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Direct employment in the wind energy sector: An EU study

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ABSTRACT

Wind energy is often said to have positive effects on employment, but few studies have systematically dealt with this matter. This article presents estimates of direct wind energy employment in all EU countries, gathered for the first time. By using a thematic survey, the authors have been able to analyse aspects such as gender distribution, company profiles and the shortage of skilled workers reported by wind energy companies. The outcomes show that wind energy deployment creates a significant number of jobs (over 104,000 in 2008), and does so at a time when other energy sectors are shrinking. There is a clear relationship between MW installed and number of jobs, but the use of a single EU job/MW ratio is not feasible, due to differences in the export/import capacity. Wind turbine manufacturers—including major sub-components—are responsible for the lion's share of the jobs, and there is a marked prevalence of males in the workforce. The scarcity of specialist roles—project managers, engineers and O&M technicians—is not likely to be solved unless a series of educational, mobility and dissemination measures are put into practice.

1. Introduction

The wind energy sector has grown exponentially since the end of the 1990s, especially within the European Union (EU), and this has affected the employment levels of the regions involved. A number of studies have attempted to measure the phenomenon (Table 4 contains a comprehensive list), but a careful scrutiny shows that many of them are in reality meta-analyses (critical re-examination and comparison of earlier works) and/or have a limited geographical coverage.

The reasons why it is difficult to quantify the number of jobs coming from wind-related activities have to do with the lack of detail in the official statistics, which does not allow researchers to exploit the data, and with the variety of company profiles that make up the sector, which can be hard to identify and examine. Tailored surveys and input–output (I–O) tables thus constitute the only sources of reliable information but they are limited by the rapid evolution of the sector; this means that even when the methodology is sound, regular updates are necessary.

In addition, there is insufficient knowledge of the employment types that are required by the wind industry. The reported shortage of skilled workers in certain fields demands a better understanding of the companies' needs and of the labour market conditions. It would also be useful to analyse whether public action can encourage a flow of workers from educational centres and declining activities to this emerging source of job opportunities.

This article tackles both problems:

- First, it offers the most updated figures on the number of jobs attributable to wind energy in the European Union. For the first time, a break-down by member state is given, accompanied by an explanation of the main job-creating companies in each country. The design and application of an EU-wide survey complemented by an analysis of the annual reports of the main wind energy companies and by the expertise of the national wind energy associations and public institutions ensures that the figures are trustful and comparable between them.
- Second, it scrutinizes, by means of the above-referred questionnaires and by in-depth interviews to key agents, the types of job the industry finds hard to fill, where and why shortages occur, and how to address these shortages.

We also seek to determine the usefulness or not of applying simplified ratios for the calculation of future employment patterns, the distribution of employment by gender and by company type, and the identification of the factors that determine the location of large manufacturing centres.

The remainder of the article is organised as follows:

Section 2 explains the methodologies that can be used to obtain wind industry employment figures, their advantages and disadvantages. It goes on to describe the questionnaire that has been used to collect data on direct employment, the results of the questionnaire and the methods used to fill in the gaps.

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Section 3 presents an updated set of wind employment figures (direct jobs) at EU level. Data for the individual member states is given, as is a break-down of the figures by gender and company type. The section includes a discussion of some methodological elements and with a comparison with the wider energy and electricity sectors.

Section 4 reveals the types of job the wind energy sector needs to fill in, analyses the causes that are behind the job shortage and suggests some measures that could be taken to alleviate the situation.

Section 5 recaps the conclusions that can be drawn from the research.

2. Employment prediction and methodologies

2.1. Methodological approaches to employment quantification

The first obstacle found by a researcher trying to quantify employment levels in the wind energy sector is the delimitation of the companies that are part of it, given the non-existence of an official classification.

Wind turbine manufacturers and major sub-component manufacturers are clearly part of the sector and normally belong to the category of manufacturing (chemical products, non-metallic mineral products, fabricated metal products or electrical machinery).

It also seems reasonable to include the companies that generate and distribute electricity from wind energy, either utilities for which green power is only part of their business or independent owners of wind farms.

A third group would be made up of promoters, which are the companies that manage all the process of wind measurement and sitting, the environmental impact assessment, installation and construction of the wind farm and the negotiation of the renting and permits.

Finally, one could incorporate the centres specialised in activities that are specific of wind energy, like wind energy measurement and forecasting; wind-related R&D; operation and maintenance of wind turbines; specific training modules, and so on. Their diversity, small size and local nature makes it difficult to identify and to target them.

