioning in a single sector. In the context of distributed generation under next electricity management systems, it is relevant disaggregated this sector. Several studies address the disaggregation of the electricity production sector (Lindner et al., 2013, Nakano et al. 2017, among others). Disaggregation entails the use of additional information sources. The data and estimation methods for disaggregate the Electricity, gas, steam and air conditioning sector of the most recent Spanish input-output table are detailed next. Although the newest Spanish input-output table is 2010, the latest supply, use tables published by national Statistics Institute (ine) correspond to 2013. As input-output table can be compiled by converting the supply and use tables (see details in methodology), the year of reference of the input-output table is 2013.

So, disaggregating rows and columns of the reference sector should be considered. Disaggregating rows are effected in separate stages. Electricity, gas, steam and air conditioning is first split into two separate sub-sectors, Production, transportation and distribution of electrical energy (CNAE35.1) and Production and distribution of gas, steam and air conditioning. (CNAE 35.2, 35.3). With this aim, the information about sales of products, sales of merchandise and provision of services supplied by Industrial Companies Survey (INE, 2014) is used as proxies. In a second step, Production, transport, distribution and commercialization of electric energy [1]are disaggregated according to Industrial Companies Survey micro-data about the same proxies. In the last stage, the production of electricity is divided in the following technologies:

- No renewable: That includes the electricity produced by pumped hydro, power stations based on gas, coal, oil and nuclear
- Renewables: That includes the electricity produced by micro (< 1MW) and small (1-10MW) no pumped hydro power stations, micro-wind (<100 kW) and photovoltaic. The electricity produced by the rest of renewable sources (wind >100 kW, no pumped hydro >10MW, biomass, municipal waste and geothermal).

To this end, gross electricity production is obtained from Eurostat database. However, there is no separation of the gross electricity production of wind and hydro according to the capacity of the plants, so micro-wind data and the shared of micro and small hydro in relation to the total of hydropower have been obtained from the Spanish Action Plan for Renewable Energy 2011-2020 (Spanish Government, 2011). In order to obtain the net electricity production, all the consumption of power stations' (10370 GWh) and the electricity consumed by pumped hydro (5960 GWh) reported by Spanish Government (2013) has been assigned to "no renewables" technologies. In order to obtain the Economic value of the net electricity production of "no renewable" technologies, the final average purchase price of energy in the electricity market has been used (Red Eléctrica Española, 2013). The average price for "other renewables" has been calculated as a weighting

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[1] In this work, Distribution and commercialization are not disaggregated for simplicity.

average of the prices of renewable technologies using as weight the electricity produced by each technology. It should be noticed that the price regulation system was phased out through Royal Decree 9/2013 of 12 July of 2013 (Spanish Government, 2013), so the average price for 2012 has been used.

Disaggregating columns is a similar process. Industrial Companies Survey (INE, 2014) data and microdata about net purchases of raw materials, net purchases of other supplies, net purchases of goods, purchases and works carried out by other companies are used as proxies for first separate electrical energy and gas, steam and air conditioning and, then split Production, transport, distribution and commercialization of electric energy. Finally, production of electricity is separated in the mentioned technologies under some assumptions: purchases between these technologies are null, self-consumption appears in the main diagonal and the rest of the elements follows a structure similar to production electric energy. The total installed capacity for PV is obtained from Spanish Government (2013), the hydro from REE (2013)- the shared of micro and small hydro in relation to the total have been obtained from the Spanish Action Plan for Renewable Energy 2011-2020 (Spanish Government, 2011), and the estimated micro wind from the same source.

3 METHODOLOGY

The distributed renewable energy sources (DRES) offer not only ground of environmental policies and energy security, but new employment and opportunities for decarbonization of the economies Eurelectric (2017). Using an input–output framework, some of the economic impacts of (DRES) can be estimated. Below the construction of symmetrical input-output table and the impact methodology are described.

