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 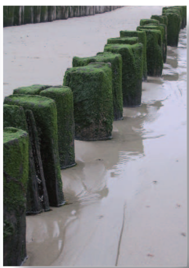   

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Assessment of regional economic impacts of an offshore wind project: a French case study [1]

Sondès Kahouli [2]
Jean-Christophe Martin [3]

Abstract

In France, within the framework of "Grenelle de la mer", it is expected that 6 GW of offshore wind will be installed by 2020. In July 2011, the first call for tender was launched by the French government for installing 3 GW in 5 areas, *i.e.* Dieppe-Le Tréport (Seine-Maritime, 750 MW), Fécamp (Seine-Maritime, 500 MW), Courseulles-sur-mer (Calvados, 500 MW), Saint-Nazaire (Loire-Atlantique, 750 MW) and Saint-Brieuc (Côtes d'Armor, 500 MW).

In this paper, we propose a regional input-output model to assess gross economic impacts of the project of Saint-Brieuc on the region of Brittany. We refer to the production, value-added and number of Full-Time Equivalent (FTE) jobs to measure the magnitude of expected regional economic impacts. We distinguish direct, indirect and induced impacts. Direct impacts take place inside companies immediately involved in the project during the development, construction, installation, and operation and maintenance phases. Indirect impacts represent changes in inter-industry purchases as they respond to the new demand induced by upstream offshore wind activities. Induced impacts measure the growth in economic activity due to the increase in income of employees/households.

Results show that the project positively impacts the Brittany's economy. Indeed, during the investment phase €0.88 M year/MW and €0.38 M year/MW of respectively production and value-added are created associated with 6.03 FTE jobs year/MW. During the O&M phase, €0.32 M year/MW and €0.15 M year/MW of production and value-added are expected in addition to 1.02 FTE jobs year/MW. Comparative analysis shows that although some results variability, our estimations are corroborated by a number of studies. In particular, it points out the fact that the magnitude of economic impacts, mainly employment impact, is depending on the share of regional investment with respect to the supply chain roles.

Discussion and policy recommendations highlight the need to review economic, technological, regulatory and social frameworks within which the offshore wind industry currently evolves in France to establish conditions for its reliable development.

Keywords

Offshore wind, Economic impacts, Regional input-output model, Saint-Brieuc (France).

JEL classification

Q_{42}; Q_{43}; D_{57}; R_{15}

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1 Introduction

Currently, economic systems are based mainly on intensive use of conventional energy sources. Because of recurrent debates about fossil fuels scarcity, climate change and energy independence, international community has agreed that such situation is no longer sustainable and that shifting to economic systems based on environmentally friendly energy sources is a pressing challenge. In this context, the European Union (EU) was committed in 2008 under the so-called climate and energy package to reduce for 2020 by 20% its greenhouse gas emissions with respect to its levels of 1990, to improve by 20% its energy efficiency and to rise to 20% the share of renewable energies in total energy consumption. To reinforce its orientation, the EU has proposed in the beginning of 2014 the 2030 policy framework for climate and energy which support and extend the climate and energy package. In particular, for 2030, it aims at reducing domestic greenhouse gas emissions by 40% below the level of 1990, improving by 30% the energy efficiency and increasing to at least 27% the share of renewable energy in total energy consumption [4].

To increase the part of renewable energies in the total energy consumption as defined by the EU, the French government has decided in 2008 under the program Grenelle de l'environnement to rise the share of renewable energies in total energy consumption to 23% by 2020 (MEEDM, 2010) [5] (*Cf.* graphic 1(a)). In particular, it has decided within the framework of Grenelle de la mer to call for the development of 6 GW marine renewable energies [6] by 2020, including mainly the offshore wind [7] (*Cf.* graphic 1(b)).

In July 2011, the first call for tender was launched by the French government for installing 3 GW of offshore wind in 5 areas located at Dieppe-Le Tréport (Seine-Maritime, 750 MW), Fécamp (Seine-Maritime, 500 MW), Courseulles-sur-mer (Calvados, 500 MW), Saint-Nazaire (Loire-Atlantique, 750 MW) and Saint-Brieuc (Côtes d'Armor, 500 MW) (*Cf.* graphic 2(a)). Only the project of Dieppe-Le Tréport (Seine-Maritime, 750 MW) were not retained [8]. In July 2013, the second call for installing an additional 1 GW of offshore wind in Dieppe-Le Tréport (Seine-Maritime, 500 MW) and Noirmoutier (Vendée,

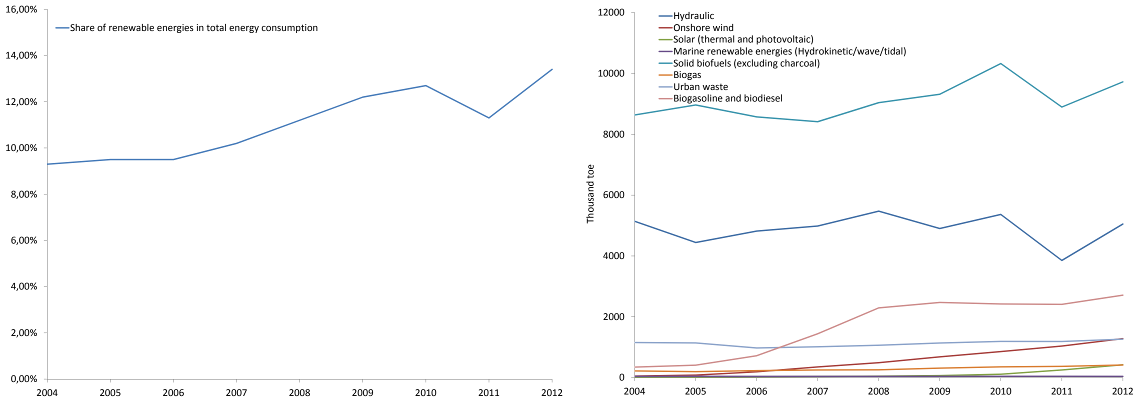
4. The EU precise that this European objective will not be declined to national objectives. Indeed, the EU aims at giving the 28 member states flexibility to transform their energy systems in a way which takes into account specificities of national contexts.

5. Currently this share is equal to 13.4%. It was equal to 9.3% in 2004 (Eurostat, 2014a).

6. France has potential maritime frontage. It accounts 3500 km of coastline, 4 maritime frontages and the second wind deposit in Europe.

7. Except in some few countries like United Kingdom (UK), Denmark, and Belgium the development of offshore wind is still very limited despite potential possible spillover effects from the onshore wind (Lindman and Söderholm (2012), Jeffrey et al. (2012), Sun et al. (2012), Allan et al. (2008, 2011a, 2011b, 2011c)) (*Cf.* Appendix A). Indeed, the technology is still suffering from a heavy lack of competitiveness and low degree of social acceptability because of its plausible social and environmental negative impacts (Fox et al. (2006), Huppop et al. (2006), Desholm et al. (2006)).

8. Winers of the call for tender are Éolien Maritime France (EMF) for projects of Fécamp (Seine-Maritime, 498 MW), Courseulles-sur-mer (Calvados, 450 MW), Saint-Nazaire (Loire-Atlantique, 480 MW) and Ailes Marines S.A.S for the project of Saint-Brieuc (Côtes d'Armor, 500 MW). EMF, whose main shareholders are EDF Energies Nouvelles and Dong Energy Power (Danish energy company), proposes wind turbines supplied by Alstom. As for Ailes Marines SAS, whose main shareholders are Iberdrola and Eole-Res SA, it offers wind turbines supplied by Areva. It also proposes a partnership with Technip and STX (MEDDE, 2014).

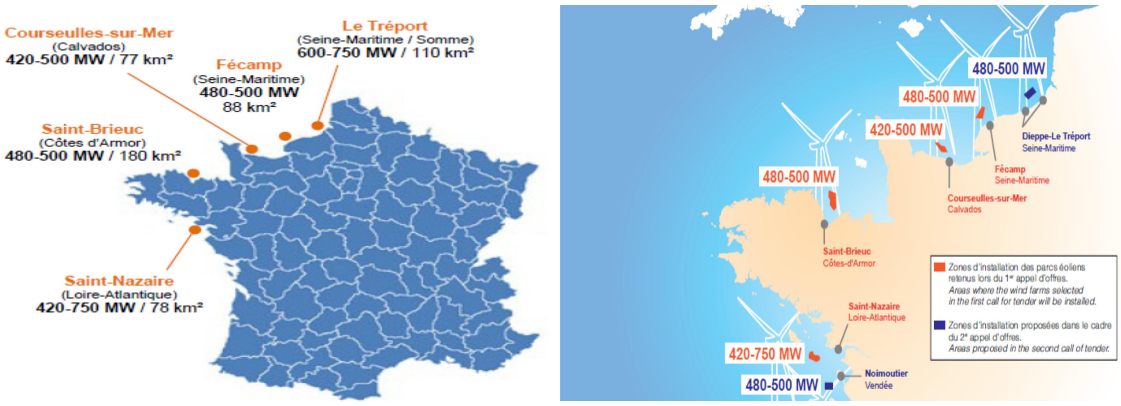


(a) (b)

Figure 1. (a) Share of renewable energies in total energy consumption in France (%), (b) Renewable energies mix in France (thousand toe)

500 MW) was annouced (*Cf.* graphic 2(b)) [9].

Although we were impeded by the lack of data because of the absence of regional



(a) (b)

Figure 2. (a) Geographical location of the 5 areas devoted to host offshore wind farms according to the first French call for tender, (b) Retained 4 areas for hosting offshore wind farms after the first call for tender (in orange) and the proposed 2 areas in the second call for tender (in blue).

accounting in France, we propose in this paper a regional Input-Output Model (I-OM) to assess gross economic impacts of the project of Saint-Brieuc on the region of Brittany [10]. We refer to the production, gross value-added and FTE jobs to measure the magnitude of expected regional economic impacts. We distinguish direct, indirect, and induced impacts. Direct impacts take place inside companies immediately involved in the project during the development, construction, installation, and operation and maintenance (O&M) phases. Indirect impacts represent changes in inter-industry purchases as they respond to the new demand induced by upstream offshore wind activities. Induced impacts measure the growth in economic activity due to an increase in income, therefore, consumption spending, of employees/households. We calculate expected economic impacts for the two phases of the

9. The winner of the second call for tender is GDF Suez in collaboration with Areva, Neoen Marine, and EDP Renouvelable.

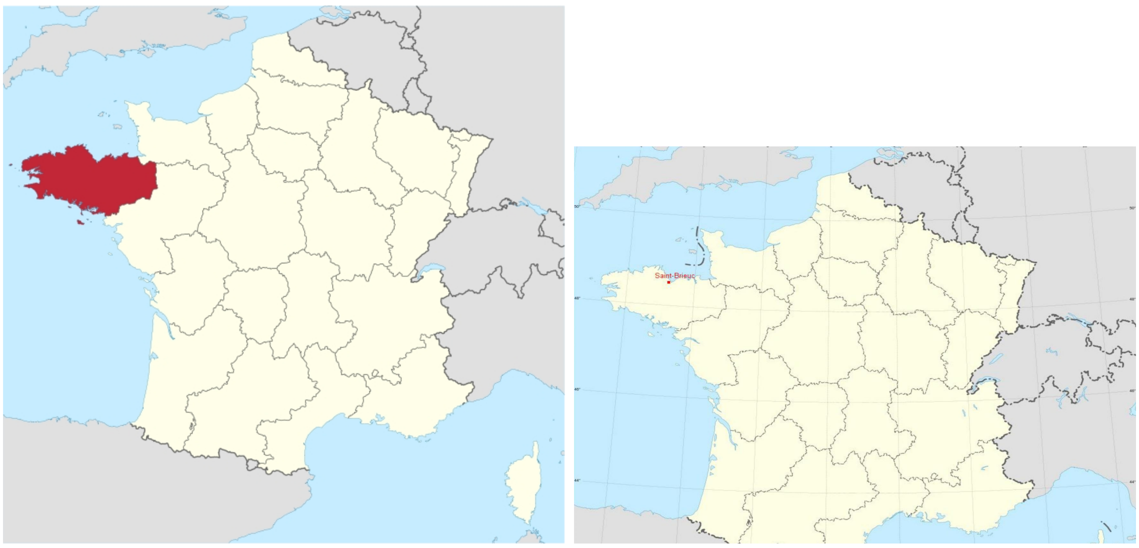
10. The difference between gross and net impacts is explained in paragraph 3.1.1.

project namely the investment, *i.e.* construction and installation, and the O&M. After discussing results within the framework of a detailed comparative analysis, we propose some policy recommendations.

The paper is structured as follows. In section 2, we present the context of the study. In particular, we describe the energy context of the region of Brittany by focusing on the electricity sector. We also present the project of offshore wind of Saint-Brieuc and its expected regional economic impacts. In section 3, we highlight the relevance of using an I-OM for impacts assessment and we present the methodology in a regional framework. In section 4, we explain how we generate results. In section 5, based on a thorough comparative analysis, we discuss results and give some policy implications. Finally, we conclude in section 6.

2 Context of the study

Brittany is a peninsular region located in the north-west part of France (*Cf.* graphics 3(a)). It hosts 5% of the French population. Between 2000 and 2008, it accounted for an average of 5% of national employment and 4% of the annual French GDP (INSEE, 2014). Its economy is mostly oriented towards service activities which represent 67% regional employment. The agriculture and industry sectors account respectively for 8% and 25% of regional employment. Currently, sectors like food, automobile, and shipbuilding face



(a) (b)

Figure 3. (a) Geographical location of the region of Brittany ("*Bretagne*") in France, (b) Geographical location of Saint-Brieuc in Brittany

considerable challenges and need to undergo a process of reorganization. For instance, despite being one of the region's longstanding economic sector, naval activities have sharply decreased over previous years. Otherwise, energy sector has a very limited economic weight and Brittany is electricity importing. This situation justifies the importance of the offshore wind project of Saint-Brieuc, a small town located in the region (*Cf.* graphic 3(b)), both in terms of supporting self satisfaction of electricity demand and of creating the opportunity for a new regional economic dynamism. According to Iberdrola and Eole-Res (2012b), it is expected that under this project the installed capacity of 500 MW ensures about 7% of total electricity consumption of Brittany and induces significant positive economic impacts mainly in terms of job creation.

In the following, we start in subsection 2.1 by presenting main features of the energy sector in Brittany. Then, in subsection 2.2, we present the project of offshore wind of Saint-Brieuc and discuss its expected economic impacts.

2.1 Energy sector in Brittany [11]

Below, we start by giving in paragraph 2.1.1 a general presentation of the energy sector in Brittany. Then, in paragraph 2.1.2, we present an overview of the electricity production in the region.

2.1.1 General presentation of the energy sector

The energy industry in Brittany is undeveloped. Indeed, in 2012 for example, the region has imported 91.1% of its energy consumption, representing 4.8% of national consumption despite it has increased its energy production by 47% in 2012 compared to 2000 (*Cf.* graphic 4).

We distinguish the production of primary and secondary energies. In 2012, while the

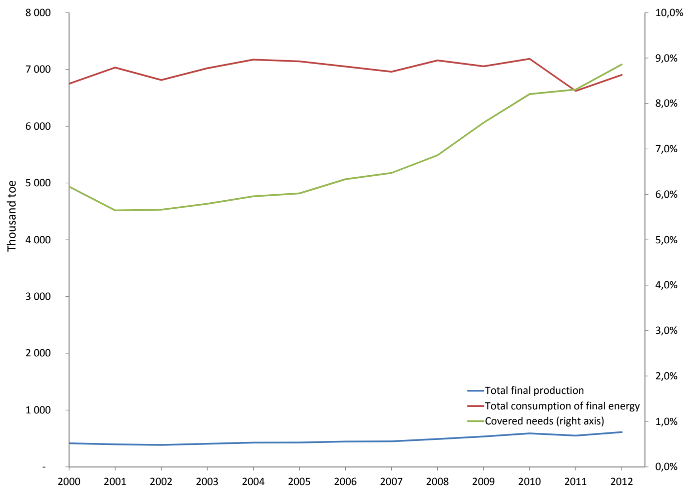


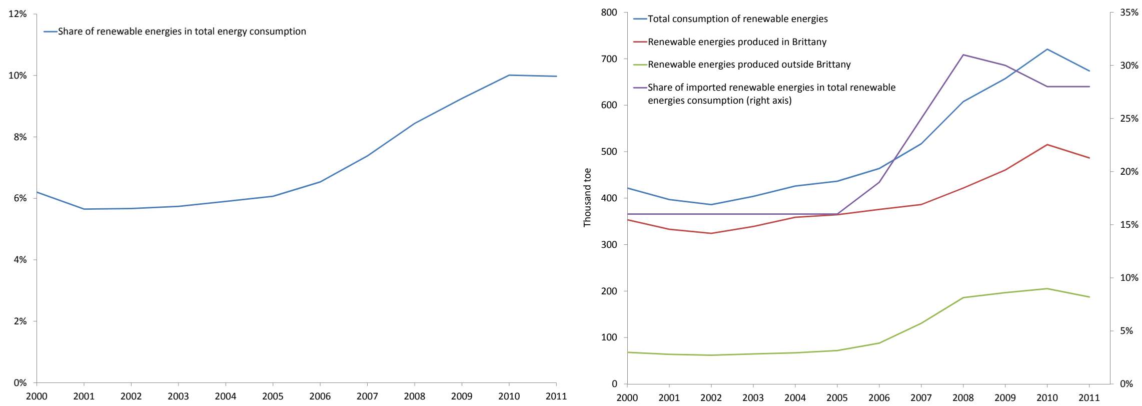
Figure 4. Total final production of energy in Brittany (thousand toe), Total consumption of final energy in Brittany (thousand toe), and covered needs (%)

production of the primary energy attains 88% of the total energy production of Brittany, the production of secondary energy represents only 12%. Three towns contribute each by more than 10% to the total regional energy production namely Rennes, Saint-Malo and Brest. This production mainly comes from renewable resources such as onshore wind (56%), hydraulic (20%), and photovoltaic (6%) (RTE, 2013). In 2012 for example, about 91% of primary energy production and 29% of secondary one was coming from renewable

11. Statistics cited in this section are extracted from the Observatoire Régional de l'Énergie et des Gaz à Effet de Serre en Bretagne (OREGES) (2011, 2012, 2013). When statistics are extracted from other sources references are cited inside the text.

resources. More generally, from 2000 to 2012 the production of renewable energies has increased by about 38% in Brittany.

By the same, since 2001 the consumption of renewable energies has also steadily increased according to an average annual growth rate equal to 0.5%. In particular, in 2012 10% of energy consumed in Brittany was produced from renewable sources. Nevertheless, although potential efforts to enhance their local consumption, renewable energies are still representing only 7.25% of total final energy consumption for the period going from 2000 to 2011 (*Cf.* graphic 5(a)). Such rate is well below the average rate of national consumption of renewable energies equalling 14%. A part of consumed renewable energies is usually imported from other regions of France (*Cf.* graphic 5(b)). For example, in 2012 71% of consumed renewable energies in Brittany was produced locally but the remaining 29% was imported mainly to meet electricity demand.