Past efforts show that the solutions adopted are divergent. A number of studies include companies from the four categories mentioned above (ADEME (2008) for France; AEE (2008a) for Spain; Boettcher et al. (2008) for the United Kingdom; Lehr et al. (2008) for Germany), while others have preferred to focus on the first two—normally adducing practical reasons and stating on their conclusions that the results should be taken as a minimum value: this is the case of the European Wind Energy Association (EWEA) in its 2003 chapter for Wind Energy—The Facts (EWEA, 2003), also the Danish Wind Industry Association (DWIA, 2008), which quantifies manufacturers and major component manufacturers, while attributing the remaining jobs to the category of indirect employment.

A practical approach followed by some consists of targeting the membership of the national wind energy associations. This practice could introduce some bias in the results—non-members are not taken into account—but does not appear to be a major problem at the moment, because the associations represent a very high share of wind energy companies, maybe due to their emerging nature and to the fact that they partially depend on public support, and thus need to keep a continuous lobby that is best dealt from an association.

In this research, we have adopted the most popular approach, therefore, including companies from the four categories, which have been identified on the basis of the national and European Wind Energy Association membership, plus the attendants to the most relevant EU conference on wind energy. The next section broadens this information.

Coming to the question of information sources, employment data in Europe is collected by means of periodic surveys, generally known as "labour force surveys", which follow the NACE methodology (***S**tatistical **C**lassification of **E**conomic **A**ctivities rev* 1.1). Wind turbine producers and operators appear under sections of "Manufacturing" (D) and "Electricity, gas and water supply" (E, 40.1). Promoters and service companies can be found in "Construction" (F), "Real state, renting and business activities" (K), "Education" (M) and some others.

As explained in the introduction, no country in Europe possesses statistics with the level of detail that would allow employment directly attributable to the wind energy sector to be quantified. The alternative consists of designing an ad-hoc approach, which can take two forms:

- Data collection based on surveys and other written information, for example company annual reports, official tax-related enterprise registers, or government statistics.
- Data collection based on estimated relationships between sectors, vectors of activity and I–O tables.

2.1.1. Pros and cons of surveys and other written information

The advantages and limitations of social surveys as tools for quantifying social/economic phenomena are extensively covered in specialised literature (see, for instance Rubio and Varas, 1999; Weisberg et al., 1996; Schuman and Stanley, 1996); therefore this article does not go into similar details.

Instead, we can sum up the critical points relating to this type of assessment, which covers direct employment only. Firstly, it is essential to appropriately identify the subject of the study—either the whole "population" or a representative sample of it. Secondly, the questionnaire needs to be easily understood by the respondents and avoid biased answers. Thirdly, the information gathered must be studied and analysed properly. For surveys such as these, the response level tends to be low in proportion to the total population/sample selected, and this can mean the results have to be completed from other sources.

When an official register is used, the validity of the information depends on its comprehensiveness, reliability and its being regularly updated. Very often the registers include only part of the data that is being investigated, and that is why they tend to be used in combination with other techniques.

2.1.2. Pros and cons of I–O models

The I–O approach is used to estimate the direct and indirect interrelationships and impacts (including employment) of one sector on all the other sectors of a particular economy. The methodology was first introduced by Wassily Leontief in the 1930s (Leontief, 1986) and in its most basic form consists of a system of linear equations containing productive coefficients that describe the relationship between input used by the sector and the final product. The I–O table traces the sources of each sector's input, whether it is purchased from other firms in the economy or imported, and provides a break-down of the sector's output, with a quantification of sales to other industries and final demand (Kulisik et al., 2007). The table provides quantitative data on the size of the effect on total employment, income and gross output.

As one can easily guess, designing I–O models is difficult, and there are few research institutions in each country which can

boast of having such a model. When an emerging sector like wind energy needs to be studied, the I–O table must be adapted. This can be done by adding a new vector to the model, or by adding new elements into the coefficients of the technical coefficient table for the economy. In both cases, the analyst will need detailed information on the characteristics of the emerging sector, and this is normally gathered through questionnaires and expert interviews (Mattas et al., 1984; Miller and Blair, 1985).

In the field of energy, the reference models at EU level are PRIMES and Green-X, prepared by the National Technical University of Athens and the University of Vienna, respectively. Employment and GDP interactions are given by ASTRA, elaborated by the Fraunhofer Institute. These models provide the figures that are published by the European Commission in its impact assessment reports, for example, its 2007 Impact Assessment on the Renewable Energy Roadmap (European Commission, 2006).