3.1 Conversion of the supply and use tables to input-output table

The Symmetric input-output table is compiled by converting the supply and use tables by the Product Technology Assumption. The transformation is based on assumptions on the sales structure: it assumes that a commodity has the same input structure –productive factors as labor, capital- in any sector it is produced. Under this method, the construction of the input-output table from the supply and use tables was carried out in several steps using Product Technology Assumption.

3.2. Employment effects

One potential of the input-output model is an estimation of how changes in final demand are transmitted and distributed into the economy through sectoral interrelationships. Thus, an increase in final demand for a particular product generates economy-wide changes: augment in the output of that product (direct effect) and increase in the demand of suppliers and so on (indirect effect).
Thus, we can formally specify:

$$\Delta\mathbf{x} = \mathbf{K}\Delta\mathbf{y} \qquad (1)$$

where K represents multipliers, $\Delta\mathbf{y}$ is the change in final demand and $\Delta\mathbf{x}$ is the modification in the production. This model allows it to assess the needs of total employment due to a one-unit change in final demand. The employment multipliers may evaluate in advance the employment impacts of economic policies destined to promote it by means of demand final increments as for example government expenditures, consumption or investment in a sector.
Direct employment coefficients estimate the relation between contracted employment and the production in an activitity. In matrix terms:

$$\mathbf{l} = \hat{\mathbf{n}}x \qquad (2)$$

*w*here **l** is contracted employment vector, x is total output vector and $\hat{\mathbf{n}}$ is the diagonal matrix of direct employment coefficients. A lineal relation between contracted employment and final demand can be obtained:

$$\Delta\mathbf{l} = \hat{\mathbf{n}}\Delta\mathbf{x} \qquad (3)$$

and

$$\Delta\mathbf{l} = \hat{\mathbf{n}}K\Delta y \qquad (4)$$

where elements of matrix **K**, k_{ij}, are a measurement of created employment directly and indirectly in sector i when the final demand of sector j increase in a unit. The sum in j of the elements k_{ij} represent the total employment multiplier of a sector.

3. 3 CO2 emissions effects

Following Alcántara (1995), the total volume of emissions is calculated as:

$$E = \mathbf{c}'\mathbf{x} \tag{5}$$

where **c** is the vector of sectoral direct emissions, **x** (nx1) represents (nx1) vector of total productions and **‘** indicates the transposition of a vector. Then, the sectoral direct emissions underpinned by the energy consumption in the process of commodity production can be determined as:

$$\mathbf{e} = \hat{\mathbf{c}}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} \tag{6}$$

Where **A** is the (nxn) matrix of technical coefficients, **y** (nx1) vector of final demand and $\hat{c}$ is the diagonal matrix of sectoral direct emissions. The sectoral total emission (direct and indirect) generated by the final demand of sectors can be estimated as:

$$\boldsymbol{\varepsilon}' = \hat{\mathbf{c}}(\mathbf{I} - \mathbf{A})^{-1}\hat{\mathbf{y}} \tag{7}$$

4 ECONOMIC IMPACTS OF DISTRIBUTED RENEWABLE ENERGY SOURCES

Europe 2020 -EU’s growth strategy- includes ambitious targets for boosting renewable (RES-E) in final energy consumption. Thus, future trends of RES-E must be considered.. Determining the impact in the output, employment and emissions on account of renewable investment requires estimation and annualisation of investment planned for 2020 and data about employment. Below details about investment for the installed capacity and employment to 2020 are presented previously to the results of economic impacts.

4.1 Investment for the installed capacity to 2020

Spanish Energy Efficiency Action Plan 2011-2020 (Spanish Government, 2011) gives forecasts regarding the gross electricity generation for 2010 -2020 in Spain for reference scenario) and for the additional energy efficiency scenario. Moreover, it also gives the energy consumed by pumping (12082 GWh) and consumption during generation (8968 GWh).