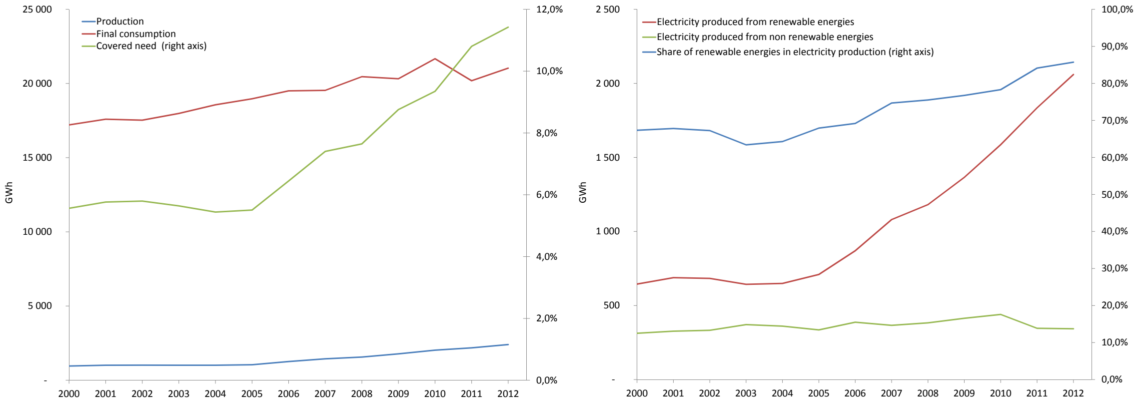
(a) (b)

Figure 5. (a) Share of renewable energies in total energy consumption in Brittany (%), (b) Total consumption of renewable energies in Brittany and their origins (toe)

2.1.2 Brief overview of the electricity production

Since 2003, the electricity consumption of Brittany is growing three times than national level because of demographic growth [12], important households demand (compared to the professionals demand), and increasing use of electric heating (RTE, 2013). For the period going from 2000 to 2012, while the consumption has increased by about 11.9% at the national scale, it has risen by 22.21% in Brittany (Eurostat, 2014a). At the same time, electricity production of Brittany has increased by 134% (*Cf.* graphic 6(a)). This production of electricity mainly comes from renewable energies. Indeed, while in 2012 in France the share of renewable resources in the production of electricity do not go beyond 20.7%, about 85.7% of the electricity produced in Brittany was generated from renewable sources (RTE, 2013) (*Cf.* graphic 6(b)). The two first sources of electricity generation are onshore wind and the tidal power plant of La Rance. In 2012, they ensured respectively 54% and 21% of total electricity production. Despite a slight slowdown, the development of the onshore wind farm continues in Brittany. By the end of 2013, the total installed

12. The population of Brittany increases on average by 25000 habitants per year (INSEE (2013).



(a) (b)

Figure 6. (a) Production of electricity (GWh), Consumption of electricity (GWh), and covered need (%) (b) Electricity produced from renewable energies in Brittany (GWh), Electricity produced from non renewable energies in Brittany (GWh), Share of renewable energies in electricity production in Brittany (%)

capacity stands at 782 MW, showing a progress of approximately 5% compared to 2012. A a consequence, the region is situated in the third place at the national scale in terms of installed capacity. It also continue developing other renewable energies like for example photovoltaic. With 143 MW, Brittany is situated at the eleventh position at the national scale in terms of total installed capacity. More generally, as of the beginning of 2000, electricity production coming from renewable sources in Brittany continues growing (*Cf.* graphic 7). It has increased by 12.4% in 2013 compared to 2012 (excluding hydro) (RTE, 2013).

However, in 2012 local electricity production is covering only 11.4% of the need of the

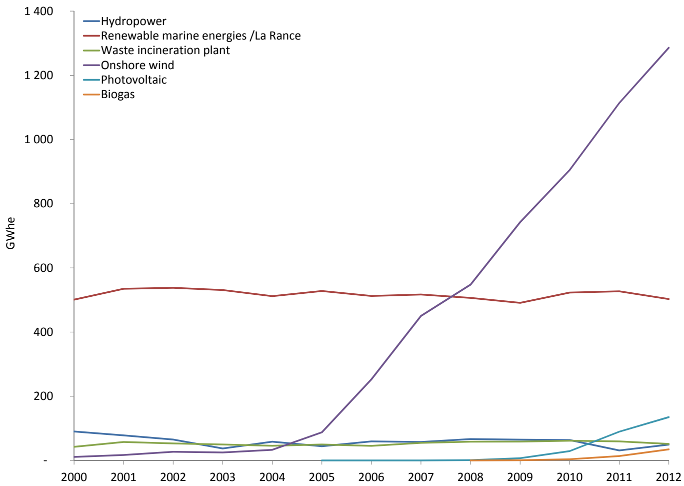


Figure 7. Renewable energies mix devoted to electricity production in Brittany (GWhe)

region which is therefore characterized by a deficient electricity supply-demand balance with a plausible situation of supply interruption in periods of peak of demand most plausibly during the winter. Brittany imports its electricity need from regions located some distance away. In particular, it imports 30% from Cordemais thermal power station (region of Loire-Atlantique) and 70% from Flamanville (region of Basse-Normandie) and Chinon (region of Centre) nuclear power Plants.

Under this context of important electricity importation associated with network weakness, the electricity network transmission RTE continues its short as well as long run investments dealing with, both, the demand and the supply sides and aiming at improving the situation[13]. In other hand, the project of offshore wind of Saint-Brieuc, which go in the same line with the national target of increasing the share of renewable energies in the total final energy consumption, is expected to rise local electricity production from renewables resources and reduce as consequence the electricity dependance of Brittany. It is also expected to generate potential regional economic impacts mainly in terms of employment.

2.2 Presentation of the project and its expected economic impacts

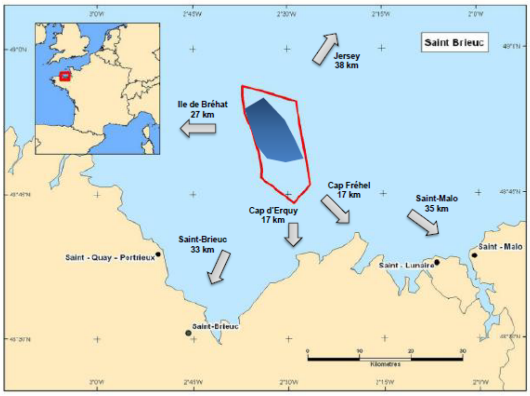
The offshore wind project of Saint-Brieuc (*Cf.* graphics 8(a) and 8(b)) is jointly conducted by Iberdrola and Eole-Res SA which respectively hold 70% and 30% of the project (together, Iberdrola and Eole-Res SA represent Ailes Marines SAS consortium). This cooperation includes the development, construction, and exploitation of the farm. According to Iberdrola and Eole-Res (2012a) and Arfi et al. (2013), the project will be performed in partnership with Neoen Marine for the development stage, Areva for turbines construction and procurement, Technip for engineering and offshore installation, RTE for network connection, and Nass & Wind for the identification and the development of manufacturing sites. Under the project of Saint-Brieuc, it was already expected to install 100 turbines of 5 MW and 175 meters of high under 8 rows on a total area of about 80 Km^2 to attain 500 MW of total installed capacity. In July 2014, Ailes Marines SAS announces that it has decided to install rather 62 turbines of 8 MW and 215 meters of high to reach a total capacity of 496 MW. The compagny explains that increasing the capacity generation of turbines permits to attain a productivity gain equal to 7% without increasing the total cost of the project initially estimated to amount €2 B broken on several items of expenditures[14] (Iberdrola and Eole-Res (2012b), Ailes Marines SAS (2014a)) (*Cf.* table 1). Moreover, Ailes Marines SAS estimates that such a gain will permit to gratify annual electricity consumption, heating included, of 840000 habitants rather than 790000 as initially estimated[15] (Ouest France, 2014).

According to Ailes Marines SAS (2013a) and Ailes Marines SAS (2014b), the project need 7 years, going from 2013 to 2020, to be completed. More precisely, from 2013 to 2015 the development will be achieved. It focuses on analyzing technical and environmental characteristics of the project as well as on performing impacts studies. From 2016 to 2020, construction and installation will be accomplished. In particular, from 2016 to 2018 main components of the farm, *i.e.* foundations, electric sub-station, and turbines, will be manufactured and 20% of the scheduled total capacity will be installed. From the beginning of 2019 to 2020, the remaining total capacity will be installed, *i.e.* 50% in 2019 and 100% in

13. In 2013, investments devoted to network development, population connecting, and renewal of existing network amounted €42 M in Brittany. In 2014,they were estimated to equal €39 M.

14. This amount does not take into account the cost of electric network connecting. The project is entirely financed by the private sector and does not beneficiate from public subsidies.

15. According to the INSEE (2013), the population of Brittany equals 3250000 habitants in January 2012.



(a)

(b)

Figure 8. Geographical location of the project of offshore wind of Saint-Brieuc

Table 1 – Cost split of the offshore wind project of Saint-Brieuc (%) (Ailes Marines SAS, 2014a)

Task	Share in total cost (%)
Turbines system	47%
Foundations	37%
Inter-turbines cable	5%
Offshore electric sub-station	4%
Studies and consulting	5%
Other	2%
Total	100%

2020. It is expected that the farm will be entirely operational by the end of 2020. It will be exploited for 20 years from 2020 to 2040 before being dismantled after that [16].

Generally speaking, it is expected that the project will enhance the development of offshore wind industry in France [17] and that this will particularly positively impact the economy of Brittany. Indeed, in addition to the potential implication of AREVA in the construction of wind turbines, several companies located mainly in the Grand-Ouest français [18] will also participate to the fabrication of 3600 turbine components (Ailes Marines SAS, 2014d). In this context, a directory of companies that could participate to the project of Saint Brieuc was prepared by Bretagne Pôle Naval under which 71 companies were identified (BPN (2011, 2012)) [19].

On the other hand, it is expected that two ports will be fitted out in Brittany. For

16. For details about the schedule of the project, interested readers can look at Ailes Marines SAS (2014b). Otherwise, some technical characteristics of the project, based on Iberdrola and Eole-Res (2012a), Iberdrola and Eole-Res (2012b) and AREVA (2012), are presented in table B.1 of the Appendix B.

17. Although that currently an offshore industry clearly identifying supply chain roles does not exist in France, some components can be locally manufactured. This permits not only to avoid high transportation costs but also to take into account some local features essential to make the technology suitable for the French context (CCICA, 2011).

18. The Grand-Ouest français is a geographical reference usually used in France to describe the North-West. Although not clearly defined and not corresponding to any administrative entity, the Grand-Ouest français includes Brittany, Normandy (Normandie) and Pays de la Loire. Sometimes, regions of Poitou-Charentes and Haute-Normadie as well as departments (départements) of Indre-et-Loire and Loir-et-Cher (both belonging to the region of Centre) are also included in the Grand-Ouest français (*Cf.* Appendix D).

19. BPN (2012) gives the list of these compagnies.

manufacturing the electric substation and jacket foundations, Ailes Marines SAS has decided to install factories in the port of Brest in the Finistère because it represents the only port in Brittany suitable for such operations. Indeed, in addition to be easily accessible from the sea, the land and the rail, it has an important available storage capacity (CCICA, 2011). A total investment of about €160 M to €170 M has been schedelud to develop and prepare the port of Brest for hosting offshore wind activities inherent to both farms of Saint Brieuc and Saint Nazaire (BPN, 2013).

As for maintenance activities, a second port will be managed in Les Côtes d'Armor near to the offshore farm of Saint Brieuc to reduce transportation costs and plausible delays. Ports of Erquy, Saint-Cast-le-Guildo and Saint-Quay-Portrieux was considered to be suitable (CCICA (2011), Arfi et al. (2013), CG Côtes d'Armor (2014)). For the selection process, four criteria defined by Ailes Marines SAS have been determinant namely the distance from the offshore wind farm (less than one hour), land and maritime accessibility (7days/7days, 24h/24h), and port facilities (docks, medians, offices and car parking) (BPN, 2013). After a competition process [20], the port of Saint-Quay-Portrieux has been selected by the end of 2013 to host maintenance activities [21].

Otherwise, it is also expected that the development of the project of Saint-Brieuc will engender positive impacts on some economic activities which are not directly related to the offshore wind sector. For instance, during the construction phase, the project could enhance hotels and restaurants activities particularly if an onshore base is considered for the construction stage (MEDDE, 2012b). Similarly, during the O&M phase, tourism could be stimulated especially as the region already has potential attractive features (CCICA, 2011).

We aim to quantify the magnitude of these regional expected economic impacts. We distinguish primary and secondary impacts. Primary impacts represent the sum of direct and indirect impacts and secondary impacts refer to induced impacts (Madlener and Koller, 2007). More precisely :

— *Direct impacts*:
They take place inside industries immediately involved in the project during the investment and O&M phases [22].

— *Indirect impacts*:
They represent changes in inter-industry purchases as they respond to the new demand induced by upstream offshore wind activities. In other words, indirect impacts represent changes affecting different industries of the economy providing directly and indirectly industries directly involved in the project.

20. Interested readers can look at Erquy (2012), Saint-Cast-le-Guildo (2012) and Saint-Quay-Portrieux (2012) for more details about the competition process.

21. CCICA (2011) presents several rounds of discussion dealing with the choice of ports devoted to construction, assembly and maintenance activities.

22. Several industries are directly involved in the project depending on which phase is considered (*Cf.* subsection 4.2. We note nonetheless that the main difficulties in calculating direct impacts is the ventilation of costs/expenditures inherent to the project among involved industries.

— *Induced impacts*:
They typically measure the growth in economic activity due to the increase in incomes, therefore, consumption spending of employees/households. The increase affecting households incomes is engendered by the production rise induced by the project.

We propose to calculate direct, indirect, and induced gross impacts during the investment and O&M phases.

3 Presentation of the methodology

This section aims at presenting the methodology that we use to estimate economic impacts of the project of offshore wind of Saint Brieuc. In particular, in subsection 3.1, after presenting a review of literature dealing with methodologies used for assessing economic impacts of renewable energy technologies, we summarize by giving arguments supporting the relevance of using an I-OM in our case. In subsection 3.2, we present some technical methodological aspects dealing with the calculation of economic impacts of the project of Saint Brieuc. Finally, in subsection 3.3, we explain how we proceed to make the French national I-OM suitable for a regional scale application.

3.1 Literature review [23]

Table 2 gives non technical literature review dealing with the assessment of economic impacts, mainly in terms of job creation, induced by the development of renewable energy technologies. It shows that two methodologies are generally used. The first is based on macroeconomic modeling exercises using I-O, Calculable General Equilibrium (CGE), and Macro-Econometric (M-E) models. In some few cases econometric regressions are also used. The second methodology, refereed to as the analytical methodology, is based on surveys and other written information, *i.e.* data collection based on interviews, company annual reports, official tax-related enterprise registers, and government statistics ((EWEA, 2009a), Sastresa et al. (2010), Lambert and Silva (2012)).

3.1.1 Macroeconomic modeling methodology

According to Table 2, I-O is the most widely used methodology, sometimes in combination with other methodologies, to assess economic impacts of renewable energy technologies.

The I-OM represents a demand-driven model. By using linear equations, it determines impacts on production and employment of an initial change in the final demand (Miller and Blair, 2009). One of its advantage is that economic activities are highly disaggregated. This implies that characteristics of production processes of different sectors of the

23. We do not intend to give an exhaustive description of advantages and drawbacks of methodologies presented in paragraphs 3.1.1 and 3.1.2.This go beyond the scope of this paper. We only aim to point out some models features which justify the use of I-OM in our case.

economy are well incorporated in the matrix of technical coefficients which indicates the value of inputs required to produce one monetary unit of production. As a consequence, by translating the impacts of renewable energy projects into final demand change, the I-OM permits to determine impacts of one project on the production and employment. In particular, by focusing on interindustrial trade, it permits to distinguish direct, indirect and induced impacts [24] (Madlener and Koller (2007), Lambert and Silva (2012), (Slattery et al., 2011)). Another advantage of the I-OM is that it is less data intensive compared to CGE and M-E models [25].

Nevertheless, in addition to not allowing for incorporating effects of innovations and consequences of changes in relative prices of inputs, Madlener and Koller (2007), Slattery et al. (2011) and Brown et al. (2012)) explain that the drawback of the static I-OM is that it does not enable to calculate net effects measuring impacts created by the project after integrating displacement effects, inherent to the investment in renewable energy rather than in conventional fossil fuel, as well as opportunity costs induced by taxes and subsidies devoted to the renewable energy projects but that can be invested in projects having greater economic impacts.

CGE and M-E models permit to overcome some drawbacks of the I-OM. In particular, they enable to incorporate real-world complexities that would render the analytical approach, therefore, impacts analysis more reliable. Indeed, within the framework of comprehensive representation of price and income interactions based on microeconomic theory, CGE models combine data from I-O tables (I-OT) [26] with assumptions about market structure and elasticities to describe the reaction of supply and demand to price changes.They also mainly enable to take into account displacement effects and opportunity costs tradeoff. Nevertheless, in addition to be data intensive, the most frequently mentioned limitation of CGE models is their lack of empirical validation (Borges, 1986). Indeed, although some exceptions, parameters of CGE models are always calibrated rather than econometrically estimated.

As a consequence, when rooted in the economic theory, the use of econometric models seems to be more suitable for practical policy decisions (Zhang and Folmer, 1998). In this context, within the framework of neo-keynesian model, Blazejczak et al. (2014) analyze the economy adjustment after an external shock induced by the expansion of renewable energy technologies where variables/equations describing the behaviour of economic agents are econometrically estimated. By the same, when studying economic impacts of renewable energy in Germany, (Lehr et al., 2012) use an economy-energy-environment model where all parameters are estimated econometrically. Econometric estimation permits therefore to go beyond linear equations used in I-OM. and to give a better description of interaction between variables. Moreover, by incorporating several counterbalancing mechanisms, M-E as well as CGE models can calculate both gross and net impacts. Nonetheless, like CGE models, despite their theoretical background, M-E models are very intensive data and usually hard to rely on for regional studies.

24. *Cf.* subsection 2.2 for impacts definition.
25. Generally, it is annually constructed by national statistical institutes (Eurostat, 2008).
26. An Input-Output Table (I-OT) represents the database for an I-OM.

Alternatively, a limited number of studies make use of econometric regressions to study regional economic impacts of renewable energy technologies. For instance, Brown et al. (2012) conduct an ex post econometric analysis of the county-level economic development impacts of wind power installations from 2000 through 2008 in the US. Although such methodology can be informative mainly within regional framework, usually the unavailability of empirical data do not permit to rely on. In particular, in a country like France where there is currently no operating offshore wind farm, necessary data for conducting an ex post analysis do not exist and it is consequently only possible to perform prospective studies.

3.1.2 Analytical methodology

According to table 2, analytical methodologies are largely used for conducting impacts studies mainly in terms of job creation. They are usually reliant on extensive surveys (Blanco and Rodrigues (2009), Sastresa et al. (2010)). However, they can also be based on other written information coming from data collected from interviews and documents like company annual reports and government statistics (EWEA, 2009a). Weisberg et al. (1996) and Schuman and Stanley (1996) detail advantages and drawbacks of analytical methods, in particular, social surveys as tools for quantifying social and economic impacts (Moreno and Lopez, 2008). With respect to the specific issue dealing with the quantification of the employment effects of renewable energy technologies, Lambert and Silva (2012) state that analytical methods are commonly used for regional or provincial studies where the I-OM can not easily be applied. Sastresa et al. (2010) argue that when being interpreted, results of analytical methodologies are more transparent and reliable than those stemming from macroeconomic models. In this context, Wang et al. (2013), in addition to use an I-OM to calculate indirect jobs, also rely on an analytical methodology to determine direct jobs engendered by Clean Development Mechanism (CDM) projects in China's power sector.