The advantages of the I–O models are the comprehensiveness of the data gathered and the fact that they reflect net economic changes—changes in the sector being studied, in other economic sectors that are linked to it, and in the whole of the economic system through changes in taxation, consumption, accumulation of capital and export capacity. The disadvantages relate to the cost of carrying out such studies and the need to get hold of an appropriate model. These types of study do not provide any details at sub-sector level and do not examine issues of gender, qualification or shortages in human resources.

2.2. Thematic survey on direct employment

In the last six or seven years, coinciding with the boom of the wind energy sector, several studies dealing with its employment repercussions have been conducted. Table 4 contains a summary of their main features and outcomes.

A careful methodological revision shows that many of them are in reality a meta-analysis (i.e., a critical re-examination and comparison of earlier works). Research based on questionnaires and/or I–O tables is less common: Denmark, Germany and Spain, being the three world leaders, boast of solid studies but the size of the other EU markets remains largely unknown. In particular, there is a lack of information on some key features affecting the wind energy labour market, like the profiles that are more demanded at the moment, shortage and gender issues. These issues can best be dealt through ad-hoc questionnaires sent to wind energy companies.

In response to these gaps, we have sought to quantify the number of people employed directly by the wind energy sector in Europe by means of a questionnaire. Direct jobs relate to employment within wind turbine manufacturing companies and sub-contractors whose main activity is supplying wind turbine components. They also include wind energy promoters, utilities/independent power producers selling electricity from wind energy and major R&D, engineering and wind energy services companies. Any other company producing intermediates, components, providing services or sporadically working in wind-related activities is deemed to provide indirect employment. Our research did not cope with the indirect and net employment effects of wind energy. Readers interested on that information can have a look at the European Commission impact assessment on the Renewable Energy Roadmap (2006), the MITRE report (Whiteley et al., 2004) or at the studies that exist in some countries (AEE, 2008a; DWIA, 2008; Lehr et al., 2008).

We attempted to minimise the main disadvantages that affect this type of methodology. The questionnaire was drafted after a careful analysis of previous research in this field, notably the questionnaires that had been used in the German, Danish and Spanish studies and a discussion with the researchers responsible for them. A draft was sent to a reduced number of respondents, who then commented on the clarity and comprehensibility of the questions and the use of excel sheet, the length of the questionnaire and some other aspects. The document was modified accordingly.

The final version of the questionnaire was dispatched by e-mail on 19 February 2008 to around 1100 organisations from 30 countries (the 27 EU member states plus Croatia, Norway and Turkey). It went to all European Wind Energy Association members and the members of the EU-27 national wind energy associations. The questionnaire was also distributed to the participants at the two very recent European Wind Energy Conferences (EWECs 2006, 2007).

The document was translated into five EU languages (English, French, German, Spanish and Portuguese), and some national wind energy associations decided to write the introductory letter in their own languages. A reminder was sent on 11 March and was followed up by telephone in April, May, June, July and August.

The questionnaire consisted of 14 questions, divided into three blocks:

(a) The first four questions collected information on the profile of the company, its field of activity (according to the classification given in Section 2.1) and the year in which it started operating in the wind energy sector.
(b) The next three questions aimed to gather relevant employment figures. The questionnaire asks for both the total number of employees in the company and the number of employees in the wind energy part, and gives some indication as to how to calculate the second figure when a worker is not devoted to wind-related activities full time. The figures were split by country, since some companies are transnational, and by gender. It would have been interesting to have this data by age and level of qualification too, but the draft sent to a sample of respondents showed us that this level of detail would be very difficult to get and that it would have a negative impact on the number of replies.
(c) The final four questions addressed the issue of labour force scarcity in the wind energy sector, trying to obtain information on the profiles that are lacking and the prospects of wind energy companies in terms of future employment levels and profiles. Questions 9 and 10 were more speculative than the rest, since it is difficult to quantify the exact number of jobs likely to be created in the next five years, but they aimed to give an order of magnitude that could be then compared with the quantitative approaches used by other researchers who have applied I–O tables.

A copy of the questionnaire in English can be found in Annexture 1. The questionnaire was complemented by in-depth reviews to a selection of stakeholders reflecting the main wind energy sub-sectors and countries. The interviews were carried out by phone, e-mail or face-to-face. They aimed to verify the data coming from the questionnaires and to address some of the topics that could not be dealt with in them, notably a more thorough explanation of the job profiles required by the industry, the scarcity problem and a rough estimate of employment according to age and qualification.

By the end of August 2008, 328 valid questionnaires had been received, implying a rate of responses of 30% approximately. In terms of size, most of the large turbine and component manufacturers, as well as the major utilities answered the questionnaire, implying that the percentage of jobs that they report is higher (around 50%).