Table 1. Gross and net electricity generation for 2020 in Spain. Additional energy efficiency scenario (GWh)

Electricity production (GWh)	**Brute**	**Net**
Total	383634	362223
Non Renewable	237193	216143
Micro Hydro <1MW (no pumped)	843	843
Small Hydro 1-10 MW (no pumped)	5749	5749
Micro wind (<100kW)	511	511
Photovoltaic	12357	12357
Other renewable	126620	126620

Moreover, the plan also gives the evolution of the installed capacity of different electricity technologies. Table 10 summarizes the evolution for micro (< 1MW) and small (1-10MW) no pumped hydro power stations, micro-wind (<100 kW) and photovoltaic.

Table 2. Evolution of the installed capacity of different electricity technologies (MW)

	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Micro wind							
New annual power	20	25	40	50	50	50	50
Accumulated power	35	60	100	150	200	250	300
Micro Hydro <1MW<1MW							
New annual power	2	2	3	3	3	3	3
Accumulated power	251	253	256	259	262	265	268
Small Hydro 1-10 MW 1-10MW							
New annual power	28	33	32	32	27	27	35
Accumulated power	1731	1764	1796	1828	1855	1882	1917
Photovoltaic							
New annual power	249	273	300	331	363	400	440
Accumulated power	5143	5416	5716	6047	6410	6810	7250

Source: Spanish Action Plan for Renewable Energy 2011-2020 (Spanish Government, 2011).

Hereafter, the investment in the installed capacity of 2020 is detailed. The annual investment cost has been calculated by averaring the floor and roof invest photovoltaic installations and taking into account the decreasing paths in those costs. The annual investment cost for hidraulic has been calculated by averaring the floor and roof invest photovoltaic installations and taking into account the decreasing paths in those costs of 1% from 2010 to 2015 and 2% from 2015 to 2020 (Spanish Action Plan for Renewable Energy 2011-2020 (Spanish Government, 2011- p. 322). The different investment cost in mini wind has been calculated by using the average ratios. Those ratios have been applied to the investment, according to the learning curve published by Spanish Energy Efficiency Action Plan 2011-2020 (Spanish Government, 2011 p. 248), that indicates that for plants $p\leq 10kW$, there will be a 7% annual reduction since 3500€/kW in 2011 and for plants $10kW<p\leq 10kW$ those cost will be reduced by 5% since 2700 €/Kw in 2011. To sum up, the estimated annual investments in the disaggregated technologies are:

Table 3. Annual estimated investments *(€ million)*

	Hydro <1MW	**Hydro 1-10MW**	**Micro wind**	**Photovoltaic**
2014	0,77	10,76	51,30	479,94
2015	0,77	12,66	60,22	484,58
2016	1,15	12,24	90,48	495,26
2017	1,14	12,19	106,23	508,37
2018	1,14	10,24	99,79	518,68
2019	1,13	10,19	93,74	531,73
2020	1,13	13,15	88,08	543,40

Source: Authors´estimation based on Spanish Action Plan for Renewable Energy 2011-2020 (Spanish Government, 2011).

4.2. Estimation of employment of renewables to 2020

The demand growth of every new power generation technologies entails the expansion of two expenditure items: operation and maintenance of installations and the likely construction and start-up of new installations to cope the demand. Assess and quantify the impact on employment of the renewable energy investment established in Europe 2020 strategy, involve identifying direct employment coefficients in 2013 and 2020. The employment of Electricity, gas, steam and air conditioning is split into Production, transportation and distribution of electrical energy and Production and into distribution of gas, steam and air conditioning using data of Industrial Companies Survey. The first is disaggregated in Production, transport, distribution and commercialization. Then electric energy production is also disaggregated in the employment of studied according to the electric energy production proxy. The statistical information in this last step is provided by Eurostat. The estimations of employment to 2020 are based on PANER predictions. The estimations of employment of disaggregated sectors to 2013 and 2020 are presented below.

Table 4. Estimation of employment (thousands of people)

Employment	**2013**	**2020**
Micro Hydro (<1MW)	0,080	0,089
Small Hydro (1-10MW)	0,618	0,639
Micro-wind	0,132	3,836
Photovoltaic	0,992	1,472
Other renewable	10,687	10,687
Non Renewable	16,582	16,582
Transport	1,576	1,576
Distribution and commercialization	16,614	16,614
Gas, steam and air conditioning	10,819	10,819

Source: Authors´estimation based on Industrial Companies Survey (INE), Energy Statistics-supply, transformation and consumption (Eurostat) and Spanish Action Plan for Renewable Energy 2011-2020 (Spanish Government, 2011).