Nevertheless, one limitation of analytical methodologies is that they do not enable to evaluate indirect and induced jobs. Only direct jobs are accounted for. Moreover, unlike macroeconomic modeling methodologies, they are rarely used to quantify impacts of renewable energy technologies on the whole economy. They are commonly used for studying only employment impacts. Otherwise, Blanco and Rodrigues (2009) precise that when analytical methods, in particular surveys, are used it is essential to choose an appropriate subject for the study, either the entire population or a representative sample of it. They add that the questions in the survey need to be defined in a way to avoid biased answers [27] and that in some cases, when the response level tends to be low, the results of surveys have to be completed from other analytical sources as for example government statistics or compagny annual reports.

27. According to EWEA (2009a), biased answers are plausible if the interviewee suspects that their opinion will have political or financial consequences, if they change their replies in order to please the interviewer, or if they like or dislike the subject matter.

Table 2 – Methodologies used for assessing economic impacts of renewable energy technologies - Non exhaustive and non technical

	Methodologies					
	Macroeconomic modeling methodologies				Analytical methodologies	
Reference	I-O model	CGE model	M-E model	Econometric regression	Surveys	Other written information
Blazejczak et al. (2014)			x			
Coffman and Bernstein (2014)		x				
Simas and Pacca (2014)						x [28]
Markaki et al. (2013)	x					
Wang et al. (2013)	x [29]					x [29]
Böhringer et al. (2013)		x				
Llera et al. (2013)						x [30]
Oliveira et al. (2013)	x					
Brown et al. (2012)				x		
Lehr et al. (2012)			x			
Collins et al. (2012)	x					
Lambert and Silva (2012)	x				x	
Slattery et al. (2011)	x					
Tourkolias and Mirasgedis (2011)	x					
Mukhopadhyay and Thomassin (2011)	x					
Cai et al. (2011)	x [29]					x [29]
Sastresa et al. (2010)						x [30]
Wei et al. (2010)						x [31]
Solar Foundation (2010)					x	
Caldés et al. (2009)	x					
Blanco and Rodrigues (2009)					x	
EWEA (2009a)					x	
DG ET (2009)	x					

Cf. next page

28. Bibliographical review, experts opinions, data collection from reviews and interviews conducted to wind power plants managers, O&M technicians, representatives of six wind turbine components manufacturers, project managers, and environmental agencies.

29. An I-OM is used to calculate indirect jobs and an analytical methodology to determine direct jobs.

30. The method proposed rely on the collection and critical analysis of the results obtained using primary information sources. The model design includes contributions extracted from a prior analysis of the existing assessment methods.

31. The methodology is based on an analytical job creation model applied for the US power sector and covering the period going from 2009 to 2030. The model synthesizes data from 15 job studies dealing with renewable energy, energy efficiency, carbon capture and storage and nuclear power.

Table 2 – Complete the previous page

	Methodologies					
	Macroeconomic modeling methodologies				Analytical methodologies	
Reference	I-O model	CGE model	M-E model	Econometric regression	Surveys	Other written information
Lehr et al. (2008)	x				x	
Pollin et al. (2008)	x					
Neuwahl et al. (2008)	x					
Moisan and Chêne (2008)						x [32]
AEE (2008)	x [33]				x [33]	x [34]
Thornleya et al. (2008)						x [35]
DWEA (2008)					x	
Moreno and Lopez (2008)			x			x [36]
European Parliament (2007)						x [37]
Madlener and Koller (2007)	x					
Hillebrand et al. (2006)			x			
FMENCNS-BMU (2006)	x				x	
Pfaffenberger et al. (2006)						x [37]
Pedden (2005)						x [37]

32. Net production and employment ratios (imports have been disregarded).
33. Indirect employment was calculated on the basis of questionnaires and the subsequent modification of I-OT. .
34. Analysis of annual reports and information in the government's tax office.
35. First, authors develop a staffing pattern for each plant based on a technical appraisal of its operational requirements. Then, they quantify jobs related to development and construction of the plant (which are available only for a fixed period) based on experience and consultation.
36. Regional information has been provided by the Regional Energy Foundation and the Spanish Renewable Energy Development Plan 2000-2010.
37. Non econometric meta-analysis.

3.1.3 The relevance of the I-OM for our impacts' studies

After analyzing advantages and drawbacks of different methodologies (*Cf.* table 3), we choose to rely on an I-OM to assess economic impacts of offshore wind project of Saint-Brieuc. Although its limitations, we believe that it provides the best trade-off between the aim of our study, robustness of expected results, and the specific constraints inherent, both, to the regional scale of the study as well as specificities of the framework within which the offshore wind industry is currently emerging in France.

Table 3 – Summary of main advantages and shortcomings of the analytical and macroeconomic modeling methodologies when used to analyze economic impacts of renewable energy technologies

	Macroeconomic modeling methodologies	Analytical methodologies
Advantages	— Can calculate multiplier effects of parameters, — Can calculate employment impacts cross upstream and downstream sectors [a], — Permit a better incorporation of real world complexities.	— Transparent and has a clear hypothesis, — Better in analyzing structural unemployment.
Drawbacks	— Need for several assumptions and large database, — Not suitable for regional studies.	— Often used for calculating only direct employment impacts, — Employment may be down scaled because of the absence of multiplier effect, — Uncertain response level.

a. Direct, indirect, and induced jobs.

More precisely, five reasons support our reliance on an I-OM:

— we do not aim to focus only on impacts on the industrial sector of offshore wind, *i.e.* bottom-up approach, but we propose to analyze impacts of the expansion of this sector on the economy, *i.e.* top-down approach,

— CGE and M-E models require ample information than the I-OM, and are generally applied at aggregate level, *i.e.* European or national [38]. Their application to regional studies is still very limited.

— I-OM are more accessible than CGE and M-E models which generally need the

38. Usually, European Union Commission sponsors several projects using CGE or M-E models to quantify the employment stemming from the diffusion of renewable energy technologies.

involvement of large and, sometimes, multidisciplinary researcher team. Indeed, national I-OT constructed by the national institute for statistic and economic studies [39] are publicly available. Due to the use of regionalization techniques, it is possible for us to conduct regional study [40],

— we aim to assess direct, indirect, and induced impacts particularly employment impacts. The I-OM is more suitable than analytical methods since usually when using them only direct impacts can be quantified,

— given the emerging nature of the offshore wind industry in France and its fragmented supply chain, we decline the use of analytical methods, in particular surveys, which need to clearly identify appropriate subjects which will be called to answer to the questionnaire. Moreover, observing the controversial framework within which offshore wind industry currently emerge in France, we wonder if the proportion of response level will sufficient to enable us drawing reliable conclusion.

For these reasons, we propose to use an I-OM for regional impact analysis of offshore wind project of Saint Brieuc. Nonetheless, although such model is still a widely used methodology for assessing the economic impact of sizable investments, its shortcomings need to be kept in mind when interpreting results.

3.2 Methodological aspects on the calculation of economic impacts

In this section, we give some technical precisions dealing with how to calculate economic impacts by using an I-OM whose technical description is detailed in Appendix C.

3.2.1 Elementary description of the required database

The database of the I-OM is the I-OT. It describes the origin and destination of products i (with $i = 1 \dots n$) and the production process of the industry j (with $j = 1 \dots n$). We consider a symmetric I-OT because one industry is assumed to produce only one product. So, the number of products is equal to the number of industries, that is n, and the production of the product i is equal to the production of the industry j when $i = j$. Due to the I-OT, it is possible to calculate the matrix of technical coefficients A indicating the goods and services needed to produce one monetary unit by each industry. Besides, the I-OT estimates for a given year the vector of the final demand Y.

The I-OT is static meaning that it accounts observable economic flows for only one given year. Therefore, to be able to achieve a prospective analysis, the data of I-OT should be adjusted in order to incorporate the development of new industries induced by the project. New columns and new rows should be added in the matrix A in order to incorporate the

39. Institut National de la Statistiques et des Études Économiques (INSEE).

40. Brown et al. (2012) have analysed the robustness of the I-OM results by comparing their results with those drawn from an ex post econometric analysis of economic impacts of wind power development in US counties. They have shown that the I-OM provide a good assessment of economic impacts despite its limitations.

production process of these new industries. The adjusted matrix A has m rows and m columns where $m > n$. As a consequence, it is necessary to know the production process, thus, technical coefficients of these new industries to calculate their socio-economic impacts within an economy. Moreover, it is essential to determine the final demand induced by the project in order to quantify expected impacts of the project. Technically speaking, in the vector of final demand Y, we should determine the change in final demand engendered by the project represented by the vector Y^*. This change can impact both the industries already incorporated in the I-OT and the newly introduced industries.

Due to the construction of this database, it is possible to calculate direct, indirect, and induced impacts coming from the project of offshore wind farm of Saint Brieuc. We consider impacts on the production, value-added, and employment.

3.2.2 Technical description of the methodology of impacts calculation

Based on Appendix C, we explain below how to calculate direct, indirect, and induced impacts :

Direct impacts

We assume that X^{di}, V^{di}, and L^{di} respectively represent the m-vectors of production, value-added and labour in industries directly involved in the project. Direct impact on the production corresponds to the value of production of industries directly affected by the change in the final demand which is induced by the project. According to the supply-demand equilibrium, the value of this production should be equal to the value of the change in final demand. So:

$$X^{di} = Y^* \tag{1}$$

By knowing respectively the m-vector of value-added per unit of production v and the m-vector of labour intensity corresponding to the quantity of labour required to produce one monetary unit of production l, we calculate direct impacts of the project in terms of value-added and quantity of labour as following:

$$V^{di} = \hat{v} X^{di} \tag{2}$$

$$L^{di} = \hat{l} X^{di} \tag{3}$$

where the circumflex accent means that the matrix is diagonal.

Indirect impacts

We assume that X^{indi}, V^{indi}, and L^{indi} respectively represent the m-vectors of production, value-added and labour of industries indirectly involved in the project. By knowing the production process of all industries, new industries included, and the final demand inherent to the project, we calculate the sum of direct and indirect impacts on the production as following:

$$X^{dir+indi} = (I - A)^{-1} Y^* = BY^* \tag{4}$$

By the same way, the direct and indirect impacts on respectively the value-added and the labour are calculated as following:

$$V^{dir+indi} = \hat{v}\,(I - A)^{-1} Y^* = \hat{v}BY^* \tag{5}$$
$$L^{dir+indi} = \hat{l}\,(I - A)^{-1} Y^* = \hat{l}BY^* \tag{6}$$

As a consequence, indirect impacts are calculated as:

$$X^{indi} = X^{dir+indi} - X^{dir} \tag{7}$$
$$V^{indi} = V^{dir+indi} - V^{dir} \tag{8}$$
$$L^{indi} = L^{dir+indi} - L^{dir} \tag{9}$$

Induced impacts

We assume that X^{indu}, V^{indu}, and L^{indu} respectively represent the m-vectors of production, value-added and labour within industries due to induced impacts. These impacts are calculated by extending the matrix of technical coefficient to household sectors $\overline{A}$. When applying the closed Leontief's model (1986) as detailed in Appendix C, the sum of direct, indirect, and induced impacts for the production is equal to:

$$X^{dir+indi+indu} = \left(I - \overline{A}\right)^{-1} Y^* = \overline{B}Y^* \tag{10}$$

Similarly, the sum of direct, indirect, and induced impacts respectively on the value-added and the labour are calculated as following:

$$V^{dir+indi+indu} = \hat{v}\left(I - \overline{A}\right)^{-1} Y^* = \hat{v}\overline{B}Y^* \tag{11}$$
$$L^{dir+indi+indu} = \hat{l}\left(I - \overline{A}\right)^{-1} Y^* = \hat{l}\overline{B}Y^* \tag{12}$$

We deduce therefore induced impacts as:

$$X^{indu} = X^{dir+indi+indu} - X^{dir+indi} \tag{13}$$
$$V^{indu} = V^{dir+indi+indu} - V^{dir+indi} \tag{14}$$
$$L^{indu} = L^{dir+indi+indu} - L^{dir+indi} \tag{15}$$

3.3 Adaptation of the I-OM to the regional scale

In order to analyze regional impacts, we calculate regional technical coefficients by subtracting in the technical coefficients the part of imports (Round, 1978):

$$a_{ij}^{R} = m_{ij} a_{ij} \tag{16}$$

where a_{ij}^R represent regional technical coefficients of industry j for input i, a_{ij} technical coefficients of industry j for input i, and m_{ij} the import rate indicating the part of input i consumed by the industry j coming from outside the region of Brittany.

The import rate incorporates national import rates m_{ij}^N representing inputs produced outside France and regional import rates m_{ij}^R indicating inputs produced in France but outside the region of Brittany:

$$m_{ij} = m_{ij}^N + m_{ij}^R \tag{17}$$

National import rates m_{ij}^N are assumed to be stable inside France regardless of the regions. They are calculated directly from the national I-OT as following:

$$a_{ij}^N = m_{ij}^N a_{ij} \tag{18}$$

Several studies focused on the estimation of regional import rates m_{ij}^R because of the lack of data on interregional trade. For instance, Leontief and Strout (1963) have developed the gravity model to estimate trade exchange of products for different regions. Though this method is more satisfactory from the theoretical point of view, it is difficult to implement. An alternative method call for the use of location quotients to estimate regional technical coefficients (Miller and Blair, 2009). The most used location quotient in the literature are the Simple Location Quotients (SLQ). Nevertheless, one of its shortcomings is that the import rate is only determined by the relative sizes of selling sector i and involved region. In this context, several studies dealing with the construction of regional I-OT were devoted to developing SLQ by calculating Weighted Location Quotients (WLQ) leading to more reliable estimations of imports rate. For instance, based on Round (1978), Flegg et al. (1995) and Flegg and Webber (1997) have elaborated a location quotient commonly noted as FLQ. It takes into account the relative size of selling sectors i, the relative size of buying sectors j, and the size of the region. Several empirical studies have shown the location quotient FLQ permits a more accurate estimation of imports rate [41].

Flegg and Webber (1997) start with Cross-Industry Location Quotient ($CILQ_{ij}$) taking into account both the size of selling sectors i relatively to the size of buying sectors j and the size of the region relative to the size of the nation λ. Therefore, they calculate the location quotient as:

$$FLQ_{ij} = CILQ_{ij}\lambda \text{ with } \lambda = \left(log_2\left[1 + \frac{V^R}{V^N}\right]\right)^{\delta} \tag{19}$$

where V^R and V^N respectively represent the total value-added of the region and the nation.

Flegg and Webber (1997) suggest to estimate δ by using the econometric tool. In the case of inadequate regional data, as in our case, they recommend to set δ=0.3. Regional technical coefficients are therefore calculated by using the equation below:

$$a_{ij}^R = \begin{cases} a_{ij}^N \text{ if } FLQ_{ij} \geq 1 \\ a_{ij}^N(FLQ_{ij}) \text{ if } FLQ_{ij} < 1 \end{cases}$$

41. It mainly permits to reduce the errors of estimation (Tohmo (2004), Flegg and Tohmo (2008), Bonfiglio and Chelli (2008).

4 Derivation of results

In subsection 4.1, we start by giving some precisions about the database construction. Then, in subsections 4.2 and 4.3, we explain how we generate results during respectively the investment and the O&M phases.

4.1 Precisions about the database construction

As explained in paragraph 3.2.1, in order to calculate economic impacts of the offshore wind project of Saint Brieuc for Brittany by using an I-OM, a regional I-OT is required. Nevertheless, as France has not developed a regional accounting system, we have regionalized the French national I-OT according to the methodology described in subsection 3.3.

More precisely, we have took the French I-OT for the year 2010 (Eurostat, 2014b) which is symmetric [42] and disaggregated in 64 industries and products according to the statistical Classification of Products of Activity 2008 (CPA 2008). The value of domestic and imported commodities consumed by institutional agents within an economy are indicated within this I-OT. We have calculated both the technical coefficients a_{ij} and the national technical coefficients a_{ij}^{N}. By using equation (19), we have also estimated the interregional trade in order to obtain the regional technical coefficients a_{ij}^{R} which enable us to calculate the indirect and induced impacts. However, the implementation of this equation requires to know the regional value-added of industries. As France has a poor regional accounting system, this regional value-added was calculated as a pro-rata of the number of employees between the region and the nation for each industry by assuming that the labour productivity is quite similar between France and Brittany [43] .

4.2 The investment phase

To calculate direct, indirect, and induced economic impacts during the investment phase, we have started by determining the vectors of final demand Y^* which represent direct impact of the project in terms of production (*Cf.* paragraph 3.2.1). These calculation have been performed by assuming that the investment phase will take 4 years going from 2016 to 2020 (*Cf.* subsection 2.2) and that the total investment cost for the this period amounts €1860 M, *i.e.* €465 M per annum (excluding the development phase). Based on table 1 from the subsection 2.2 and on Junginger et al. (2004), IHS EER (2010), RIH (2011), GL BPN (2011), FEM (2011), Scottish Entreprise (2011), Sun et al. (2012) and Johnstone et al. (2013), we have defined the investment cost split into different items of expenditures as shown in the first column of the table 4. Then, we have determined affected industries (according to the CPA nomenclature) as well as the part of total investment cost (in % and in €M) which is allocated to each item of expenditures with respect to affected industries as presented in the forth last columns of table 4.

42. Eurostat (2014b) provides a symmetric I-OT since it publishes both the use and the make matrices. For more information with regard to the construction of this symmetric I-OT interested readers can look at Eurostat (2008).

43. The number of employees for regions and industries is given by the 2011 population census (INSEE, 2011).

To convert these expenditures into a vector of final demand, we should first estimate which part of them will be allocated to the region of Brittany. As indicated in the ESA (2010), all transactions of uniregional institutional units are allocated to the region in which such units have their centre of predominant economic interest. Usually, the production activity takes place where the establishments are located. However, in some cases, the place where the production activity is carried out can be different from the place where the establishment is located, *i.e.* construction sector. The production value is therefore recorded in the region where the production activity takes place (and not in the place where the establishment is located) if the activity requires significant labour input for at least one year.

Giving this rule, we explain below the conversion of the cost/investment expenditures into a vector of final demand as given by the table 5.

The first item of investment expenditures, *i.e.* wind turbine: construction, assembly and installation, integrates in fact different stages of production. Mainly, two stages should be distinguished: the construction, and the assembly and installation. As we have no information on the breakdown of the cost between these two stages, we have assumed that the 50% goes to the construction stage *i.e.* €118 M, and 50% to assembly and installation, *i.e.* €118 M. The stage of construction includes the production of the different windmill components like for example blade, mast and generator. According to AREVA (2012), this production is carried out by companies which are mainly located outside the region of Brittany, in particular in the city of Le Havre which belongs to the region of Normandy. Therefore, no expenditures can be associated to Brittany with respect to this stage. As for the assembly and installation stages, the assembly will also be carried out outside Brittany in the port of Le Havre close to the place where the different components of wind turbine will be constructed. However, for the installation, we have assumed that some local site office will be installed in Brittany in order to supervise works. We have therefore assumed that the expenditures allocated to assembly and installation will be equitably divided between these two stages with one part, the one inherent to the installation stage, for Brittany region, *i.e.* €59 M.