Table 1
Survey results[a].

Country	No. of direct jobs reported by the survey
Austria	270
Belgium	1161
Bulgaria	91
Cyprus	1
Czech Republic	52
Denmark	9875
Estonia	5
Finland	194
France	2076
Germany	17,246
Greece	812
Hungary	11
Ireland	875
Italy	1087
Latvia	6
Lithuania	6
The Netherlands	824
Poland	312
Portugal	425
Romania	27
Slovakia	22
Slovenia	4
Spain	10,986
Sweden	1234
UK	2763
Rest of Europe	70
TOTAL	50,434

(a) These countries have been included in the "Rest of Europe" category—last row of the table.
Source: Own elaboration.
[a] In few cases, the questionnaires were filled in by the researchers themselves. This happened when the figures were communicated through a phone call or an e-mail.

Table 2
Replies received from the top-10 world suppliers and operators.

Top-10 world suppliers	Answer to the questionnaire
Vestas (Denmark)	Yes
GE Wind (US)	Yes, complemented by annual report
Gamesa (Spain)	Yes
Enercon (Germany)	Yes, complemented by annual report
Suzlon (India)	Yes
Siemens (Denmark)	Yes
Acciona (Spain)	Yes
Goldwind (China)	No factories in Europe
Nordex (Germany)	Yes
SINOVEL (China)	No factories in Europe
Top-10 world operators[a]	
Iberdrola (Spain)	Yes
Acciona (Spain)	Yes
FPL (US)	No activity in Europe
EdP (Portugal)	Yes, complemented by annual report
Babckock Brown (Austrialia)	No
Long Yuang Electric power group (China)	No activity in Europe.
Eurus Energy Holding (Japan)	No activity in Europe.
NRG Energy (US)	No activity in Europe.
EdF (France)	Yes
Cielo Wind Power (US)	No activity in Europe.

Source: Own elaboration. Company ranking comes from BTM Consult, March 2008.
[a] Operators are much more local in nature than the manufacturers, and this is why the top-10 world operators do not coincide with the European ones.

The results of the survey are the following: Tables 1 and 2. Fig. 1.

The figures are good for this type of survey, but required the use of supplementary sources in order to fill in the gaps and to validate the results. This was done by

(1) reviewing the annual reports and websites of the main wind energy companies, notably the large wind energy manufacturers, component manufacturers, wind energy developers and utilities. As these companies are on the stock market, they publish some information on their activities and structure that can be used to roughly estimate wind energy figures.
(2) using the results of the studies coming from the three main wind energy markets—Denmark, Germany and Spain. The latter two countries base their numbers on questionnaires very similar to the ones used by us, an exhaustive analysis of the governmental registers for tax-related purposes, national input–output tables and other technical coefficients in order to estimate the effects on indirect employment. The Danish Wind Industry Association, in turn, collects information about employment from all its members on an annual basis and then predicts indirect jobs through technical coefficients and multipliers.
(3) assessing the data compiled by the national wind energy associations. France, the United Kingdom and Portugal are currently carrying out studies covering employment issues amongst others. Their preliminary conclusions have been taken into account in this report, although some modifications have been necessary to ensure that the results were fully comparable with ours. For the other countries, experts from the national associations and governmental bodies were contacted.

Additionally, we undertook an in-depth examination of the factors behind the repeatedly reported shortage of workers in the wind energy business and the profiles that are particularly difficult to find. This was done through in-depth interviews (conducted face-to-face, by e-mail and by telephone) with the human resource managers of a selection of wind energy companies covering a range of types of work and geographical areas. The results were compared with those from questions 7 to 10 of the general questionnaire.

3. Main results

3.1. Direct employment in Europe

Wind energy companies in the EU currently employ around 104,350 people. The total number of wind energy-related jobs in the EU can be compared with the results obtained in the survey for 'Wind Energy–The Facts' (EWEA, 2003): 46,000 workers.[1] The growth experienced between 2003 and 2007 (226%) is consistent with the evolution of the installed capacity in Europe (276%; EWEA, 2008) over the same period, and with the fact that most of the larger wind energy companies are European.

A significant proportion of direct wind energy employment (*circa* 72%) is based in three countries, Denmark, Germany and Spain, whose combined installed capacity also adds up to 70% of the total in the EU. Nonetheless, the sector is less concentrated now than it was in 2003, when these three member states accounted for 89% of EU employment and 84% of total cumulative installed capacity (EWEA, 2003). This is due to the opening up of manufacturing and operation centres in emerging markets and to the local nature of many wind-related activities, such as promotion, O&M, engineering, legal services and so on. The situation in the eastern European member states is varied, with Poland in a leading position. Wind energy employment in these countries will probably rise significantly in the next three to five

[1] 15 Member States considered.