4.2 Effects of distributed renewable energy sources

Under input-output framework, the direct and undirected effects of an increment in renewable investments are calculated. The next table presents the sectors with the greatest annual impact on the output due to an increase in the investments in the disaggregated renewable sources. Annual uplifts of output in relation to annual production are indicated in brackets. In order to isolate the effects of investments in the disaggregated renewable sources, the rest of the sectors have remained at the same level as 2013.

Table 5. Output impact due to investment (€ million)

	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Mining and quarrying	12.48 (1.53)	25.33 (1.53)	39.12 (1.53)	53.57 (1.53)	68.06 (1.53)	82.71 (1.53)	97.57 (1.53)
Chemicals and chemical products	9.49 (1.16)	19.25 (1.16)	29.72 (1.16)	40.70 (1.16)	51.71 (1.16)	62.85 (1.16)	74.14 (1.16)
Small Hydro	11.44 (1.40)	24.89 (1.50)	37.91 (1.48)	50.86 (1.45)	61.74 (1.39)	72.57 (1.34)	86.55 (1.36)
Small Wind	54.53 (6.68)	118.54 (7.16)	214.72 (8.40)	327.65 (9.36)	433.72 (9.75)	533.37 (9.87)	626.99 (9.84)
Photovoltaic	510.17 (62.53)	1025.27 (61.95)	1551.72 (60.72)	2092.11 (59.78)	2643.46 (59.45)	3208.68 (59.38)	3786.31 (59.40)
Electricity distribution and commercialization	62.91 (7.71)	127.60 (7.71)	197.04 (7.71)	269.82 (7.71)	342.81 (7.71)	416.62 (7.71)	491.46 (7.71)
Constructions and construction works	10.02 (1.23)	20.33 (1.23)	31.40 (1.23)	43.00 (1.23)	54.63 (1.23)	66.39 (1.23)	78.32 (1.23)
Wholesale trade services, except of motor vehicles and motorcycles	13.95 (1.71)	28.30 (1.71)	43.70 (1.71)	59.84 (1.71)	76.03 (1.71)	92.40 (1.71)	109.00 (1.71)
Telecommunications services	10.18 (1.25)	20.66 (1.25)	31.90 (1.25)	43.68 (1.25)	55.49 (1.25)	67.44 (1.25)	79.55 (1.25)
Security and investigation serv.; serv. to buildings and landscape; office support and other business support serv.	11.53 (1.41)	23.38 (1.41)	36.10 (1.41)	49.44 (1.41)	62.81 (1.41)	76.34 (1.41)	90.05 (1.41)

Source: Authors´estimation.

We observe that although the major impact of the investments in the disaggregated renewable sources occurs on their owns sectors, that investment also impact on other sectors as chemicals and chemical sector when producing materials such as silicon for photovoltaic modules, business support service sector when installing power generation facilities and distribution and commercialization electricity sector. Related to distribution sector, it should be noticed that the combination of new technology solutions (smart grids) help to better integrate renewable energy under distributed generation resources (DER), just like that photovoltaic, small or micro wind or combined heat and power (CHP) units.It is highlighted that small wind require significant initial investments in relation to their size and are less profitable than large turbine plants because all system components have decreasing costs in relation to their size (Valentine, 2011), so the same investment reached with medium and high size of wind plants would produce less effect of Spanish output. Bortolini et al (2015) presents a complete technical and economic analysis of small wind turbines extended to five of the major European Union (EU) countries including Spain. We would like to point out that the obtained results about the effect of disaggregated renewable sources on different sector depends of the available data about the disaggregated cost per activities involved in the investment (insurance, management, etc). In Spain, Ogayar et al (2009) developed different equations through which it is possible to approximate costs for the construction of new small hydroelectric plants according to several different activities; however, the information required for its calculation was not available for the present study. 6It should be noticed that distributed energy resources reduces transmission and distribution network investments needs which have been not taken into account in this study as only capacity investment has been considered. The impacts of renewable sources on employment are presented in the table 6. Sectors with the highest employment generation have been bringed to the attention.