In sum, we have estimated that among €235 M invested each year for the wind turbine construction, assembly and installation (the first item of expenditures in table 4), nearly €60 M will go to the Brittany region.

With regard to the second item of investment expenditures, *i.e.* foundations: construction and installation, we have assumed that a local site office will be installed in Brittany to supervise works. Therefore, all the expenditures induced by these activities, belonging to the construction industry classification, will be affected to the Brittany.

The third item of the investment expenditures, *i.e.* marine network: construction and installation, includes two stages namely the construction and the installation of marine network. We have assumed that each one will imply 50% of investment expenditures, *i.e.* €25 M. Since BPN (2011, 2012) argue that multiple local compagnies in Brittany have the skills to produce electrical cable, we have assumed that 50% of investment expenditures devoted to the construction stage of the marine network will benefit to Brittany, in particular to the electrical equipment industry, *i.e.* €12.5 M. As for the installation phase, we have assumed that some local site office will be installed in the Brittany to supervise the works. Thus, all investment expenditures devoted to the installation will be benefit to the region.

Finally, we have assumed that all investment expenditures under the the fourth item *i.e.* connection: cable and shored-based position, can be recorded for the benefit of the Brittany. In fact, we can surely assumed that at least one local site office will be installed in Brittany to coordinate the operations inherent to able and shored-based position.

The table 5 below, which summarizes the annual investment expenditures affected to the Brittany, gives the different elements of the final demand vector that will be used to determine the economic impacts of the investment phase of the offshore wind project of Saint-Brieuc for the region of Brittany.

Table 4 – Assumptions about investment cost allocation to items and industries according to the French aggregated nomenclature (NA-38) during the investment phase (2016-2020)

Item of expenditures	Affected industries	Share in total cost (%)	Share in total cost (M€)	
			Total (M€)	Annual (M€)
Wind turbine: construction, assembly and installation	F: constructions and construction works	47	940	235
Foundation: construction and installation	F: constructions and construction works	23	460	115
Marine network: construction and installation	F: constructions and construction works C27: electrical equipment	10	200	50
Connection: cable and shored-based position	F: constructions and construction works	13	260	65
Farm development	—	7	140	47
Total	—	100	2000	512

Table 5 – Assumptions about investment cost allocation to Brittany with regard to items of expenditures and affected industries during the investment phase (2016-2020)

Item of expenditures	Affected industries		Total cost
	Construction industry	Electrical equipment industry	
Wind turbine: construction, assembly and installation	60	0	60
Foundation: construction and installation	115	0	115
Marine network: construction and installation	25	13	38
Connection: cable and shored-based position	65	0	65
Total	253	25	278

4.3 The O&M phase

Economic impacts during the O&M phase are coming from the production and maintenance activities of the offshore wind farm of Saint Brieuc.

We have used the output approach to estimate direct impact of the project in terms of production (European Commission et al. (2009)). We have multiplied the expected physical production by the expected unitary price. According to Iberdrola and Eole-Res (2012a, 2012b), AREVA (2012) and CRE (2012), the production is expected to equal 1750 GWh per annum and the unitary net price €66500 per GWh (CRE, 2012). The value of production is therefore estimated at €116 M per annum. According to Lehr et al. (2008), the rate of value-added is equal to 50%, thus, value added is about €58 M. With regard to the employment impact, based on Oxford Economics (2010), Colbert-Busch et al. (2012), Zammit and Miles (2013) and Sercy et al. (2014), we consider a weighted average value of estimations of expected number of jobs calculated for offshore wind farms during the O&M phase [44] equal to 0.4 FTE jobs per MW [45]. Applying this value implies that the offshore wind farm of Saint Brieuc totalling 500 MW would induce 200 employees.

To estimate the indirect and induced impacts, we have assumed that the production process -different inputs representing intermediate consumption as well as primary inputs such as labour and capital- of the offshore wind is quite similar to the production process of the onshore wind since current offshore wind technologies build on onshore wind technology (Sun et al., 2012). Then, we have refereed to Lehr et al. (2008), which have estimated the different inputs/intermediate consumption required to produce one monetary unit of the electricity coming from the wind energy farms (*Cf.* table 6), to estimate indirect and the induced impacts inherent to the O&M phase. More precisely, we have calculated indirect and induced impacts using matrix of regional technical coefficients from respectively the open and the closed Leontief's model (1986) (*Cf.* Appendix C). We have used equations 4 to 9 and equations 10 to 15 to respectively calculate indirect and induced impacts.

5 Discussion of results and policy implications

In subsection 5.1, we summarize results and give a comparative analysis [46]. In subsection 5.2, we present an overview of economic, technological, regulatory and social contexts within which the offshore wind industry evolves in France, and give some policy recommendations.

5.1 Summary and comparative analysis

Tables 7a and 7b summarize results. In particular, table 7a quantifies annual direct, indirect, and induced impacts for each phase of the project and table 7b presents the same

44. After eliminating the highest value calculated by Zammit and Miles (2013).

45. Details about estimations of Oxford Economics (2010), Colbert-Busch et al. (2012), Zammit and Miles (2013) and Sercy et al. (2014) are presented in tables C.2 and 8, section 5.1 below.

46. Depending on the available information, we have been able to perform comparative analysis for only employment impact of the projet of Saint Brieuc.

Table 6 – Values of inputs required for the production of one monetary unit of power from the offshore wind farm of Saint Brieuc (Duong et al. (2009), Lehr et al. (2008))

Nomenclature CPA 2008	Title	Value (€)
C22-C23	Rubber and plastic products and other non-metallic mineral products	0,015
C25	Fabricated metal products, except machinery and equipment	0,095
C27	Electrical equipment	0,125
C28	Machinery and equipment n.e.c.	0,090
C29-C30	Transport equipments	0,050
F	Constructions and construction works	0,030
G	Wholesale and retail trade services	0,055
H	Transportation and storage services	0,010
K	Financial and insurance services	0,015
LZ	Real estate services	0,015
	Total intermediate consumption	0,500
	Compensation of employees	0.120
	Other net taxes on production	0.025
	Operating surplus, net	0.355
	Value added at basic prices	0.500
	Production	1

results according to different metrics [47].

Results show that the most important share of impacts will be induced during the investment phase. In particular, during this phase going from 2016 to 2020, production is expected to amount €442 M and gross value-added €191 M which is also respectively equivalent to €0.88 M year/MW and €0.38 M year/MW. They also show that the investment phase may probably induce 3016 FTE jobs which is equal to about 6.03 FTE job year/MW. During the O&M phase lasting from 2020 to 2040, annual amounts of production and gross value-added are expected to respectively reach €163 M or equivalently €0.32 M year/MW and €79 M or equivalently €0.15 M year/MW. As for employment, 511 FTE jobs, thus, 1.02 FTE jobs year/MW are annually expected.

Based on two reviews of literature respectively dealing with the quantification of economic impacts of offshore wind project of Saint Brieuc (table C.1 from Appendix E [48]) and overseas offshore wind projects (table C.2 from Appendix E), table 8 below presents a comparative analysis dealing with employment impacts of the offshore wind farm of Saint Brieuc. Part I of this table which presents results of studies assessing economic impacts of the offshore wind farm of Saint Brieuc [48] shows that in our results the expected employment impact in Brittany during the investment and O&M phases, distinctively considered, is relatively high compared to results of quoted references. In particular, while our results show that 1919 direct FTE jobs are expected in Brittany during the investment phase, Nass&Wind (2011) states that between 1500 to 2000 direct FTE jobs will be generated whatever the region. During the O&M phase, Nass&Wind (2011) and Oxford Economics

47. The aim of presenting results according to different metrics is to facilitate comparison with other results.

48. None of estimations quoted in table C.1 from Appendix E and the part I of table 8 have been published in academic literature. They have been collected from various internet sources, *i.e.* reports, press conference documents, local press, where usually no detail about methodology were available.

Table 7a – Summary of annual economic impacts (1) [*Quantification of direct, indirect, and induced impacts*]

Type of impacts	Production (M€)	Value-added (M€)	Jobs (FTE)
	The investment phase (2016-2020)		
Direct impacts [a]	278	11	1919
Indirect impacts [a]	68	30	460
Induced impacts [a]	96	50	637
Total	442	191	3016
	The O&M phase (2020-2040)		
Direct impacts [b]	116	58	200
Indirect impacts [b]	26	10	153
Induced impacts [b]	21	11	158
Total	163	79	511

a. Aggregated economic impacts for the four years investment phase.
b. Annual economic impacts.

Table 7b – Summary annual economic impacts (2)

Metric	Production (M€)	Value-added (M€)	Jobs (FTE)
	The investment phase (2016-2020)		
Economic impacts (per MW)	0.88 [a]	0.38 [a]	6.03 [a]
	The O&M phase (2020-2040)		
Economic impacts (per MW)	0.32 [b]	0.15 [b]	1.02 [b]

a. $0.88 = \frac{442}{500}$, $0.38 = \frac{191}{500}$, $6.03 = \frac{3016}{500}$
b. $0.32 = \frac{163}{500}$, $0.15 = \frac{79}{500}$, $1.02 = \frac{511}{500}$

(2010) have respectively estimated the total expected number of direct FTE jobs for all involved regions/geographical areas at 60 and 110 [49]. Our results suggest that 200 FTE jobs will be created in Brittany.

Considering aggregated investment and O&M employment impact, the comparative analysis shows that Ailes Marines SAS (2014c) underestimate the number of expected jobs in Brittany. Indeed, while they assert that 1000 direct FTE jobs would be created, our results show that there will be rather 2119 direct FTE jobs. Similarly, when compared to estimations of BPN (2011), quoted in CCICA (2011), our results show that the important share of employment impact will occur in Brittany. More precisely, they show that among 2500 direct FTE jobs, 2119 will be located in Brittany implying that around 84% of employment impacts will benefit to this region. Conversely, compared to results of EWEA (2009a) showing that 5500 direct and indirect jobs can comparatively be expected from the project of Saint Brieuc, our results state that only 49% of expected direct and indirect jobs would benefit to Brittany, *i.e.* 2732 direct and indirect jobs.

Conclusion n°1 : The most important employment impact is expected to occur during the investment phase. Depending on the regional investment share that will be decided by stackholders, Brittany can largely benefit from positive impact in terms of number of jobs

49. Average value.

locally created, at the expense of other involved geographical areas.

The part II of the table 8 deals with studies assessing employment impact of overseas offshore wind projects [50]. Results of US DE (2013) stating that for a farm with 500 MW, 4.99 FTE jobs per MW and 1.66 FTE jobs per MW (annual) are expected during respectively investment and O&M phases rather corroborate our results showing that 6.03 FTE jobs per MW and 1.02 FTE jobs per MW (annual) would be generated during respectively the same phases. Nevertheless, Oxford Economics (2010), Sercy et al. (2014), and Colbert-Busch et al. (2012) show that our results underestimate employment impact during the investment phase and slightly overestimate it during the O&M phase. For example, while according to Colbert-Busch et al. (2012), 500 MW of installed offshore wind capacity would engender 3.62 FTE jobs year/MW during the investment and 0.67 during the O&M, our results show that 6.03 FTE jobs year/MW and 1.02 FTE job year/MW will respectively be induced during the same phases. Conversely, estimations from Carbon Trust (2008) assert that our results overestimate impacts during the investment. Indeed, while according to our results 6.03 FTE jobs per MW are expected, Carbon Trust (2008) states that only 1.41 FTE jobs per MW at most could be generated. As for total employment impact, results of Flynn and Carey (2007) show that ours overestimate the expected total number of jobs. While our results show that a total impact ratio equal to 7.05 per MW (annual) can be induced, Flynn and Carey (2007) calculate a ratio equal to 3.92 jobs per MW.

Conclusion n°2 : Although some studies corroborates our results, they seems to rather slightly underestimate total employment impact for Brittany during the investment phase and overestimate it during the O&M.

It is worthy to note that, as shown in the second and last columns of table 8, these conclusions should be considered with a lot of caution. Indeed, the comparative analysis from which they were deduced has been performed on the basis of studies suffering from :

— assumptions variability and insufficient information with regard to what phases are included in estimations, *i.e.* development, construction, assembly, installation, and what type of jobs are included, *i.e.* direct, indirect or induced. Usually, only aggregated results are presented [51].
— discrepancy with regard to boundaries of jobs definition. In this context, Simas and Pacca (2014) argue that "*manufacturing of key components, power plant construction and O&M are considered direct jobs. However, some studies include planning and project management, research and development, energy companies, utilities, banks, and other services*". They add that "*the definition of indirect jobs is even*

50. As shown in table C.2 from Appendix E, estimations quoted in part II of table 8 are generated from modeling exercises based on well founded theoretical approaches contrary to estimations presented in part I of the same table (*Cf.* footnote number 48).
51. This is the case in the part I of the table 8.

vaguer. While some authors estimate the indirect effects of materials and services consumed on the upstream supply chain, other studies consider consultancies and several minor components not directly related to the sector. There are also studies which include induced jobs in the final quantification. Usually job losses in other energy industries due to high investments costs of renewable energy technologies is not accounted for. The treatment of the differences between temporary and permanent jobs is also an issue that is often not addressed".

— lack of transparency and details with respect to methodologies and tools used to quantify economic impacts [51],

— differences in metrics. Usually, when analyzing the investment phase, the ratio "person-year per MW installed" is frequently used indicating temporary labour force, while for the O&M phase the ratio "number of jobs per MW installed" is used to refer to the number of people that would need to be employed continuously to operate the plant. Nevertheless, there is a need to consign the number of jobs throughout the whole life of an installation to make easier comparative analysis (Kammen et al., 2004).

How these points, taken individually or simultaneously, may induce results variability and subsequent comparative analysis sensitivity has been extensively covered in the literature (Blanco and Rodrigues (2009), Sastresa et al. (2010), Lambert and Silva (2012), Simas and Pacca (2014)). It is largely accepted that results from different assessments exercises are variable and sometimes conflicting. Therefore, although comparative analysis can be instructive, results are not really reliably comparable.

Table 8 – Comparative analysis dealing with the employment impact of the offshore wind farm of Saint-Brieuc [*based on tables C.1 and C.2*]

Reference	Phase	Results: In the reference	Results: In our model	Commentary with regard to the considered reference
		Part I — Comparison of our results (*Cf.* table 7a) with those quoted in references dealing with employment impact of the offshore wind farm of Saint Brieuc (*Cf.* table C.1)		
Ailes Marines SAS (2014c)	Manufacturing, installation, and O&M	1000 jobs	2119 jobs	2119 = 1919 + 200. Only direct jobs are accounted for.
Nass&Wind (2011) [52]	Manufacturing and installation	[1500-2000] jobs [53]	1919 jobs	Probably indirect and induced jobs are not accounted for.
	O&M	60 jobs [53]	200 jobs	Only direct jobs are accounted for.
Oxford Economics (2010) [52]	O&M	[95-125] jobs [53]	200 jobs	Probably only direct jobs are accounted for.
EWEA (2009a) [52]	Global impacts	5500 jobs [53]	2732 jobs	2732 = 1919 + 460 + 200 + 153. Induced jobs are not accounted for.
	O&M	150 jobs [53]	353 jobs	353 = 200 + 153. Induced jobs are not accounted for.
European Commission (2001) [52]	Conception, development, manufacturing, installation and O&M	[2010-2250] jobs [53]	1919 jobs	Probably only direct jobs are accounted for.
	O&M	30 jobs [53]	200 jobs	Probably only direct jobs are accounted for.
BPN [52]	Global impacts	2500 jobs [53]	1919 jobs	Probably only direct jobs are accounted for.
	O&M	[60-80] jobs [53]	200 jobs	Probably only direct jobs are accounted for.
		Part II — Comparison of our results (*Cf.* table 7b) with those of studies assessing economic impacts of overseas offshore wind farms (*Cf.* table C.2)		
Sercy et al. (2014)	Construction and component manufacturing	23.97 jobs per MW	6.03 jobs per MW	$23.97=\frac{959}{40}$
	O&M	0.25 jobs per MW (annual)	1.02 jobs per MW (annual)	$0.25=\frac{10}{40}$
US DE (2013)	Construction	4.99 jobs per MW	6.03 jobs per MW	$4.99=\frac{20100}{4027}$
	O&M	1.66 jobs per MW (annual)	1.02 jobs per MW (annual)	$1.66=\frac{6700}{4027}$
Zammit and Miles (2013)	Construction	[19-39] jobs per MW	6.03 jobs per MW	—
	O&M	[1.64-1.67] per MW	1.02 jobs per MW (annual)	—
Colbert-Busch et al. (2012)	Component manufacturing and installation	3.62 jobs per MW (annual)	6.03 jobs per MW (annual)	$3.62=\frac{293+3329}{1000}$

Cf. next page

52. Quoted in CCICA (2011).
53. This estimation is relative not only to Brittany but also to all geographical areas which can be impacted by the project.

Table 8 – Complete the previous page

Reference	Phase	Results: In the reference	Results: In our model	Commentary with regard to the considered reference
	O&M	0.67 jobs per MW (annual)	1.02 jobs per MW (annual)	$0.67=\frac{678}{1000}$
Oxford Economics (2010)	O&M	[0.35 [54]-0.45 [55]] job per MW	1.02 per MW (annual)	$0.35=\frac{7230}{25000}$ and $0.45=\frac{450}{1000}$
EWEA (2009a)	Farm development, turbine and component manufacturing, and installation.	15.1 jobs per annual MW [56]	n.a.	Number of jobs deals with, both, offshore and onshore wind. Induced jobs are not accounted for.
	O&M	0.33 jobs per (cumulative) MW	1.02 jobs per MW (annual)	
Boettcher et al. (2008)	O&M	0.34 jobs per MW	1.02 jobs per MW (annual)	$0.34=\frac{6734}{20000}$
Carbon Trust (2008)	RD&D, engineering and design, turbine and component manufacturing and services	[1.10-1.41] jobs per MW	6.03 jobs per MW	$1.10=\frac{32000}{29000}$ and $1.41=\frac{41000}{29000}$
	Installation and O&M	[0.27-1] per MW	1.05 per MW (annual)	$0.27=\frac{8000}{29000}$ and $1=\frac{29000}{29000}$
GWEC (2008)	Farm development, turbine and component manufacturing, and installation	15.1 jobs per annual MW [56]	n.a.	Estimation in GWEC (2008) is extracted from EWEA (2009a). It deals with, both, offshore and onshore wind. Induced jobs are not accounted for.
	O&M	0.33 jobs per (cumulative) MW	1.02 jobs per MW (annual)	
Flynn and Carey (2007)	Manufacturing, installation, and O&M	3.92 jobs per MW	7.05 per MW (annual) [57]	$3.92=\frac{1881}{480}$

54. This estimation is associated with an expected installed capacity equal to 20.5 GW by 2020.
55. This estimation is associated with an installed capacity equal to 1 GW by 2010.
56. It means 15.1 jobs per additional installed MW in one year.
57. $7.05 = 6.03 + 1.02$ where 6.03 represents the number of jobs per MW (annual) during the investment phase and 1.02 the number of jobs per MW (annual) during tO&M.

5.2 Policy implications

In this section, we start in subsection 5.2.1 by presenting an overview of the context within which the offshore wind industry currently evolves in France. Then, in subsection 5.2.2, we give some policy recommendations in the light of our results.