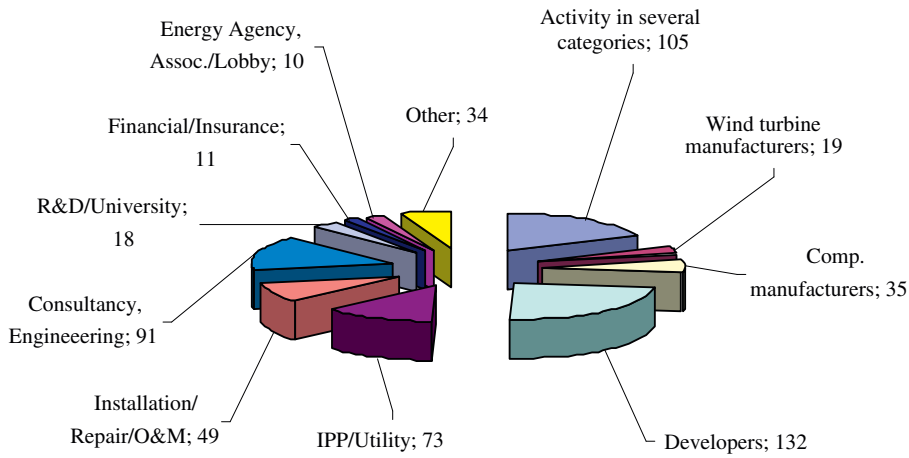

Fig. 1. Number of questionnaires received by type of company. *Source*: Own elaboration.

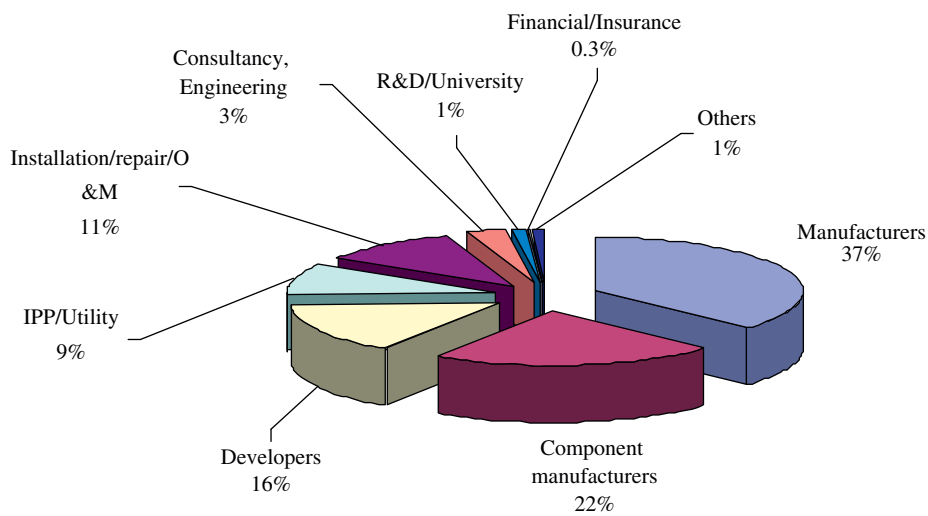

Fig. 2. Direct employment by type of company, according to the survey results. *Source*: Own elaboration.

years, boosted by a combination of attractive markets, a well-qualified labour force and lower production costs.

In terms of gender, the survey shows that males make up 78% of the industry's workforce. In the overall EU labour market, the percentage is 55.7%. The large proportion of men in the wind energy industry corresponds with their traditional predominance in the production, building and engineering sectors. Women, in contrast, are more concentrated in sectors of the labour market like households, health and social work, education and retailing (Statistical Office of the European Communities, Eurostat, 2007a,b).

If we look at the different types of company, wind turbine and component manufacturers are responsible for the lion's share of the jobs (59%). These results are consistent with what has been found by other studies (AEE, 2008b; Lehr et al., 2008). Fig. 2.

3.2. Summary of the situation in each member state

If we take a closer look at the situation in each of the EU member states, the picture would be the following: Table 3.