Table 6. Expected increase in employment in 2020 (thousands of people)

Sector	**Total employment**
Micro-wind	46,883
Photovoltaic	0,848
Constructions and construction works	0,364
Wholesale trade services, except of motor vehicles and motorcycles	1,139
Land transport services and transport services via pipelines	0,573
Legal and accounting services; services of head offices; management consulting services	0,386
Security and investigation services; services to buildings and landscape; office administrative, office support and other business support services	1,762
Total economy	57,496

Source: Authors´estimation based on Industrial Companies Survey (INE), Energy Statistics-supply, transformation and consumption (Eurostat) and Spanish Action Plan for Renewable Energy 2011-2020 (Spanish Government, 2011).

Micro-wind is the sector which is expected to grow more in employment. In fact, PANER (Action Plan for Renewable Energy) expects a significant increase in production which leads to this increase of almost 47.000 individuals. A similar impact, albeit on a smaller scale, shall be found in photovoltaic sector. Business and management support services and wholesale trade services have also seen increase their number of employed persons in response to the upturn in economic activity generated by the construction of new plants. Additionally, it may be seen the increase o employment in a sector directly involved in the enlargement of plants as construction. Thus, the development of disaggregated renewable sources directly generates jobs in the own sector (at the operation and maintenance stage) but also indirectly induces jobs in other sectors as construction sector (at the investment stage) and other sectors. Distributed renewable energy resources create employment opportunities in the service sectors too. For example wind turbines generates several environmental impacts (see Zerrahn 2017 for a literature of wind power externalities) as a deterioration of the aesthetic quality of landscapes, so an study of the environmental impact of the installation of new plants are sometimes required in order to get the license for the installation.

This analysis is being expanded to integrate the possible emissions reductions with reference Europe 2020. Thus, cut of 20% in greenhouse gas emissions from 1990 levels and increase of renewable (RES-E) in final energy consumption to 20% and the improvement in energy efficiency in 20%. The analytical framework that accounts this impact is based on a hybrid model that combine magnitudes in physical units such as emissions and magnitudes quantified in monetary units, as the sectorial production. Data about emissions level has been obtained from Environmental accounts. Air Emission Accounts elaborated by INE. To share emissions of electricity energy sector, the production of energy sources has been multiplied by emission factor (IDEA). Then the previous methodology about asses CO2 emissions has been applied over a scenario based on Europe 2020. Then the increase of renewable (RES-E) in final energy consumption has been calculated uniformly: equally increase in disaggregated technologies. Subsequently, new emissions have been calculated as of input-output model and next reductions rates between 2013 and 2020 have been estimated. The main results are set out in table 7.

Table 7. Expected emissions reductions in 2020

Sector	**Emissions reductions** (%)
Mining and quarrying	0.67
Coke and refined petroleum products	0.31
No renewable	17.35
Gas, steam and air conditioning	1.20
Total economy	21.67

Source: Authors´estimation based on Environmental accounts. Air Emission Accounts (INE) and Spanish Action Plan for Renewable Energy 2011-2020 (Spanish Government, 2011).

The expected emissions reductions in the economy as a whole will be 21.67 %. The greatest reductions from its 2013 position are seen in activities like Mining and quarrying, Coke and refined petroleum products, Gas, steam and air conditioning and No renewables. Thus, the increment of the disaggregated renewable sources contributes to tones of CO2 avoidance annually. However, it would be possible that they could have negative effects on other environmental issues. For example related to small hydro, Valero (2012) provided a characterization of the water quality status in a river stretch around a small hydro plan sited in the northwest Spain, for four years after its construction and showed that the plant caused an adverse effect in the ecosystem and biological quality of the water during two years (Manzano-Agugliaro et al. 2017 summarized an overview of socials aspects and environmental issues, among others, of small hydropower and its research trends in Europe).