5.2.1 An overview of the French context

We focus below on describing the French economic, technological, regulatory and social contexts within which the offshore wind industry is emerging.

Economic context

Offshore wind costs are high not only in France but also even in countries where the cumulative installed capacity is the most important like in the UK or Denmark (*Cf.* Appendix A). In particular, between 2001 and 2010 total offshore wind costs have risen considerably although important variability among projects. For instance, Lemming et al. (2008) state that CAPEX [58] and OPEX [59] oscillate between 1200 €/kW and 2700 €/kW for offshore wind projects developed between 1997 and 2007. Similarly, Douglas Westwood (2013) asserts that the average CAPEX for offshore wind projects developed in the UK amounts 2800 €/kW but that some costs can reach 3000 to 4000 €/kW. As for OPEX, while KPMG (2007) argues that they are equal to 26.4 €/MWhe, DGEMP (2008) and Lemming et al. (2008) respectively consider that they are situated around to 22 and 16 €/MWhe.

IHS EER (2010) explains that in addition to be induced by the farm size, distance from the coast, water depth, meteorological conditions, and site characteristics, the high offshore wind costs are "*driven by tight competition to secure turbines and the development of more technically complex projects, as near-shore and shallow-water projects are often already developed or in the process of being built*".

In France, where the offshore wind technology is still emerging, such high costs can seriously inhibit its development. In the long run, cost reduction can be expected due to experience accumulation and economies of scale [60]. Nevertheless, as argued by Blanco (2009), Snyder and Kaiser (2009), and Musial and Ram (2010), in the short and medium run public financial support mechanisms are crucial to cope with these high costs. Currently in France, such mechanisms do not exist for the investment phase. In this context, the farm of offshore wind of Saint Brieuc amounting a total cost equal to €2 B is entirely financed by the private sector (Ailes Marines SAS, 2013a) [61]. However, during the oper-

58. CAPital EXpenditures.
59. OPeration EXpenditures.
60. Blanco (2009) states that for a doubling of the total installed capacity, the cost per kWh of offshore wind power would decrease by 9 to 17%. According to Junginger et al. (2004), the cost of offshore wind power range between 60 and 120 €/MWh compared with 3 to 8 €/MWh for the onshore wind power. Considering an operation period equal to 3000 hours and an investment costs around 3000 €/kWe, Hansen and Percebois (2010) give an offshore wind power cost equal to 135 €/MWh. Moreover, Sun et al. (2012) argue that it is expected that the capital cost of offshore follows the same cost reduction path of the onshore wind in the future. It might drop to 1274 €/kW in 2020 and 1161 €/kW in 2050.
61. According to CESER (2012), it is expected that the construction of the first four French offshore wind farms costs €7 B.

ation phase, electricity produced from offshore wind can get a benefit from feed-in tariffs as a financial supporting mechanism. More precisely, for an operation period equal to 20 years, the feed-in tariffs is fixed to 130 €/MWh for the 10 first years and between 30 to 130 €/MWh for the 10 last years depending on the geographical location of the farm. In France, the CSPE "Contribution au Service Public de l'Électricité" permits to finance feed-in tariffs since it aims to dispatch on the collectivity the additional financial burden engendered by the production of electricity from renewable sources in general and offshore wind in particular. According to the CRE (2012), the additional financial charge which will be generated by the four scheduled offshore wind farms of the first French call for tenders amounts €1.1 B per year starting from 2020 [62], the expected operation date.

Technological and industrial context

In France, the development of fixed offshore wind technology [63] technology can largely beneficiate from spillover effects from fixed onshore. Indeed, at the global scale France occupies the sixth position in terms of national installed onshore wind capacity (EWEA, 2009a). As a consequence, actors like developers, component manufacturers, engineering and consulting companies involved in onshore wind industry can also integrate the offshore industry. Nevertheless, those actors, in particular manufacturers, are usually foreign. According to CGEIET and CGEDD (2012), until 2012 none of them have an assembly plant in France.

With the recent ambition of France to establish a string national offshore wind industry, it is expected that this situation change. Indeed, in the two French offshore wind call for tenders the assessment of applications has been based on the criteria of "Industrial and social quality of the project" [64] which encourage French industrial progress by supporting local organization of the value chain, local creation of economic activity, and local development of experience effects (CRE, 2011). The introduction of such criteria has brought Alstom [65] to schedule an industrial development program aiming at enhancing national technological development of offshore industry. In particular, Alstom has expected to set up 2 manufactories in Saint Nazaire for the construction of generators and nacelles, 2 manufactories in Cherbourg for the construction of blades and masts, an engineering and R&D center in the region of Pays-de-Loire, 4 industrial sites for foundations, and 3 for pre-assembly and installation (Ailes Marines SAS, 2012). By the same, as already detailed in section 2.2, Ailes Marines SAS [66] has defined a development program which aim at establishing a sustainable and an independent French offshore wind industry with both

62. This corresponds to an additional annual cost amounting €160 MWh.

63. We distinguish fixed and floating offshore wind technologies. In France, there is currently no deadline for future floating offshore wind farm construction and installation. However, MERiFIC (2013a) states that the assembling of a 1 MW demonstrator is scheduled and that a pre-series of 5 machines of 5 MW each one are due to be built between 2014 and 2016.

64. This criteria accounts for 40% of the total rating.

65. Alstom is a member of Éolien Maritime France, the winning consortium of offshore wind farms of Fécamp (Seine-Maritime, 500 MW), Courseulles-sur-mer (Calvados, 500 MW), and Saint-Nazaire (Loire-Atlantique, 750 MW).

66. Ailes Marines SAS is the winning consortium of the offshore wind farm of Saint-Brieuc (Côtes d'Armor, 500 MW).

local and export development opportunities. Under this program, human skills and local companies (mainly in Brittany) has been identified to be involved in different role along the supply chain (MERiFIC (2013a), Ailes Marines SAS (2013a), BPN (2012), CESER (2012)).

Political, legal and regulatory context

As detailed in section 1, under the impulsion of the EU legislation [67], the political context in France is propitious for the development of renewable energies in general and offshore wind in particular. Indeed, within the framework of Grenelle de la mer two tenders calling for the development of six offshore wind farms was respectively launched in 2011 and 2013. The current French minister of Écologie, Développement durable et Énergie has recurrently displayed her aim to make France the European leader in offshore wind field (MEDDE, 2014b).

Nevertheless, in France the complexity and instability of regulatory framework can seriously imped implication of stakeholders as for example private investors whose financial support is important (CESER, 2012). Moreover, ambiguous and misfit legal framework could prevent the development of offshore wind industry. According to CESER (2009), the legislation that "*is currently applied to the implantation and operating of marine renewable energies, including offshore wind, is a stack of measures often transposed from onshore area*" [68]. Guéguen-Hallouët (2013) adds that this legislation is not yet adapted for marine energy installations. It represents a mixture between energy and sustainable development legislation. It is therefore unsuitable and represents a source of insecurity (Cudennec, 2013). Several academicians and/or lawyers are currently working to improve and define propitious legal and regulatory frameworks ensuring reliable and sustainable development of offshore wind industry (*Cf.* for example Guéguen-Hallouët and Boillet (2012), Boillet (2013), Bettio (2013), Billet (2013), Terneyre (2013), Michalak (2013)).

Social context

Since the development of offshore wind farms is still emerging in France, involved population usually wonder what impacts can be induced. To answer questions and ensure social acceptability, several debates have been organized. In particular, under the project of Saint Brieuc and after being seized by Ailes Marines SAS, the national commission of public debate Commission Nationale du Débat Public (CNDP) has organized a public debate from March 25, 2014 to July 24, 2014 to discuss with the local population of Brittany about the project [69]. In particular, 11 public seminars was ensured within which 2500

67. We mainly cite the directive 2001/77/CE of September 27, 2001 stating the increase of the share of renewable energies in total energy demand to 22% (adjusted to 21% in 2004), the Climate and energy package of 2008, and the 2030 framework for climate and energy policies of 2014.

68. Traduced from French: "*la réglementation qui s'applique actuellement aux projets d'implantation en mer de systèmes d'exploitation de l'énergie des vents, des vagues et des courants est un empilement de mesures souvent transposées du domaine terrestre et inadaptées au milieu marin*"

69. For more details, interested readers can look at http://www.debatpublic.fr/projet-parc-eolien-mer-au-large-baie-saint-brieuc. We note that three public debates have been also organized for the three other offshore wind projects belonging to the first call for ten-

participants have asked 392 questions and formulated 105 opinions. The public debate has otherwise induced 29387 visitors/tourists to discover the site of Saint Brieuc (CNDP (2013a), CNDP (2013b)).

Although by the end of this debate some questions are still unanswered pending the outcome of impact studies associated with the project, it shows that local population is rather agree with the development of the project but request for heterogeneous compensation measures which depend on sensitivities, interests, and who or what the stakeholders represent or defend (Kermaroget et al., 2014). For example, according to Ailes Marines SAS (2013a), Ailes Marines SAS (2013b), Lalancette et al. (2014) the population recurrently call for :

— enhancing the local job creation,
— respecting initial usages of the sea as well as it users,
— limiting the plausible negative environmental impacts,
— providing financial indemnity.

Yet, under the project of Saint Brieuc a collaboration agreement between Ailes Marines SAS and actors pertaining to the fishing sector aiming at defining measures to support sustainable fisheries and at stating measures to monetary compensate for plausible negative impacts was signed. Also, a convention of collaboration lying Ailes Marines SAS and the committee Yachting of Les Côtes d'Armor which aims at developing and promoting the sailing in the Bay of Saint-Brieuc for a period of 10 years was also concluded.

5.2.2 Policy recommendations

Many measures involving government, industry, and other stakeholders are required in France before the offshore wind industry achieves a significant degree of maturity and positively impacts the economy as shown by our results.

Economic literature, in particular Schumpeter (1942) and Schmookler (1966), recommends the implementation of technology push and market pull measures. It also argues that these measures should be simultaneously implemented to ensure their synergy effects. While during the research and development (R&D) phase, technology push measures, *i.e.* government R&D, subsidies, tax credit, permit to promote generation of knowledge flows necessary to understand and control the technology and to overcome barriers to market entry, during the demonstration and deployment phases market pull mechanisms, *i.e.* feed-in tariffs, Renewables Obligations (RO), tax, permit to enhance the diffusion of the technology by creating demand and developing markets.

By referring to the contribution of the economic literature, we propose below five policy recommendations which can help enhancing the development of offshore wind industry in France.

ders. Details about these debates are available at http://www.debatpublic.fr/projet-parc-eolien-mer-au-large-courseulles-mer, http://www.debatpublic.fr/projet-parc-eolien-mer-au-large-fecamp, and http://www.debatpublic.fr/projet-parc-eolien-mer-saint-nazaire for respectively the offshore wind project of Courseulles-sur-mer (Calvados, 500 MW), Fécamp (Seine-Maritime, 500 MW), and Saint-Nazaire (Loire-Atlantique, 750 MW).

Recommendation 1: Ensuring funding

In France, the development of offshore wind projects usually require the involvement of different funders as for instance energy companies, projects developers, banks, and institutional investors. Indeed, it is expected that the construction of the four offshore wind farms of the first call for tenders costs €7 B (CESER, 2012). Nevertheless, because of such huge cost and the uncertainty about the future prospects of market development, funders are risk averse. They are reticent with regard to investing in such innovative projects. Defining funding support mechanisms would encourage their involvement. They can take place before and/or after the beginning of the project. For instance, while during the early development government commitment in projects funding and/or loans guarantying is crucial to support the industry [70], providing sufficient post-investment returns and ensuring the stability of such financial support policies, *i.e.* feed-in tariffs [71], Renewables Obligation [71], tax, is essential during the operation phase to guarantee reliable and sustainable development of the industry.

Recommendation 2: Defining and stabilizing regulatory and legal frameworks

There is crucial need for defining and ensuring the stability of legal and regulatory frameworks, currently fuzzy, unsuitable, and unstable, in order to reduce risk aversion of both national and overseas stakeholders and encourage the development of the offshore wind industry. In particular, three points should be considered in priority :

— the creation of a sole tool for territorial planning,
— the definition of a harmonious licensing system,
— the supervision of appeals procedures.

Recommendation 3: Encouraging R&D

Its important to encourage and support R&D activities. They particularly permit to overcome lock-in factors and to ensure technical breakthrough. They should aim at creating test sites and demonstrative platforms to promote French expertise and encourage overseas collaborations usually source of positive spillover. They should involve public and private participants and aim to enhance both fundamental research and industrial innova-

70. We note that offshore wind project of Saint Brieuc expected to cost €2 B is exclusively privately funded by Ailes Marines (Ailes Marines SAS, 2013b). Conversely, according to Craik (2012) a project of offshore wind farm costing €1 B is generally funded by a three public institutions and seven to ten commercial banks.

71. Currently in France, differentiated feed-in tariffs beneficiate to energies produced from renewable sources depending on the source of energy production (Hansen and Percebois (2010), CESER (2012)). In the UK, the Renewables Obligation (RO) and Renewables Obligations (Scotland) (RO(S)) are the main support mechanisms (Jeffrey et al., 2012).

tion [72]. The governmental financial commitment to R&D activities is obviously still very important [73].

Recommandation 4: Developing skilled workforce

Given the embryonic nature of the offshore wind industry in France, its fragmented supply chain and the uncertainty with regard to its future development prospects, a shortage of skilled workers in some roles as for instance offshore security and maintenance technicians can be expected (Gautier, 2010). In the short term, the supply of skilled workforce is likely to come from other sectors including onshore wind, offshore oil and gas, automotive and aerospace although there are challenges in attracting experienced workers. Alternatively, workforce could be sourced internationally within the framework of overseas collaborations that could promote learning transfer. In the long term, after identifying whenever possible needs, it is important to define a long term strategy for workforce training and planning. The training supply should operate on the two levels of initial training (formation initiale) and continues training (formation continue). It is also important to ensure training of trainers under professional training courses (formation professionnelle) since this act in a way to consolidate the promotion of jobs specific to offshore wind [74].

Recommandation 5: Ensuring social acceptability

French population is still not familiar with offshore wind project and the degree of social acceptability can not be ensured. As a consequence, communication aiming at informing, explaining and answering to questions of the population should be reinforced. Debates and information rounds should be frequently organized and diffusion of information in local press generalized. Moreover, the social acceptability usually involves wondering about the establishment of compensation measures for stakeholders who may perceive some of their activities and interests to be modified after the implementation of an offshore wind

72. We cite two initiatives aiming to encourage R&D activities dealing with marines renewable energies in France, in particular the offshore wind. The first corresponds to the creation in 2012 of France Énergie Marine (FEM), located in Brest. It represents public-private partnership involving 58 members. It is also called an institute of excellence in low-carbon energy or in French Institut d'Excellence en Énergie Décarbonée. In addition to promoting test sites and offering training programs, FEM performs R&D activities dealing with technical and non technical lock-in factors to the diffusion of marines renewable energies (FEM, 2014a). The second initiative, supported by the Cellule Énergie of the Centre Nationale de la Recherche Scientifique (CNRS), aims at creating a research group (Un Groupe de Recherche (GdR)) associating academic researchers and dealing with the theme of marine renewable energies in France. Under a one day workshop entitled Les enjeux scientifiques autour des Energies Marines Renouvelables happening by November 12, 2014 in Paris, a partial identification of interested researchers and questions of research was performed. Generally speaking, the aim of the group is to study technological, social, economic, and legal questions associated with the development of renewable marines energies. The list of participants to this GdR is available at CNRS (2014).

73. Under the French programm entitled Les investissments d'avenir, the government participation in funding France Énergie Marine is equal to €34,3 M, giving a total budget (for 9 years) amounting €130 M (FEM, 2014b).

74. Main institutions delivering training courses related to offshore wind in particular and to marine renewable energies in general in France are L'École Centrale of Nantes (http://www.ec-nantes.fr/), L'ENSTA Bretagne of Brest (http://www.ensta-bretagne.fr/), L'École Navale (http://www.ecole-navale.fr/), Les lycées maritimes, and Les lycées professionnels marins (Gautier, 2010).

farm.

6 Conslusion

Currently in France no offshore wind farm is operating or under construction although its potential maritime frontage. It is only on July 2011 that the first call for tender was launched by the French government for the development of 3 GW of offshore wind followed by a second call for tender in July 2013 for the development of an additional 1 GW.

While opponents to the large scale diffusion of offshore wind usually point out its high cost and lack of competitiveness, its advocates argue that expected economic benefits can be important. This paper presents a case study which aims at assessing local economic impacts of the 500 MW of the offshore wind farm of Saint Brieuc for the region of Brittany. We use a regional I-OM. We distinguish primary and secondary impacts. Primary impacts represent the sum of direct and indirect impacts and secondary impacts refer to induced impacts.

Results show that depending on the rate of regional investment with respect to the supply chain roles, the project positively impacts the Brittany's economy. Indeed, during the investment phase €0.88 M year/MW of production, €0.38 M year/MW of gross value-added and 6.03 FTE jobs year/MW are expected. During the O&M phase, €0.32 M year/MW of production, €0.15 M year/MW of gross value-added and 1.02 FTE jobs year/MW are also expected. These results put into attention the key role that can be played by offshore wind investments in stimulating local economies. Through job creation, economic sectors development, and household expenditures increase, such investments contribute to economic growth. Therefore, in a context of economic deceleration particularly felt in France associated with recurrent alarming debates about resources depletion and climate change problem, accelerating the development of offshore wind represents an opportunity. Short-run and long-run measures targeting to support both demand and supply sides are necessary. We particularly distinguishes technology push, *i.e.* government R&D, subsidies, tax credit, and market pull, *i.e.* feed-in tariffs, Renewables Obligations (RO), tax, measures. Successful experiences like in UK or Denmark show the effectiveness of the combination of both of them. Conversely, they also put into attention the delay of France in mobilizing its human, technological and geographical resources to develop offshore wind industry. Regional collaborations and international cooperation can surely accelerates the process and permits a wider benefits.

A Overview of the global offshore wind capacity [75]

Table A.1 – Global cumulative offshore wind capacity in 2011 and 2012

	Installed capacity (MW)	
Country	2011	2012
UK	2093.6	2947.9
Denmark	874.3	921.1
Belgium	195	379.5
Germany	200.3	280.3
Netherlands	246.8	246.8
Sweden	163.7	163.7
Finland	26.3	26.3
Ireland	25.2	25.2
Norway	2.3	2.3
Portugal	2	2
PR China	262.6	389.6
Japan	25.2	25.3
Total	4117.3	5410.0

Table A.2 – The latest top 25 largest operational offshore wind farms in the world in 2011

Farm	Production (MW)	Country	Number of turbines	Date of commission
Thanet	300	UK	100	2010
Homs Rev II	209	Denmark	91	2009
RØdsand II	207	Denmark	91	2009
Lynn and Inner Dowsing	194	UK	54	2008
Valney 1	184	UK	51	2011
Robin Rigg (Solway Firth)	180	UK	60	2010
Gunfleet Sands	172	UK	48	2010
Nysted (RØdsand I)	166	Denmark	72	2003
Bligh Bank (Belwind)	165	Belgique	55	2010
Homs Rev I	160	Denmark	80	2002
Princess Amalia	120	Netherlands	60	2008
Lillgrund	110	Sweden	48	2007
Egmond aan Zee	108	Netherlands	36	2006
Donghai Bridge	102	Chine	34	2010
Kentish Flats	90	UK	30	2005
Barrow	90	UK	30	2006
Burbo Bank	90	UK	25	2007
Rhyl flats	90	UK	25	2009
North Hoyle	60	UK	30	2003
Scroby Sands	60	UK	30	2004
Alpha Ventus	60	Germany	6	2009
Baltic 1	48	Germany	21	2011
Middelgrunden	40	Denmark	20	2001
Juangsu Rudong	32	China	16	2010
Kemi Ajos I and II	30	Finland	10	2008

75. Informations contained in tables A.1 and A.2 are respectively extracted from www.gwec.com [Accessed October 9, 2014] and MEDDE (2012b).