And additional remark can be made, regarding the usefulness or not of the technical coefficients (jobs/MW ratio in its simpler form) that are used by some analysts to get a fast estimate of the number of jobs that wind energy deployment can bring to a certain country or region. If we take the numbers from Table 3 and divide them between the MW installed in each country at the end of 2007, we find that the job/MW ratio varies significantly. The highest fraction is found in Belgium and Denmark (6.97 and 5.44, respectively) and the lowest in Austria and in the Czech Republic (0.76 and 0.86). Representative countries like Spain, Germany or France offer diverging results (1.35; 1.71; 2.44). Some outcomes have an easy explanation—e.g., Denmark exports practically all is production—but not others. The inclusion of indirect jobs (figures coming from the national studies that exist) does not improve the ratios: 7.36 in Denmark; 3.95 in Germany; 2.49 in Spain. More generally, this indicator is difficult to use for comparison between countries or sectors because of the ambiguous definitions of wind energy-related activities (i.e., whether they are restricted to manufacturing and operation, or also comprise other jobs) and import–export relations.

Our conclusion is that the jobs/MW ratio should not be used to ascertain the gross employment effects that will come from the deployment of wind energy in a non-determined region or country: a case-by-case analysis has to be made. The factors that—according to our respondents—determine where to set up a business are market size, proximity to one of the three traditional leaders, the existence of a positive national regulation (including

Table 3
Summary of employment profiles (direct jobs) in the different EU member states.

Country	No. of direct jobs	Employment-creating companies
Austria	750	Austria is a recognised leader in renewable energies, especially in the biomass and small hydro sub-sectors. Most of the direct employment linked to wind energy technology comes from sub-suppliers, consultancies, developers and independent power producers. In contrast with other EU member states, many wind energy investors are small companies made up of local residents, and this explains why local acceptance is high.
Belgium	2000	Since the early years of wind energy development, Belgium has in some ways been a pioneer, setting up a competitive component-manufacturing industry specialising in gearboxes, cranes, dredging and software. Nowadays, the country is taking another important step with the operation of the first 6 MW onshore wind farm and the construction of a 30 MW far-shore farm, which opens up a variety of job opportunities not only in the traditional sectors of construction, development and operation, but also in vessel construction and logistics, remote control devices and so on.
Bulgaria	100	The approval in 2007, of a feed-in tariff for wind energy projects has attracted the main international wind energy developers and power producers. Currently there are no large manufacturing facilities in the country, but this situation will change soon, since several large investors have ambitious plans there. For now, wind energy jobs are concentrated in development and operation. There are some companies that produce electrical equipment and subcomponents.
Czech Republic	100	As for Bulgaria, there are a variety of wind energy developers and operators, both national and international, present in Czech territory. The future growth of the wind industry and its corresponding impact on employment will depend on the government removing the administrative and grid access barriers that currently hinder wind energy projects.
Denmark	17,000 (23,500)	Denmark was the first country which believed in wind energy as a large-scale solution for electricity generation (20% of annual production today). The three largest wind turbine and components manufacturers account for a staff of 13,000. The additional 4000 constitutes a conservative estimate of the remaining categories used in this article, and the total number of jobs (direct+indirect) goes up to 23,500. The country is a world leader in wind energy companies, especially turbine and component manufacturers, R&D centres and specialised service companies. Almost 40% of the capacity installed globally is made up of turbines produced by Danish manufacturers.
Finland	800	Finland has a competitive renewable energy industry, driven by the biomass and biofuels segments and strongly export-orientated. For wind energy, the country specialises in the production of certain components and there is one Finnish company that manufactures wind turbines suitable for a cold climate. An improvement of the support mechanism could drive large investments, since the resource is good and the Nordpool market offers an adequate framework for the integration of wind energy into a large power area.
France	6000	The rapid growth of wind energy installations (6th world power) has led to an industry based on developers of different sizes, component manufacturers (transformers, cranes, masts, and electronic equipment), engineering and consulting companies. France is also the leader in the manufacturing of anti-cyclone wind turbines, which do not need cranes for installation. The interest of the national power company in renewable energy investments and the settlement of the main international groups reflect a changing mentality ,and points to the consolidation of a national industry with strong potential (up to 16,000 direct jobs in 2012 according to a recent report from ADEME, the French National Energy Agency).
Germany	38,000	Germany is the country with the most wind-related jobs—a total of 38,000 are directly attributable to wind energy companies[a] and a slightly higher amount is indirectly related to the sector. According to the BMU, over 80% of the value chain in the German wind energy sector in 2007 was exported (Federal Ministry of the Environment, BMU 2006 and 2008).
Greece	1800	There are sizeable numbers of wind farm owners in Greece, and the main turbine suppliers and promoters have opened up offices there, although they do not produce locally. Major subcontractors include erection specialists, tower and crane manufacturers, as well as a number of institutes devoted to engineering and R&D activities.
Hungary	100	The Hungarian wind energy market is growing up, and wind-related jobs are linked to wind farm development and construction, legal and technical services. There is also a large carbon-fibre group which, since 2004, has devoted a significant part of its business to supplying this strategic raw material to large wind energy manufacturers.
Ireland	1500	The wind energy landscape of Ireland is dominated by wind farm developers, some of which have gained strong international positions. The country can also boast of a variety of companies specialising in engineering, legal services, insurance, and finance. The construction of the first offshore wind farms has led to some new offshore companies.
Italy	3000	The steady growth of the Italian market has encouraged a number of international turbine manufacturers to locate and expand operations to Italy. There are several local wind turbine manufacturers—some of which have specialised in small-scale and offgrid applications—and a combination of local and foreign developers. The former national power company decided to invest in renewable energy installations and some other EU utilities have followed their path. Other sources of employment are linked to engineering, financial, and legal services.
The Netherlands	2000	Farmers, co-operatives, small and medium-size wind turbine manufacturers, and independent power producers were important for the development of wind energy in the Netherlands, especially during the 1980s and 1990s. Today, large utilities and developers dominate the scene, and this is reflected in the employment figures. On the manufacturing side, there are several small- and medium-size wind turbine manufacturers, as well as component manufacturing centres. The Netherlands is also well-known for the excellence of its R&D centres. Nowadays, the market and employment opportunities seem to be moving towards the offshore segment.
Poland	800	There are around 100 companies operating in the wind energy market in Poland, many of which are local developers. The country does not yet have any manufacturing centres, but at least one company is planning to open up a factory. Prospects are good and employment figures should rise significantly in the next two to three years.
Portugal	3000	Two wind energy manufacturers will open production facilities in Portugal by the end of 2008 and beginning of 2009, respectively, creating over 3000 new jobs. Excluding these, there are already around 350 jobs in promotion, 50–100 in consultancy and engineering, and 50–100 in sub-supplier businesses. Wind energy operation is important, and the former national utility has one of the largest renewable energy portfolios in the world.
Spain	20,500	Spain is ranked third in terms of capacity installed worldwide and has some of the largest wind turbine manufacturers, developers and operators. According to a recent study carried out by the Spanish Wind Energy Association (AEE), the sector employs 20,781 people (data from December 2007), most of whom are involved in the production of wind turbine components