5 CONCLUSIONS

In 2020, renewable in final energy consumption should come onto 20% following the milestone of Europe 2020 and greenhouse gas emissions should reduce to 20% from 1990 levels. The progresses in the current achievement of Europe 2020 are uneven in Europe. The information relating to the latest data available by Eurostat indicates that Spain is still away from the goal. In 2015, the rate of renewable in final energy consumption is 16.15%.

In this framework, small decentralized generation technologies based on engines, wind turbines, fuel cells and photovoltaic (PV) systems and micro-generation technologies, among others can be key. Distributed generation is supposed to contribute to the security of supply and be able get falls of transmission and distribution peak load and in distribution grid losses. However, these technologies are mostly non-dispatchable, thus its own output cannot be controlled. Furthermore, their production has subject to stochastic regime: production does not always coincide with demand. In Spain, marked renewable imbalance has persisted. At present hydraulic and wind are the main renewable powers in Spain (they represent 13% and 20% and of the total gross electricity production respectively in 2013, EUROSTAT). In this context, the aggregation of distributed generation resources based on renewables could reduce the imbalance costs contributing to EU2020 engagement and increase a reliable electricity supply compared to stand-alone renewable DERs units. Moreover, the aggregation of DERs are able to participate in other electricity markets as in the provision of ancillary services -voltage and frequency regulation (Spanish Royal Decree 413/2014).

Economically, the investment in these technologies can originate relevant induced effects in the economy. For example, Micro- wind, Small Hydro and photovoltaic have large economic direct and indirect effects in the Spanish economy in term of output and employment, but the variability on renewable should be considered. The estimated co-benefits in terms of output and new jobs in the economy are relevant and help to the transformation to not only lower-carbon economy but a prosperous nation. For future, a 100% renewable energy system in Europe is technically possible (Connolly et al., 2016). Integrating the electricity sector with other parts of the energy system in a Smart Energy System will be one of the most efficient solutions for energy systems based on renewable (Markovska et al, 2016).

REFERENCE LIST

Abdmouleh, Z., Alammari, R. A., & Gastli, A. (2015). Review of policies encouraging renewable energy integration & best practices. *Renewable and Sustainable Energy Reviews*, *45*, 249-262.

Alcántara, V. (1995). Economía y contaminación atmosférica: hacia un nuevo enfoque desde el análisis input-output. Doctoral thesis, Universitat de Barcelona.

Alcántara, V., del Río, P., & Hernández, F. (2010). Structural analysis of electricity consumption by productive sectors. The Spanish case. *Energy*, *35*(5), 2088-2098.

Cámara Sánchez, Á., Flores García, M., & Fuentes Saguar, P. D. (2011). Análisis económico y medioambiental del sector eléctrico en España. *Estudios de Economía Aplicada*, *29*(2), 493-514.

Connolly, D. Lund, H. & Mathiesen, B.V. (2016).Smart Energy Europe: The technical and economic impact of one potential 100% renewable energy scenario for the European Union. *Renewable and Sustainable Energy Reviews*, 60, 1634–1653.

Del Río, P., & Mir-Artigues, P. (2014). Combinations of support instruments for renewable electricity in

Europe: a review. *Renewable and Sustainable Energy Reviews*, *40*, 287-295.

Dietrich, K., Latorre, J. M., Olmos, L., & Ramos, A. (2015). Modelling and assessing the impacts of self supply and market-revenue driven Virtual Power Plants. *Electric Power Systems Research*, *119*, 462-470.

Eurelectric (2017). A Brigth Future for Europe. The value of electricity in decarbonising the European Union. Brussels, Belgium.

European Commission (2010): Europe 2020 – A strategy for smart, sustainable and inclusive growth. Working paper {COM (2010) 2020}. European Commission, Brussels.