B Some characteristics of the offshore wind project of Saint-Brieuc

Table B.1 – Some characteristics of the offshore wind project of Saint-Brieuc

Site characteristics	Number	Comment
Average speed of wind	8.5 m/s	—
Annual production	1750 GWh/year	7% of annual electricity consumption of Brittany
Equivalent power	3500 hours	—
Loading factor	40%	—
Availability	93%	7% of waste. Wind turbines rotate 90% of time
Distance from the coast	17 km [a]	80% more that 20 km
Average depth	34 m	—
Minimum distance between rows	1 km	Possibility of fishing between wind turbines
Commissioning date	From 2018 to 2020 [b]	—
Date of dockyard completion	2020	—
Lifetime : O&M	20 years : from 2020 to 2040	—
Avoided CO_2 emissions	488800 tons p.a	—
Cost of installing 1 MW	€4 M	—

a. For the first offshore turbine.
b. In 2018, 2019 and 2020, 20%, 50% and 100% of total capacity will respectively be installed.

C Brief technical presentation of the Leontief's model (1986)

We distinguish the open and the closed Leontief's models (1986):

C.1 The open Leontief's model (1986)

The starting point of the closed Leontief's model (1986) is the supply-demand equilibrium relationship described as following:

$$X = Zi + Y \tag{C.1}$$

where X is the n-vector [76] of the production, Z the $(n \times n)$ matrix of the intermediate consumption, i the n-vector composed only of the number 1, and Y the n-vector of final demand which integrates the final consumption [77], the gross capital formation, the inventory change, and the exports.

The model define an $(n \times n)$ matrix of technical coefficients A indicating the monetary amount of inputs required to produce one monetary unit. It is calculated as follows:

$$A = ZX^{-1} \tag{C.2}$$

The Leontief's model (1986) assumes that the technical coefficients are stable. Therefore, inputs are supposed to be complementary and the model do not allow for the integration of innovation effects in the production processes. Moreover, the stability of technical coefficients implies that scale effects are constant.

Incorporating equation (C.2) into equation (C.1) gives:

$$X = AX + Y \tag{C.3}$$

After arrangement and factorization, we obtain:

$$X = (I - A)^{-1}Y = BY \tag{C.4}$$

where $B = (I - A)^{-1}$ is the $(n \times n)$ inverse matrix of Leontief and I the identity matrix.

The inverse matrix of Leontief is the core element of the Leontief's model (1986). It allows to link the production vector X to the final demand vector Y by indicating the total -direct and indirect- production required to satisfy one monetary unit of the final demand. Indeed, the different elements of the inverse matrix of Leontief b_{ij} indicate the required value of production of different industries i to satisfy one monetary unit of demand for the product j. By summing in the matrix B the different rows i for the column j, we find the production multipliers for the product j:

$$O_j^X = \sum_{i=1}^{n} b_{ij} \tag{C.5}$$

76. We note that n represents the number of products within an economy.

77. The demand for final consumption comes from households, public administrations and non-profit institutions serving households.

The production multipliers O^X permit to estimate the indirect impacts.

Equation (C.4) can be extended to incorporate the value-added and employment. The Leontief's model (1986) supposes that the value-added per unit of production is stable as indicating in the following equation:

$$V = \hat{v}X \tag{C.6}$$

where V is n-vector of the value-added by industry j and v the n-vector of the value-added per unit of production for each industry j. We note that the circumflex accent means that the matrix is diagonal.

By integrating equation (C.6) into equation (C.4), we obtain:

$$V = \hat{v}\,(I - A)^{-1}\,Y = \hat{v}BY \tag{C.7}$$

The elements of the matrix $\hat{v}B$ $(v_i b_{ij})$ indicate the total -direct and indirect- value added of industry j stemming from the demand of product i. By summing in the matrix $\hat{v}B$ the different rows i for the column j, we find the value-added multipliers for the product j:

$$O_j^V = \sum_{i=1}^{n} v_i b_{ij} \tag{C.8}$$

The same reasoning is adopted for the employment. The Leontief's model (1986) supposes that the employment per unit of production is stable as indicated in the following equation:

$$L = \hat{l}X \tag{C.9}$$

where L is n-vector of the employment by industry j and l the n-vector of the employment per monetary unit of production for each industry j. By integrating equation (C.9) into (C.4), we obtain:

$$L = \hat{l}\,(I - A)^{-1}\,Y = \hat{l}BY \tag{C.10}$$

Elements of the matrix $\hat{l}B$, noted $(l_i b_{ij})$, indicate the total -direct and indirect- employment of industry j stemming from the demand of product i. By summing in the matrix $\hat{l}B$ the different rows i for the column j, we find the employment multipliers for the product j:

$$O_j^L = \sum_{i=1}^{n} l_i b_{ij} \tag{C.11}$$

C.2 The closed Leontief's model (1986)

The closed Leontief's model (1986) is an extension of the open model. Indeed, it assumes that households sector is endogenous [78]. Subsequently, in order to integrate the household sector, the vectors and matrix in equation (C.1) should be modified. Indeed, the $(n \times n)$ matrix Z becomes the $(n+1)\,(n+1)$ matrix $\overline{Z}$. It henceforth integrates

78. Such an assumption means that a household earns income in payment for its labor input and that he spends it for the consumption of goods and services.

an additional row corresponding to the payment of household labour input Z_R and an additional column corresponding to the final consumption of households Z_C:

$$\overline{Z} = \begin{pmatrix} Z & Z_C \\ Z_R & 0 \end{pmatrix}$$

Moreover, the n-vector X becomes the $(n+1)$-vector $\overline{X}$ by integrating an additional row X_{n+1} corresponding to the household production that is equal to the total payment of labour input:

$$\overline{X} = \begin{pmatrix} X \\ X_{n+1} \end{pmatrix}$$

The new n-vector of final demand $\overline{Y}$ excludes from the vector of final demand in open model the vector of household final consumption, since it is integrated in the matrix $\overline{Z}$.

The supply-demand equilibrium is therefore written as follows:

$$\overline{X} = \overline{Z}i + \overline{Y} \tag{C.12}$$

The $(n+1)\,(n+1)$ matrix of technical coefficients is calculated as in the open model:

$$\overline{A} = \overline{Z}\overline{X}^{-1} \tag{C.13}$$

By integrating equation (C.13) into equation (C.12), and after arrangement and factorization, we obtain:

$$\overline{X} = \left(I - \overline{A}\right)^{-1}\overline{Y} = \overline{BY} \tag{C.14}$$

where $B = \left(I - \overline{A}\right)^{-1}$ is the $(n \times n)$ inverse matrix of Leontief. Its elements $\overline{b}_{ij}$ indicate the value of production - direct, indirect, and induced - of industry j required to satisfy one monetary unit of demand for the product i. By summing in the matrix $\overline{B}$ the different rows i for the column j, we find the production multipliers for the product j:

$$O_j^{\overline{X}} = \sum_{i=1}^{n} \overline{b}_{ij} \tag{C.15}$$

By adopting the same reasoning as in the open model, it is possible to calculate the value-added and employment multipliers:

$$O_j^{V} = \sum_{i=1}^{n} v_i\overline{b}_{ij} \tag{C.16}$$

$$O_j^{L} = \sum_{i=1}^{n} l_i\overline{b}_{ij} \tag{C.17}$$

D Geographical location of the Grand-Ouest Français [79]

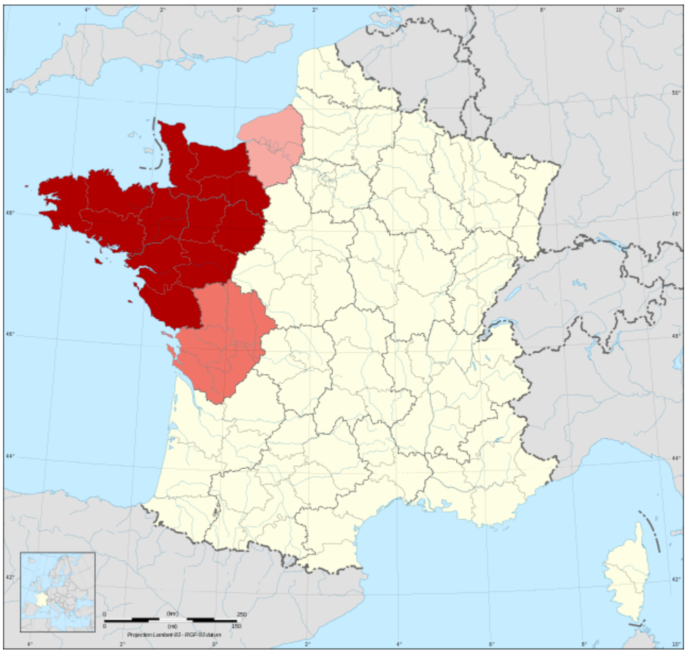


Figure 9. The Grand-Ouest français

79. Dark red refers to the regions of Brittany, Normandy and Pays de la Loire representing together the Grand-Ouest Français. Light red points out departements (départements) of Indre-et-Loire and Loir-et-Cher (both belonging to the region of Centre) which are sometimes included when defining the Grand-Ouest français (*Cf.* footnote number 18).

E Reviews of literature dealing with estimations of employment impact of offshore wind farms

Table C.1 – Overview of estimations of employment impact of the offshore wind farm of Saint Brieuc - Non exhaustive

References	Topic	Methodology	Expected employment impact
Ailes Marines SAS (2014c) [a]	Assessing employment impact of the offshore wind farm of Saint Brieuc.	n.a. [b]	— 2000 direct FTE jobs are expected in the Grand-Ouest (1860 devoted to the manufacturing and installation and 140 to the O&M) among which 1000 are expected in Brittany.
CCICA (2011) [c]	Assessing employment impact of the offshore wind farm of Saint Brieuc.	n.a.	— Oxford Economics (2010): 95 to 125 FTE jobs are expected during the O&M. — EWEA (2009a): 5500 FTE jobs are expected among which 150 would be devoted to the O&M. — European Commission (2001): 2010 to 2250 FTE jobs are expected among which 30 would devoted to the O&M. — Bretagne Pôle Naval (BPN): 2500 FTE jobs are expected among which between 60 to 80 devoted to the O&M.
Nass&Wind (2011) [d]	Assessing employment impact of the offshore wind farm of Saint Brieuc.	n.a.	— 2000 direct FTE jobs are expected during the manufacturing and installation and 60 during the O&M.

a. Estimations quoted in this reference has been also cited in the local press (*Cf.* Ouest France (2014)).

b. Not available.

c. CCICA (2011) presents a compilation of estimations of employment impact of the offshore wind project of Saint Brieuc based on Oxford Economics (2010), EWEA (2009a), European Commission (2001) and Bretagne Pôle Naval (BPN). We note that bibliographic details of European Commission (2001) and Bretagne Pôle Naval are not available in CCICA (2011). Therefore, information about the methodologies that have been used to estimate the number of jobs are unknown. As for methodologies used in Oxford Economics (2010) and EWEA (2009a) they are presented in table C.2.

d. Quoted in CCICA (2011).

Table C.2 – Overview of studies assessing economic impacts of overseas offshore wind farms - Non exhaustive

References	Topic	Country	Methodology	Results
Sercy et al. (2014)	Assessing economic and fiscal impacts of 40 MW of offshore wind farm for South Carolina from 2016 to 2036.	US	Policy Insight PI+ economic modeling engine (Regional Economic Models, Inc. REMI). It is an input-output and computable general equilibrium based model as well as a new economic geography model. Economic impacts are estimated using employment, total compensation, output, net state or local government revenue, and direct, indirect and induced impacts[80].	— In 2016, during the construction and the manufacture of components, creation of 959 direct, indirect, and induced jobs, \$46.3 M of wages, and \$148.4 M of output is expected. — During the O&M phase (2017-2037), annual creation of 10 direct, indirect, and induced jobs, \$934000 of wages, and \$2.8 M of output is expected.
US DE (2013)	Assessing economic impacts of offshore wind development in Georgia, South Carolina, North Carolina, and Virginia.	US	Jobs and Economic Development Impact (JEDI) model based on an input-output methodology[81] . Economic impacts are estimated using employment, earning, and output as metrics. The model estimates gross impacts which are distributed across three categories namely project development and onsite labor impacts, local revenue and supply chain impacts, and induced impacts.	— In 2020, where 25% of the supply chain investment will be locally performed, 252 MW are expected to induce 4220 FTE jobs during the construction and 410 annual FTE jobs during the O&M. — In 2030, where 62% of the supply chain investment will be locally performed, 4027 MW are expected to induce 20100 FTE jobs during the construction and 6700 annual FTE jobs during O&M[82].
Zammit and Miles (2013).	Assessing economic impacts of offshore wind development in Georgia, South Carolina, North Carolina, and Virginia.	US	Jobs and Economic Development Impact (JEDI) model based on an input-output methodology[81]. The model built around three variables: market and deployment, regional investment, and cost. For each variable, three development paths were considered. Three scenarios running from 2020 to 2030 were generated: the first assumes small offshore industry with limited regional investment, the second supposes a moderate growth of the offshore wind industry, and the third considers a fast development of the industry.	— During the construction, 19 to 39 FTE jobs per MW would be created depending on the rate of regional development of the supply chain[83]. — During the O&M, 1.64 to 1.67 FTE jobs per MW would be created. — As the industry grows, projected earnings and outputs are higher.

Cf. next page

80. More details about the model are available at www.remi.com.
81. More details about JEDI model are available at www.nrel.gov/analysis/jedi/ and in Lantz et al. (2013).
82. These results are relative to a scenario which consider a moderate deployment of offshore wind.
83. Regional development of the supply chain supports more jobs per MW.

Table C.2 – Complete the previous page

References	Topic	Country	Methodology	Results
Colbert-Busch et al. (2012)	Assessing economic impacts of 1000 MW of offshore wind industry in South Carolina. Assessing fiscal impacts of existing wind energy supply chain in South Carolina.	US	The Regional Dynamics (REDYN) economic modeling engine based on Social Accounting Matrix (SAM) and input-output functions derived from sector relationships revealed in the SAM. Those relationships provide a framework for defining equilibrium processes in the model's computable general equilibrium functions [84].	— Between 2016 and 2025, the manufacture of wind turbine components will annually generate 293 direct, indirect, and induced jobs, \$18.3 M of wages, \$54.9 M of output, and \$5.7 M of combined state and local government revenue. Installation would annually generate 3329 average annual direct, indirect, and induced jobs, \$163.1 M of wages, \$270.7 M of output, and \$51.2 M in combined state and local government revenue. — Between 2026 and 2030, the O&M are expected to annually generate 678 direct, indirect, and induced jobs, \$41.8 M of wages, \$115.2 M of output, and \$13.4 M in combined state and local government revenue.
Oxford Economics (2010)	Assessing employment impacts of the O&M phase of offshore wind projects in the UK in 2010 and 2020.	UK	Input-output methodology.	— In 2010, a total installed capacity of 1 GW engenders about 450 jobs among which 290 are direct and 160 indirect and induced. — An expected installed capacity equal to 20.5 GW by 2020 would induce about 7230 jobs among which 4000 are direct, 1660 indirect, and 1570 induced.
EWEA (2009a)	Assessing employment impacts wind energy in the EU [85].	EU	Data collection based on surveys. Modeling exercise using scenarios projection.	— During development, manufacturing and installation: 15.1 direct and indirect jobs per new MW are expected, — During O&M: 0.33 direct and indirect jobs per (cumulative) MW are expected.

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84. More details about REDYN model are available at http://www.redyn.com/.
85. This reference deals with both onshore and offshore wind energy.

Table C.2 – Complete the previous page

References	Topic	Country	Methodology	Results
Boettcher et al. (2008)	Assessing the employment impacts of wind [85], wave and tidal industries in the UK by 2020.	UK	Employment model based on five input variables namely capacity, labour intensity, cost reduction, local content, and export market share. The model calculates employment split into technologies, regions, and export and domestic markets along the value chain. The evolution of employment is captured by a scenario engine.	— An installed onshore and offshore wind capacity of 27 GW would generate 30000 jobs [86], — An installed offshore capacity of 20 GW would induce 6734 jobs during the O&M [87].
Carbon Trust (2008)	Assessing how much offshore wind power capacity could reasonably be required to make UK reaching the 2020 renewable energy target and what would be required to deliver needed wind capacity cost effectively?	UK	n.a.	— The UK will need to install 29 GW of offshore wind to reach the 2020 renewable energy target. Between 40000 to 70000 jobs and £6 M to £8 M of annual revenues are consequently expected [88]. Jobs will be dispatched as following: — 3000 to 4000 in RD&D, engineering, and design, — 7000 to 15000 in turbine and component manufacturing, — 22000 in services, — 8000 to 29000 in installation [89] and O&M.
GWEC (2008) [90]	Global wind energy outlook for 2008 [85].	Global	n.a.	— During the development, manufacturing, and installation: 11 to 15.1 direct and indirect jobs per additional MW are expected, — During O&M: 0.33 direct and indirect jobs per (cumulative) MW are expected [91].

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86. More details about the distribution of this number are not available.
87. Quoted in BWEA (2010) and Oxford Economics (2010).
88. Depending on the level of government involvement to support offshore wind industry.
89. Includes indirect jobs related to installation and construction of turbines, foundations, substations, and grid connections.
90. Quoted in EWEA (2009a).
91. Cited numbers represent assumptions used in GWEC (2008) for scenario construction for Germany, Denmark, Spain, and the Netherlands.

Table C.2 – Complete the previous page

References	Topic	Country	Methodology	Results
Flynn and Carey (2007)	Assessing economic and fiscal impacts to South Carolina from 480 MW of installed capacity of offshore wind.	US	An economic impact model with scenarios projection depending on the level of regional involvement of South Carolina in the manufacture and assembly of turbine generators.	— 1881 direct, indirect, and induced FTE jobs are expected, — An increase of annual output by $287 M and of annual disposable income by up to $93 M are expected, — An increase in income tax revenues of up to $2.8 M and in corporate income tax revenues of up to $190000 over the two years period of manufacturing and installation are expected.

References

AEE. Estudio macroeconómico del impacto del sector eólico en españa, 2008. Asociación Empresarial Eólica (AEE). Elaborated by Deloitte.

Ailes Marines SAS. Appel d'offres éolien en mer. Ambitions et expertises pour une filière industrielle française, 2012. URL www.edf-energies-nouvelles.com/_[Accessed_November_05,_2014]. EDF EN, DONG Energy, WPD, Nass&Wind, ALSTOM. 9 p.