Table 3 (*continued*)

Country	No. of direct jobs	Employment-creating companies
		(32%) and in the provision of specialised services (31%). Wind turbine manufacturers account for 16% of the wind workforce, and the remaining 21% belong to development and operation companies. It is expected that this figure will increase to 21,000 people in 2012. When indirect employment is taken into account, the total number is 37,730 workers (end of 2007).
Sweden	2000	Sweden has for a long time been a supplier of components to the wind turbine industry. This is still the case, but new agents are entering the market, notably promoters and developers. Most of the large wind energy companies are present in Sweden. The emergence of the first offshore wind farms will benefit the local industry, not only in pure wind energy activities, but also in support services such as vessel construction and transportation, other logistics, remote control devices and so on.
UK	4500	In the UK, the importance of offshore wind energy and small wind turbines is reflected by the many businesses working in this area. There are also large wind energy operators and developers, some of them with a solid international position. Finally, a variety of prestigious wind energy engineering, consultancy and advanced service companies have been established.
Rest of EU	400	Eastern European countries like Estonia and Romania are rapidly expanding and there are plans to build several wind turbine and turbine component factories in the next couple of years. In the meantime, the main international groups are opening up national branches in the key locations. Local companies are springing up in the fields of development, construction and engineering.

Source: Own estimates; ADEME (2008); AEE (2008a,b); Boettcher et al. (2008); DWIA (2008); Federal Ministry of the Environment in Germany, BMU (2008); National Wind Energy Associations contributions.

[a] The 2006 German Ministry of the Environment, Nature Conservation and Nuclear Safety, BMU study (carried out by Lehr et al. (2008) found that 43% of gross wind energy jobs (63,900) were direct; the rest—including O&M—indirect. The Ministry published new data in 2008 (Federal Ministry of the Environment in Germany, BMU 2008; 84,300 jobs) but it does not distinguish between direct and indirect jobs. For the purposes of this article, we have made the split based on the same assumptions (43% direct and 57% indirect).

special schemes for industrial development) and the quality and cost of the labour force. Table 4.