Haas, R., Resch, G., Panzer, C., Busch, S., Ragwitz, M., & Held, A. (2011). Efficiency and effectiveness of promotion systems for electricity generation from renewable energy sources–Lessons from EU countries. *Energy*, *36*(4), 2186-2193.

INE (2014). Industrial Companies Survey.

Institute for Diversification and Energy Saving (2006): Energía eólica, *Manuales de Energías Renovables* , Ministerio de Industria, Turismo y Comercio e Instituto para la Diversificación y Ahorro de la Energía, Madrid.

Institute for Diversification and Energy Saving and the Boston Consulting Group (2011): Evolución tecnológica y prospectiva de costes de las energías renovables. Estudio Técnico PER 2011-2020, Instituto para la Diversificación y Ahorro de la Energía, Madrid.

Lindner, S.; Legault, J. & Guan, D. (2013). Disaggregating the electricity sector of china's input–output table for improved environmental life-cycle assessment. *Economic Systems Research, 25*, 300-320.

Manzano-Agugliaro, F., Taher, M., Zapata-Sierra, A., Juaidi, A., & Montoya, F. G. (2017). An overview of research and energy evolution for small hydropower in Europe. *Renewable and Sustainable Energy Reviews*, *75*, 476-489.

Markovska, N.; Duic, N.; Mathiesen, B.V.; Guzovic, Z.; Piacentino, A.; Schlör, H.; Lund, H. (2016). Addressing themain challenges of energy security in the twenty-first century Contributions of the conferences on Sustainable Development of Energy, Water and Environment Systems. *Energy,* 115, 1504–1512.

Nakano, S., Arai, S. & Washizu, A. (2017). Economic impacts of Japan's renewable energy sector and the feed-in tariff system: using an input—output table to analyze a next-generation energy system. *Environmental Economics and Policy Studies*, 19(3), 555–580.

Nosratabadi, S. M., Hooshmand, R. A., & Gholipour, E. (2017). A comprehensive review on microgrid and virtual power plant concepts employed for distributed energy resources scheduling in power systems. *Renewable and Sustainable Energy Reviews*, *67*, 341-363.

Ogayar, B., Vidal, P. G., & Hernandez, J. C. (2009). Analysis of the cost for the refurbishment of small hydropower plants. *Renewable Energy*, *34*(11), 2501-2509.

Ramos-Carvajal, C., & Moreno-Cuartas, B. (2013). Characterization of Spanish economic sectors from an economic and environmental perspective: Evolution and forecast of greenhouse gas emissions. *Regional and Sectoral Economic Studies*, *13*(2), 117-134.

Spanish Goverment (2013): Real Decreto Ley 9/2013, de 12 de julio, por el que se adoptan medidas urgentes para garantizar la estabilidad financiera del sistema eléctrico. *Boletín Oficial del Estado (BOE)* núm. 167, de 13 de julio de 2013, páginas 52106 a 52147

Spanish Goverment (2014): Real Decreto 413/2014, de 6 de junio, por el que se regula la actividad de producción de energía eléctrica a partir de fuentes de energía renovables, cogeneración y residuos, *Boletín Oficial del Estado (BOE)*, núm. 140, de 10 de junio de 2014, 43876- 43978.

Spanish government (2011): Spanish *Action Plan* for *Renewable Energy 2011-2020* IDAE. Ministry of Industry, Tourism and Commerce

Spanish Government (2013): La Energía en España 2013, Ministry of Industry, Energy and Tourism, Madrid.

Valentine, S. V. (2011). Understanding the variability of wind power costs. *Renewable and Sustainable Energy Reviews*, *15*(8), 3632-3639.

Valero, E. (2012). Characterization of the water quality status on a stretch of River Lérez around a small hydroelectric power station. *Water*, *4*(4), 815-834.

Zapata, J., Vandewalle, J., & D'haeseleer, W. (2014). A comparative study of imbalance reduction strategies for virtual power plant operation. *Applied Thermal Engineering*, *71*(2), 847-857.

Zerrahn, A. (2017). Wind Power and Externalities. *Ecological Economics*, in press.