Ailes Marines SAS. Projet éolien en mer de la Baie de Saint Brieuc. Le dossier du maître d'ouvrage. Débat public mars - juillet 2013, 2013a. URL http://www.developpement-durable.gouv.fr/Dossier-de-presse-Vers-un-nouveau.html_[Accessed_November_05,_2014]. 132 p.

Ailes Marines SAS. Projet éolien en mer de la Baie de Saint Brieuc. Présentation du projet, 2013b. URL http://cpdp.debatpublic.fr/cpdp-eoliennes22/INFORMER/BILAN_ET_COMPTE_RENDU_DU_DEBAT.HTM_[Accessed_November_21,_2014]. 21 p.

Ailes Marines SAS. Un projet industriel : le coût et le financement, 2014a. URL www.http://http://www.eolienoffshoresaintbrieuc.com_[Accessed_October_08,_2014].

Ailes Marines SAS. Un projet industriel : le calendrier du projet, 2014b. URL www.http://http://www.eolienoffshoresaintbrieuc.com_[Accessed_October_08,_2014].

Ailes Marines SAS. Un projet industriel : les emplois mobilisés, 2014c. URL www.http://http://www.eolienoffshoresaintbrieuc.com_[Accessed_October_08,_2014].

Ailes Marines SAS. Un projet industriel : la fabrication des éléments constitutifs du parc, 2014d. URL www.http://http://www.eolienoffshoresaintbrieuc.com_[Accessed_October_12,_2014].

G. Allan, I. Bryden, P. McGregor, T. Stallard, K. Swales, K. Turner, and R. Wallace. Concurrent and legacy economic and environmental impacts from establishing a marine energy sector in Scotland. *Energy Policy*, 36:2734–2753, 2008.

G. Allan, M. Gillmartin, P. McGregor, and K. Swales. Levelised costs of wave and tidal energy in the UK: cost competitiveness and the importance of banded renewables obligation certificates. *Energy Policy*, 39:23–39, 2011a.

G. Allan, P. McGregor, and K. Swales. The importance of revenue sharing for the local economic impacts of a renewable energy project: a social accounting matrix approach. *Regional studies*, 45(9):1171–1186, 2011b.

G. Allan, I. Eromenko, , P. McGregor, and K. Swales. The regional electricity generation mix in Scotland : a portfolio selection approach incorporating marine technologies. *Energy Policy*, 29:6–22, 2011c.

AREVA. Éolien en mer : création d'une filière industrielle en Bretagne et en Normandie. Rencontre entreprises - Langueux, 2012. URL http://www.bretagne.cci.fr/files/

crci_bretagne/Actualites/2012juin/AREVA-Rencontre-entreprises-Langueux-290512-VF.pdf_[Accessed_September_03,_2014].

B. Arfi, R. Berrada, T. Deffains, and A. Mercat. Territorialisation de l'éolien offshore dans la Baie de Saint Brieuc, 2013. Projet Sciences Humaines. INSA Rennes et SciencesPo Rennes.

N. Bettio. *Énergies marines renouvelables. Enjeux juridiques et socio-économiques*, chapter La procédure d'implantation des éoliennes offshore en droit français, pages 73–91. A. Pédone edition, 2013. UMR AMURE Centre de droit et d'économie de la mer. Actes de colloque. Brest, le 11 et 12 octobre 2012.

P. Billet. *Énergies marines renouvelables. Enjeux juridiques et socio-économiques*, chapter L'exploitation de l'énergie marine au risque du droit de l'environnement, pages 41–52. A. Pédone edition, 2013. UMR AMURE Centre de droit et d'économie de la mer. Actes de colloque. Brest, le 11 et 12 octobre 2012.

M. I. Blanco. The economics of wind energy. *Renewable and Sustainable Energy Reviews*, 13(6-7):1372–1382, 2009.

M. I. Blanco and G. Rodrigues. Direct employment in the wind energy sector: an EU study. *Energy Policy*, 37:2847–2857, 2009.

J. Blazejczak, F. G. Braun, D. Edler, and W. P. Schill. Economic effects of renewable energy expansion: a modelsed analysis for Germany. *Renewable and Sustainable Energy Reviews*, 40:1070–1080, 2014.

M. Boettcher, N. P. Nielsen, and K. Petrick. A closer look at the development of wind, wave & tidal energy in the UK. Employment opportunities and challenges in the context of rapid industry growth, 2008. URL http://www.bain.com/publications/articles/employment-opportunities-and-challenges-in-the-context-of-rapid-industry-growth.aspx_[Accessed_October_13,_2014]. Bain & Compagny.

C. Böhringer, A. Keller, and E. Van der Werf. Are green hopes too rosy? Employment and welfare impacts of renewable energy promotion. *Energy Economics*, 36:277–285, 2013.

N. Boillet. *Énergies marines renouvelables. Enjeux juridiques et socio-économiques*, chapter La planification des énergies marines renouvelables en droit français, pages 53–72. A. Pédone edition, 2013. UMR AMURE Centre de droit et d'économie de la mer. Actes de colloque. Brest, le 11 et 12 octobre 2012.

A. Bonfiglio and F. Chelli. Assessing the behaviour of non-survey methods for constructing regional input-output tables through a Monte Carlo simulation. *Economic Systems Research*, 20:243–258, 2008.

A. M. Borges. Applied general equilibrium models: an assessment of their usefulness for policy analysis. *OECD Economic studies*, 7:7–43, 1986.

BPN. Éolien offshore posé. Besoins industriels des donneurs d'ordre et offre des entreprises de la région Bretagne, 2011. URL www.themavision.fr_[Accessed_October_14,_2014]. GL Garrad Hassan pour Bretagne Pôle Naval.

BPN. Les entreprises de l'industrie éolienne offshore en Bretagne. Annuaire 2012, 2012. URL www.bretagnepolenaval.org_[Accessed_October_13,_2014]. Bretagne Pôle Naval.

BPN. Les ports misent sur l'éolien offshore, 2013. URL www.bretagnepolenaval.org_[Accessed_October_12,_2014]. Bretagne Pôle Naval.

J. P. Brown, J. Pender, R. Wiser, E. Lantz, and B. Hoen. Ex post analysis of economic impacts from wind power development in US counties. *Energy Economics*, 34:1743–1754, 2012.

BWEA. What does the Round 3 announcement mean?, 2010. British Wind Energy Association.

W. Cai, C. Wang, J. Chen, and W. S. Green economy and green jobs: myth or reality? The case of China's power generation sector. *Energy*, 36(10):5994–6003, 2011.

N. Caldés, M. Varela, M. Santamaria, and R. Sáez. Economic impact of solar thermal electricity deployment in Spain. *Energy Policy*, 37:1628–1636, 2009.

Carbon Trust. Offshore wind power: big challenge, big opportunity. Maximising the environmental, economic and security benefits, 2008. URL http://www.carbontrust.com/resources/reports/technology/offshore-wind-power_[Accessed_October_14,_2014].

CCICA. Projet de parc éolien offshore de la baie de Saint-Brieuc. Rapport final du groupe de travail "Éolien offshore", 2011. URL http://www.exceltys.com/article/photo/dossier645/GT_EOLIEN_OFFSHORE2011VF.pdf_[Accessed_September_05,_2014]. Chambre de l'Industrie de du Commerce des Côtes d'Armor (CCICA). 63 p.

CESER. Des énergies marines en Bretagne : A nous de jouer, 2009. URL http://www.bretagne.fr/internet/jcms/preprod_35266/des-energies-marines-en-bretagne-a-nous-de-jouer-2009_[Accessed_November_07,_2014]. Conseil Économique, Social et Environnemental de Bretagne (CESER). 424 p.

CESER. Des énergies marines en Bretagne (2) : Concrétisons la filière, 2012. URL http://www.bretagne.fr/internet/jcms/preprod_162352/des-energies-marines-en-bretagne-concretisons-la-filiere_[Accessed_November_05,_2014]. Conseil Économique, Social et Environnemental de Bretagne (CESER). 228 p.

CG Côtes d'Armor. Port de maintenance du parc éolien en Baie de Saint Brieuc : le point de vue du conseil général des Côtes d'Armor, 2014. URL http://cotesdarmor.fr/_[Accessed_October_05,_2014].

CGEIET and CGEDD. Éolien et photovoltaïque : enjeux énergétiques, industriels et sociétaux, 2012. Rapport à Monsieur le Ministre du Redressement productif Madame la Ministre de l'Écologie, du Développement durable et de l'Énergie. 132 p.

CNDP. Bilan du débat public projet d'un parc éolien en mer au large de la Baie de Saint Brieuc. 25 mars - 24 juillet 2013, 2013a. URL http://www.developpement-durable.gouv.fr/Dossier-de-presse-Vers-un-nouveau.html_[Accessed_November_21,_2014]. Commission Nationale de Débat Public. 11 p.

CNDP. Projet d'un parc éolien en mer au large de la Baie de Saint Brieuc. compte-rendu du débat public qui s'est tenu du 25 mars au 24 juillet 2013, 2013b. URL http://www.developpement-durable.gouv.fr/Dossier-de-presse-Vers-un-nouveau.html_[Accessed_November_21,_2014]. Commission Nationale de Débat Public. 49 p.

CNRS. Les pages web de la Cellule énergie du CNRS. GT5 - énergies marines, hydrauliques et éoliennes, 2014. URL http://www.celluleenergie.cnrs.fr/spip.php?article243_[Accessed_November_26,_2014]. Centre Nationale de la Recherche Scientifique (CNRS).

M. Coffman and P. Bernstein. Linking hawaii's islands with wind energy. *Annals of Regional Science*, DOI 10.1007/s00168-014-0644-y, 2014.

E. Colbert-Busch, R. T. Carey, and E. W. Seltzman. South Carolina wind energy supply chain survey and offshore wind economic impact study, 2012. URL http://sti.clemson.edu/reports/cat_view/293-regional-economic-analysis-laboratory_[Accessed_October_17,_2014]. Clemson University. Retoration Institute. Clemson-Strom Thurmond Institute.

A. R. Collins, E. Hansen, and M. Hendryx. Wind versus coal: comparing the local economic impacts of energy resource development in Appalachia. *Energy Policy*, 50:551–561, 2012.

D. Craik. Offshore wind finance : riding the storm, 2012. URL http://social.windenergyupdate.com/offshore-wind/offshore-wind-finance-riding-storm_[Accessed_November_24,_2014].

CRE. Cahier des charges de l'appel d'offres n° 2011/s 126-208873 portant sur des installations éoliennes de production d'électricité en mer en France métropolitaine, 2011. URL http://www.cre.fr/documents/appels-d-offres/appel-d-offres-portant-sur-des-installations-eoliennes-de\discretionary{-}{}{}production-d-electricite-en-mer-en-france-metropolitaine. Commission de Régulation de l'Énergie (CRE). Ministère de l'Écologie, du Développement durable, des Trasnports et du Logement. Ministère de l'Économie des Finances et de l'Industrie. 80 p.

CRE. Journal officiel de la République française. Commission de Régulation de l'Énergie (CRE), Avril 2012. URL http://energie2007.fr/images/upload/jo_28042012_delib_cre_1.pdf.

A. Cudennec. *Énergies marines renouvelables. Enjeux juridiques et socio-économiques*, chapter L'exploitation des énergies marines renouvelables. Une activité complexe, source d'insécurité juridique, pages 323–330. A. Pédone edition, 2013. UMR AMURE Centre de droit et d'économie de la mer. Actes de colloque. Brest, le 11 et 12 octobre 2012.

M. Desholm, A. D. Fox, P. Beasley, and J. Kahlert. Remote techniques for counting and estimating the number of birds-wind turbine collision at sea: a review. In wind, fire and water : renewable energy and birds. *The International Journal of Avian Science*, 148(suppl. 1):76–89, 2006.

DG ET. The impact of renewable energy policy on economic growth and employment in the European Union, 2009. URL `http://ec.europa.eu/energy/renewables/studies/doc/renewables/2009_employ_res_summary.pdf_[Accessed_December_23,_2014]`. DG Energy and Transport.

DGEMP. Synthèse publique de l'étude des coûts de référence de la production électrique, 2008. URL `http://www.developpement-durable.gouv.fr/Les-couts-de-reference-de-la.html_[Accessed_November_05,_2014]`. 30 p.

Douglas Westwood. The world offshore wind market. Forecast 2013 - 2022, 2013. URL `www.douglas-westwood.com/_[Accessed_November_05,_2014]`. Douglas Westwood (DW). ISBN 9781-905-183-91-3.

M. H. Duong, F. Ghersi, and R. Thello. Les effets en emploi d'un captage et stockage du CO2 en France. une étude macroéconomique comparée avec les énergies renouvelables, 2009. Centre Internatinale de Recherche sur l'Environnement et le Développement (CIRED). Rapport SOCECO 2.

DWEA. Environmental and employment benefits of wind, 2008. URL `www.windpower.org_[Accessed_December_23,_2014]`. Danish Wind Energy Association DWEA.

Erquy. Dossier de présentation du port d'Erquy pour l'accueil de la plate-forme de maintenance du futur parc éolien offshore en Baie de Saint Brieuc, 2012. URL `http://cotesdarmor.fr/lamenagement_du_territoire/la_mer_et_le_littoral/projet_dun_parc_eolien_en_mer.html_[Accessed_October_12,_2014]`. Communauté de communes Côte de Penthièvre.

ESA. European system accounts 2010, 2010. URL `http://ec.europa.eu/eurostat/documents/3859598/5925693/KS-02-13-269-EN.PDF/44cd9d01bc64-40e5-bd40-d17df0c69334`.

European Commission, International Montery Fund, Organisation for Economic Co-operation and Development, United Nations, and World Bank . System of national accounts 2008, 2009. ISBN 978-92-1-161522-7. 722 p.

European Parliament. Employment potential of renewable forms of energy and increased efficiency of energy use, 2007. Briefing note. DG Internal Policies of the Union. Policy department: Economic and Scientific Policy. IP/A/EMPL/FWC/2006-03/SC3.

Eurostat. Eurostat manual of supply, use and input-output tables, 2008. URL http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/_[Accessed_December_17,_2014]. Luxembourg: Office for Official Publications of the European Communities.

Eurostat. Energy statistics - main indicators, 2014a. URL http://ec.europa.eu/eurostat/web/energy/data/database_[Accessed_December_17,_2014].

Eurostat. ESA supply, use and input-output tables, 2014b. URL http://ec.europa.eu/eurostat/web/esa-supply-use-input-tables/data/workbooks_[Accessed_December_21,_2015].

EWEA. The economics of wind energy, 2009a. URL http://www.ewea.org/_[Accessed_October_11,_2014]. European Wind Energy Association (EWEA).

FEM. Présentation stratégique de France Énergies Marines. France Énergies Marines (FEM). Version B, 2011. Plouzané.

FEM. Qui sommes-nous? L'organisation, 2014a. URL http://www.france-energies-marines.org/Qui-sommes-nous/L-organisation_[Accessed_November_26,_2014]. France Énergies Marines (FEM).

FEM. Qui sommes-nous? Historique, 2014b. URL http://www.france-energies-marines.org/Qui-sommes-nous/Historique_[Accessed_November_26,_2014]. France Énergies Marines (FEM).

A. T. Flegg and T. Tohmo. Regional input-output models and the FLQ formula: a case study of Finland, 2008. Economics discussion paper series N8/08. School of Economics, University of the West of England.

A. T. Flegg and C. D. Webber. On the appropriate use of location quotients in generatingregional input-output tables: reply. *Regional studies*, 31:795–805, 1997.

A. T. Flegg, C. D. Webber, and M. V. Elliott. On the appropriate use of location quotients in generating regional input-output tables. *Regional studies*, 31:58–86, 1995.

R. G. Flynn and R. T. Carey. The potential economic impact of an offshore wind farm to the State of South Carolina, 2007. URL http://www.offshorewindhub.org/resource/1000_[Accessed_October_13,_2014]. The Strom Thurmond Institute.

FMENCNS-BMU. Renewable energy: employment effects. Impact of the expansion of renewable energy on the German labour market, 2006. URL http://www.bmu.de/english/_[Accessed_December_23,_2014]. Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (FMENCNS) - BMU.

A. D. Fox, M. Desholm, J. Kahlert, T. K. Christensen, and I. K. Petersen. Information needs to support environmental impact assessment of the effects of European marine offshore wind farms on birds. *The International Journal of Avian Science*, 148:129–144, 2006.

G. Gautier. Énergies marines renouvelables. Emplois, compétences, formation : quelles perspectives d'avenir?, 2010.

GL BPN. Éolien offshore posé : besoins industriels des donneurs d'ordre et offre des entreprises de la région Bretagne. GL Garrad Hassan et Bretagne Pôle Naval (BPN), 2011. 29 p.

G. Guéguen-Hallouët. *Énergies marines renouvelables. Enjeux juridiques et socio-économiques*, chapter L'appel d'offres éolien en mer à l'épreuve des règles européennes de concurrence, pages 93–106. A. Pédone edition, 2013. UMR AMURE Centre de droit et d'économie de la mer. Actes de colloque. Brest, le 11 et 12 octobre 2012.

G. Guéguen-Hallouët and N. Boillet. L'appel d'offres Éolien en mer. quelques réflexions à propos d'un nouvel avatar juridique, 2012. JCP A, n° 40, 8 octobre 2012, pp. 27-34.

GWEC. Global wind energy outlook 2008, 2008. URL `http://www.gwec.net/publications/global-wind-energy-outlook/gweo-2008/_[Accessed_October_15,_2014]`. Global Wind Energy Council (GWEC).

J. P. Hansen and J. Percebois. *Énergie, économie et politiques*. Bruxelles et Paris, de Boeck edition, 2010. 978-2-8041-6177-4 (ISBN).

B. Hillebrand, H. Butterman, J. Behringer, and M. Bleuel. The expansion of renewable energies and employment effects in Germany. *Energy Policy*, 34:3484–3494, 2006.

O. Huppop, J. Dierschke, K. M. Exo, E. Fredrich, and R. Hill. Bird migration studies and potential collision risk with offshore wind turbines. *The International Journal of Avian Science*, 148:90–109, 2006.

Iberdrola and Eole-Res. Le projet éolien en mer en Baie de Saint-Brieuc : un projet breton de territoire durable. Mai 2012a. URL `http://www.bretagne.cci.fr/files/crci_bretagne/Actualites/2012juin/PrAsentation-BG-rencontre-industriels-120529-VF.pdf_[Accessed_June_05,_2014]`. Rencontres avec les industriels bretons. Langueux.

Iberdrola and Eole-Res. Le projet éolien en mer en Baie de Saint-Brieuc : un projet breton de territoire durable. Mai 2012b. URL `http://www.bretagne.cci.fr/files/crci_bretagne/Actualites/2012juin/PrAsentation-BG-CBE-120529-VF.pdf_[Accessed_June_08,_2014]`. 7^{ième} conférence bretonne de l'énergie. Saint-Brieuc.

IHS EER. Global offshore wind energy market and strategies 2010 - 2025. November 2010. URL `http://www.emerging-energy.com/uploadDocs/Excerpt_GlobalOffshoreWindEnergyMarketsandStrategies2010.pdf`. IHS Emerging Energy Research. 6 p.

INSEE. Données de recensement de la population 2011. emploi au lieu de travail en 2011, 2011. URL `http://www.insee.fr/fr/themes/detail.asp?reg_id=99&ref_id=td-emploi-lieu-travail-11_[Accessed_January_01,_2014]`. Fichier EMP2 emploi au lieu du travail par sexe, statut et secteur d'activité économique.

INSEE. Le bilan démographique 2012 en Bretagne, 2013. URL http://insee.fr/fr/themes/document.asp?reg_id=2&ref_id=20134_[Accessed_December_08,_2014]. Octant analyse n°50. 5 p.

INSEE. Institut National de la Statistique et des Études Économiques, 2014. URL http://www.insee.fr/fr/_[Accessed_October_05,_2014].

H. Jeffrey, B. Jay, and M. Winskel. Accelerating the development of marine energy : exploring the prospects, benefits and challenges. *Technological forecasting and social change*, 2012.

C. M. Johnstone, D. Pratt, J. A. Clarke, and A. D. Grant. A techno-economic analysis of tidal energy technology. *Energy*, 49:101–106, 2013.

M. Junginger, A. Faaij, and W. C. Tunkenburg. Cost reduction prospects for offshore wind farms. *Wind engineering*, 28(1):97–118, 2004.

D. Kammen, K. Kapadia, and M. Fripp. Putting renewables to work: how many jobs can the clean energy industry create, 2004. In: Report of the renewable and appropriate energy laboratory. Berkeley, CA: University of California.

C. Kermaroget, H. Levrel, and A. Carlier. The impact and compensation of offshore wind farm development: analysing the institutional discourse from a French case study. *Scottish Geographical Journal*, 130(3):188–206, 2014.

KPMG. Offshore wind farms in Europe: Survey, 2007. URL http://www.kpmg.com/fr/fr/pages/default.aspx_[Accessed_November_05,_2014].

S. Lalancette, P. Le Floc'h, and B. Le Gallic. Stakeholders' views about the implementation of offshore wind power: The project of the bay of Saint Brieuc (France), 2014. URL http://www.lemna.univ-nantes.fr/39590980/0/fiche___pagelibre/_[Accessed_January_05,_2015]. 11ème Conférence Annuelle Territoires, Espaces et Politiques Publiques (TEPP), 25 et 26 septembre 2014 - Nantes.

R. J. Lambert and P. P. Silva. The challenges of determining the employment effects of renewable energy. *Renewable and Sustainable Energy Reviews*, 16:4667–4674, 2012.

E. Lantz, M. Goldberg, and D. Keyser. Jobs and Economic Development Impact (JEDI) model: offshore wind user reference guide, 2013. URL www.nrel.gov/publications_[Accessed_October_17,_2014]. Technical Report. National Renewable Energy Laboratory NREL/TP-6A20-58389. Contract No. DE-AC36-08GO28308.

U. Lehr, J. Nitsch, M. Kratzat, C. Lutz, and D. Edler. Renewable energy and employment in Germany. *Energy Policy*, 36:108–117, 2008.

U. Lehr, C. Lutz, and D. Edler. Green jobs? Economic impacts of renewable energy in Germany. *Energy Policy*, 47:358–364, 2012.

J. Lemming, P. E. Morthorst, and N. E. Clausen. Offshore wind power experiences, potential and key issues for deployment, 2008. URL www.risoe.dk/rispubl/reports/ris-r-1673.pdf_[Accessed_November_05,_2014]. Risø National Laboratory for Sustainable Energy. Technical University of Denmark. Risø-R-1673(EN). ISBN 978-87-550-3725-0.

W. Leontief and A. Strout. *Structural independence and economic development*, chapter Multiregional input-output analysis, pages 119–149. 1963. London: Macmillan. Reprint in Leontief W. (1986), Input-output economics, Oxford University Press, USA.

W. W. Leontief. *Input-output economics.* Oxford University Press, USA, 1986.

Å. Lindman and P. Söderholm. Wind power learning rates: a conceptual review and meta-analysis. *Energy Economics*, 34(3):754–761, 2012.

E. Llera, S. Scarpellini, A. Aranda, and I. Zabalza. Forecasting job creation from renewable energy deployment through a value-chain approach. *Renewable and Sustainable Energy Reviews*, 21:262–271, 2013.

R. Madlener and M. Koller. Economic and CO2 mitigation impacts of promoting biomass heating systems: an input-output study for vorarlberg, Austria. *Energy Policy*, 35: 6021–6035, 2007.

M. Markaki, A. Belegri-Roboli, P. Michaelides, S. Mirasgedis, and D. P. Lalas. The impact of clean energy investments on the Greek economy: an input-output analysis (2010 - 2020). *Energy Policy*, 57:263–275, 2013.

MEDDE. Énergies marines renouvelables : Étude méthodologique des impacts environnementaux et socio-économiques, 2012b. Ministère de l'Écologie, du Développement durable et de l'Énergie (MEDDE). 361 p.

MEDDE. Premier appel d'offres éolien en mer, 2014. URL http://www.developpement-durable.gouv.fr/6-avril-2012-Designation-des.html_[Accessed_October_10,_2014]. Ministère de l'Écologie du Développement Durable et de l'Énergie (MEDDE).

MEDDE. Conférence de presse de Ségolène Royale. Dossier de presse. Vers un nouveau modèle énergétique : accélérer le développement des énergies renouvelables en mer, 2014b. URL http://www.developpement-durable.gouv.fr/Dossier-de-presse-Vers-un-nouveau.html_[Accessed_November_05,_2014]. Ministère de l'Écologie, du Développement Durable et de l'Énergie (MEDDE). 13 p.

MEEDM. Plan d'action national en faveur des énergies renouvelables (période 2009 - 2020). Ministère de l'Écologie, de l'Énergie, du Dévelopement durable et de la Mer, 2010. URL www.developpement-durable.gouv.fr_[Accessed_October_06,_2014]. 120 p.

MERiFIC. Présentation stratégique de France Énergies Marines. Technopôle Brest-Iroise & Cornwall Marine Network for the MERiFIC Project, 2013a. 79 p.

S. Michalak. *Énergies marines renouvelables. Enjeux juridiques et socio-économiques*, chapter Energies marines renouvelables et responsabilité entre droit public et droit privé : une harmonisation souhaitable, pages 261–281. A. Pédone edition, 2013. UMR AMURE Centre de droit et d'économie de la mer. Actes de colloque. Brest, le 11 et 12 octobre 2012.

R. E. Miller and P. D. Blair. *Input-Output Analysis: Foundations and Extensions*. Number 978-0-521-51713-3 (ISBN). Cambridge University Press, second edition, 2009.

F. Moisan and A. Chêne. Maîtrise de l'énergie et développement des énergies renouvelables : état des lieux des marchés et des emplois, 2008. URL `http://www.ademe.fr/_[Accessed_December_23,_2014]`. ADEME&Vous. Stratégie & Études, n° 34.

B. Moreno and A. J. Lopez. The effect of renewable energy on employment. The case of Asturias (Spain). *Renewable and Sustainable Energy Reviews*, 12:732–751, 2008.

K. Mukhopadhyay and P. J. Thomassin. Macroeconomic effects of the ethanol biofuel sector in Canada. *Biomass and Bioenergy*, 35(7):2822–2838, 2011.

M. Musial and B. Ram. Large-scale offshore wind power in the United States sassessment of opportunities and barriers, 2010. URL `http://www.nrel.gov/wind/pdfs/40745.pdf._[Accessed_November_03,_2014]`. National renewable energy laboratory report.

Nass&Wind, 2011. URL `http://nassetwind.com_[Accessed_October_20,_2014]`.

F. Neuwahl, A. Löschel, I. Mongelli, and L. Delgado. Employment impacts of EU biofuels policy: combining bottom-up technology information and sectoral market simulations in an input-output framework. *Ecological Economics*, 68(1-2):447–460, 2008.

Observatoire Régional de l'Énergie et des Gaz à Effet de Serre en Bretagne (OREGES). L'environnement en Bretagne, cartes et chiffres clés, 2011. URL `http://www.observatoire-energie-ges-bretagne.fr/Indicateurs-et-bilans/Bilans-regionaux-annuels_[Accessed_October_08,_2014]`. 16 p.

Observatoire Régional de l'Énergie et des Gaz à Effet de Serre en Bretagne (OREGES). L'environnement en Bretagne, cartes et chiffres clés, 2012. URL `http://www.observatoire-energie-ges-bretagne.fr/Indicateurs-et-bilans/Bilans-regionaux-annuels_[Accessed_October_06,_2014]`. 28 p.

Observatoire Régional de l'Énergie et des Gaz à Effet de Serre en Bretagne (OREGES). L'environnement en bretagne, cartes et chiffres clés, 2013. URL `http://www.observatoire-energie-ges-bretagne.fr/Indicateurs-et-bilans/Bilans-regionaux-annuels_[Accessed_October_01,_2014]`. 28 p.

C. Oliveira, D. Coelho, P. Pereira Da Silva, and C. H. Antunes. How many jobs can the RES-E sectors generate in the Portuguese context? *Renewable and Sustainable Energy Reviews*, 21:444–455, 2013.

Ouest France. Saint Brieuc. Soixante deux éoliennes offshore de 8 MW, 2014. URL http://www.entreprises.ouest-france.fr/article/saint-brieuc-soixante-deux-eoliennes-offshore-8-mw-10-07-2014-153154_[Accessed_October_08,_2014].

Oxford Economics. Analysis of the employment effects of the operation and maintenance of offshore wind parks in the UK, 2010. URL www.oxfordeconomics.com_[Accessed_October_08,_2014]. A Report for Vestas Offshore.

M. Pedden. Economic impacts of wind applications in rural communities, 2005. URL www.nrel.gov/docs/fy06osti/39099.pdf_[Accessed_December_23,_2014]. NREL Technical Monitor: Flowers, L. Subcontract Report NREL/SR-500-39099.

W. Pfaffenberger, K. Jahn, and M. Djourdjin. Renewable energies: environmental benefits, economic growth and job creation. Case study paper, 2006. Bremer Energie Institut. Germany.

R. Pollin, H. Garrett-Peltier, J. Heintz, and H. Scharber. Green recovery: a program to create good jobs and start building a low-carbon economy, 2008. Department of Economics and Political Economy Research Institute (PERI), University of Massachusetts - Amherst. 42 p.

RIH. Pour un développement durable des activités maritimes et des territoires maritimes. Juin 2011. URL http://rih-lehavre.com/upload/RIH_ACTES_2011_FR.zip. Les Rencontres Internationales du Havre (RIH). 62 p.

J. I. Round. An interregional input-output approach to the evaluation of nonsurvey methods. *Journal of Regional Science*, 18:179–194, 1978.

RTE. Bilan électrique 2013 et perspectives: Bretagne. Réseau de Transport d'Électricité (RTE), 2013. URL http://www.rte-france.com/fr/nous-connaitre/espace-presse/dossiers-de-presse/rte-ouest-bilan-electrique-2013-perspectives-en-region-bretagne_[Accessed_October_01,_2014]. 31 p.

Saint-Cast-le-Guildo. Saint-Cast port d'Armor port de maintenance, 2012. URL http://cotesdarmor.fr/lamenagement_du_territoire/la_mer_et_le_littoral/projet_dun_parc_eolien_en_mer.html_[Accessed_October_12,_2014]. Communauté de communes Pays de Matignon. Pays de Dinan. CEPR.

Saint-Quay-Portrieux. Port de Saint-Quay-Portrieux : le port pour la maintenance des éoliennes offshore en Côtes d'Armor, 2012. URL http://cotesdarmor.fr/lamenagement_du_territoire/la_mer_et_le_littoral/projet_dun_parc_eolien_en_mer.html_[Accessed_October_12,_2014].

E. Sastresa, A. Usón, I. Bribián, and S. Scarpelleni. Local impact of renewables on employment: assessment methodology and case study. *Renewable and Sustainable Energy Reviews*, 14:679–690, 2010.

J. Schmookler. *Invention and economic growth*. Harvard Univeristy Press, 1966.

H. Schuman and P. Stanley. *Questions & answers in attitude surveys: experiments on question form, wording, and context.* Reprint edition, 1996. Thousand Oaks, CA: SAGE Publications.

J. A. Schumpeter. *Capitalism, socialism and democracy.* New York : Harper, 1942.

Scottish Entreprise. A guide to offshore wind and oil & gas capability, 2011. URL `http://www.scottish-enterprise.com/~/media/SE/Resources/Documents/GHI/Guide-offshore-wind-oil-gas.ashx`. 42 p.

K. Sercy, R. T. Carey, and E. W. Seltzman. South Carolina offshore wind economic impact study - Phase 2, 2014. URL `http://sti.clemson.edu/reports/cat_view/293-regional-economic-analysis-laboratory_[Accessed_October_17,_2014]`. Coastal Conservation League. Clemson-Strom Thurmond Institute.

M. Simas and S. Pacca. Assessing employment in renewable energy technologies: a case study for wind power in Brazil. *Renewable and Sustainable Energy Reviews*, 31:83–90, 2014.

M. C. Slattery, E. Lantz, and B. L. Johnson. State and local economic impacts from wind energy projects: Texas case study. *Energy Policy*, 39:7930–7940, 2011.

B. Snyder and M. J. Kaiser. Ecological and economic cost-benefit analysis of offshore wind energy. *Renewable Energy*, 34(6):1567–1578, 2009.

Solar Foundation. National solar jobs census 2010: a review of the US solar workforce, 2010. URL `http://thesolarfoundation.org/research/national-solar-jobs-census_[Accessed_December_23,_2014]`.

X. Sun, D. Huang, and G. Wu. The current state of offshore wind energy technology development. *Energy*, 41:298–312, 2012.

P. Terneyre. *Énergies marines renouvelables. Enjeux juridiques et socio-économiques*, chapter Le droit applicable au marché des énergies marines renouvelables, pages 255–259. A. Pédone edition, 2013. UMR AMURE Centre de droit et d'économie de la mer. Actes de colloque. Brest, le 11 et 12 octobre 2012.

P. Thornleya, J. Rogersb, and Y. Huang. Quantification of employment from biomass power plants. *Renewable Energy*, 33:1922–1927, 2008.

T. Tohmo. New developments in the use of location quotients to estimate regional input-output coefficients and multipliers. *Regional Studies*, 38:43–54, 2004.

C. Tourkolias and S. Mirasgedis. Quantification and monetization of employment benefits associated with renewable energy technologies in Greece. *Renewable and Sustainable Energy Reviews*, 15(6):2876–2886, 2011.

US DE. Potential economic impacts from offshore wind in the Southeast region, 2013. URL `wind.energy.gov/_[Accessed_October_16,_2014]`. US Departement of Energy. Energy Efficiency & Renewable Energies. DOE/GO-102013-3858.

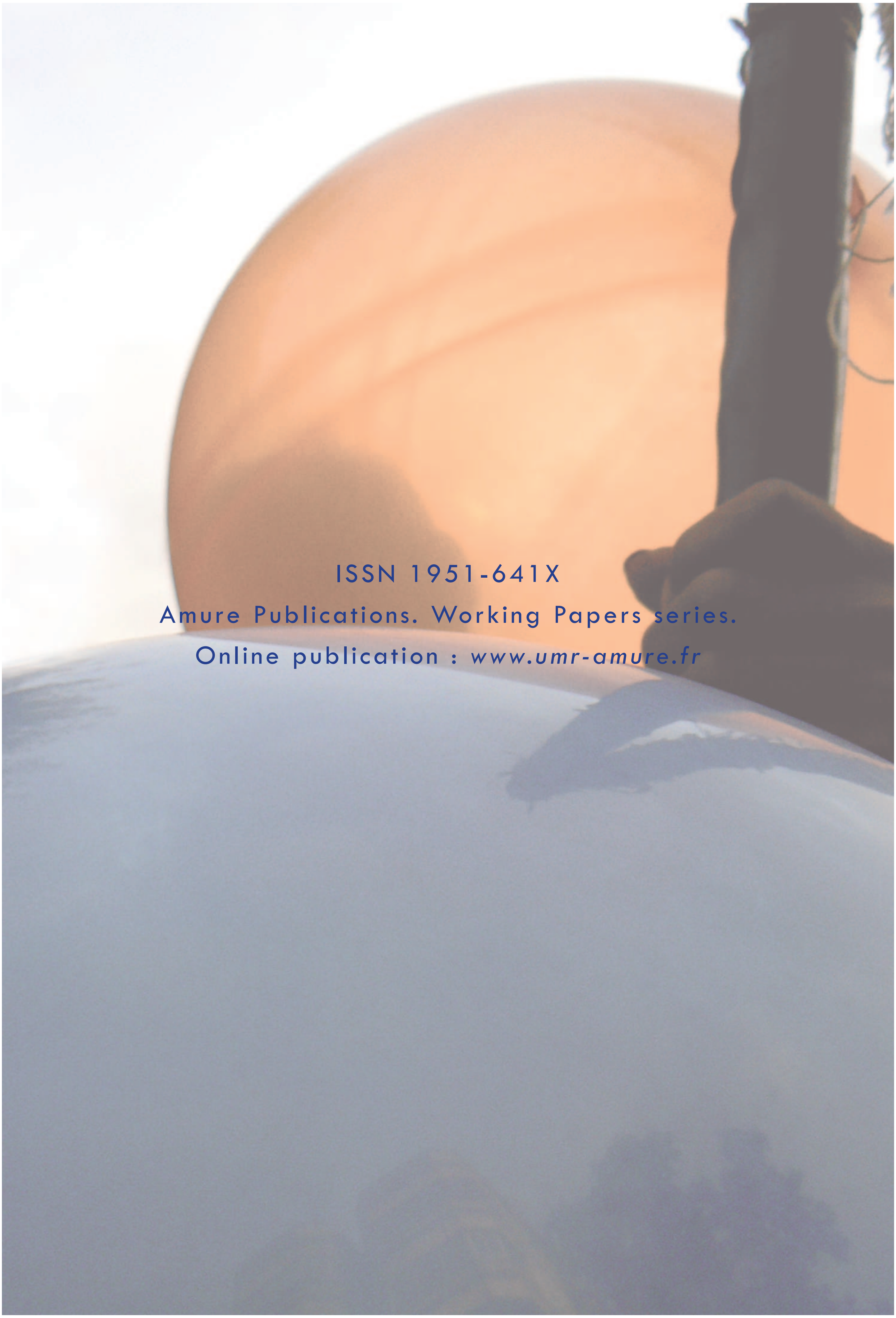
C. Wang, W. Zhang, W. Cai, and X. Xie. Employment impacts of CDM projects in China's power sector. *Energy Policy*, 59:481–491, 2013.

M. Wei, S. Patadia, and D. Kammen. Putting renewables and energy efficiency to work: how many jobs can the clean energy industry generate in the US. *Energy Policy*, 38(2): 919–931, 2010.

H. F. Weisberg, J. A. Krosnick, and B. D. Bowen. *An introduction to survey research, polling, and data analysis.* Third edition, 1996. Thousand Oaks, CA: SAGE Publications.

D. Zammit and J. Miles. Potential economic impacts from offshore wind in the United States - The Southeast region. Applying the offshore JEDI model to estimate economic impacts of potential offshore wind farms along the South Atlantic coast, 2013. URL `http://www.windsystemsmag.com/article/detail/548/potential-economic-impacts-from-offshore-wind-in-the-united-states--the-southeast-region/_[Accessed_October_16,_2014]`.

Z. X. Zhang and H. Folmer. Economic modelling approaches to cost estimates for the control of carbon dioxide emissions. *Economic Economics*, 20:101–120, 1998.



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