4. The shortage of workers in the wind energy sector

4.1. Job profiles and scarcity issues

In the last two to three years, wind energy companies have repeatedly reported an acute shortage of workers within certain fields. This shortage coincides with a general expansion of the European economy, whose growth rates have been among the highest since the end of the World War II. Statistical Office of the European Communities and Eurostat (2008b) demonstrates that job vacancies have been difficult to fill in all sectors.[2] The changeover rate of workers is high, both for skilled and non-skilled roles.

In the case of wind energy, the general pressure to hire more workers resulting from strong economic growth is reinforced by the extraordinary performance of the sector itself since the end of the 1990s. From 2000 to 2007, wind energy installations in the EU increased by 339% (EWEA, 2008). This has led to a multiplication of job offers in all the sub-sectors, especially in manufacturing and development. Generally speaking, the shortage is more pressing for those positions that require a high degree of experience and responsibility:

- Manufacturers report a shortage for two types of role: firstly, engineers and secondly, O&M and site management activities.
- Wind energy promoters need more project managers—the professionals responsible for getting the permits in the country where the wind farm is going to be installed. It requires a rare combination of specific knowledge of the country in question and wind energy expertise.
- Other profiles, such as financiers or sales managers can occasionally be hard to find, but in general are less of a problem for wind energy companies, maybe because the qualifications that they require are not so specialised.
- For R&D institutes the picture is not clear: of the two consulted, one did not report any problems, while the other complained about the impossibility of hiring experienced researchers. Manufacturers are short of experts in aerodynamics, computational fluid dynamics and other R&D areas.

Most of the sources interviewed did not blame the quality of the university system as the origin of the shortage in human resources, although several pointed out that the recent graduates often need an additional specialisation to work in wind energy that is organised by the company itself. The general view is that the number of engineers that graduate every year is insufficient for the needs of modern economies, which rely heavily upon technological sectors and products.

In contrast, there seems to be a gap in secondary education, where the range and quality of the courses dealing with wind-related activities (mainly O&M, health and safety, logistics and site management) can be insufficient. The skills needed for these profiles change from country to country and sometimes between regions, and this is an additional barrier to the transnational movement of workers.

All experts agree that the wind energy sector is an attractive option for the younger generations. The problem arises when this attractiveness is not complemented by transparent information on the vacancies that are available. This is precisely the main complaint of human resource managers: wind energy is not perceived as a suitable career path until the student has started his university/secondary studies, thus reducing the number of candidates.

4.2. Suggested actions towards an equal supply and demand for labour in the wind energy sector

The following paragraphs include suggestions of ways to ease the human resource problem in the wind energy sector and to facilitate the integration of unemployed people. Some measures require the intervention of the public authorities, while others can

[2] Job vacancy statistics, annual data. Statistical Office of the European Communities and Eurostat, 2008a.

Table 4
Summary of studies dealing with employment creation in the wind energy sector.

Source	Title	Geographical coverage	Methodology	Main results
ADEME (2008)	ADEME&Vous. Stratégie & Études. Maîtrise de l'énergie et développement des énergies renouvelables.	France	Net production/ employment ratios (imports have been disregarded).	7000 jobs in the manufacturing of wind turbines and major sub-components; 500 in companies operating wind energy farms.
AEE (2007)	Eólica 07. Todos los datos, análisis y estadísticas del sector eólico.	Spain	Questionnaires to Spanish wind energy companies, complemented by information from official tax-related registries.	There are more than 300 wind energy companies in Spain, which create 15,450 direct jobs and another 19,560 indirect jobs. This figure may go up to 58,800 if government objectives (20,000 MW in 2012) are achieved. 29.97% of the jobs are in the O&M sub-sector; 22.72% in the manufacturing of the machines; 19.42% in technical and engineering services; 9.12% in manufacturing; 3.24% in R&D and 4.53% in "others".
AEE (2008a)	Estudio macroeconómico del impacto del sector eólico en España.	Spain	Analysis of annual reports+information in the government's tax office. Indirect employment was calculated on the basis of questionnaires and the subsequent modification of I–O tables.	Over 430 companies were studied. Direct employment stood at 20,781 by the end of 2007; 48% of which in manufacturing activities, 30% in service companies and the remaining 16.2% in promotion and operation. The total number of jobs (direct+indirect) was 37,730 at that time. The study estimates that direct employment in 2012 will account for 31,134 people.
Algoso and Rusch (2004)	Job Growth from renewable energy development in the Mid-Atlantic.	Mid-Atlantic States of the United States of America: Maryland, Delaware, New Jersey and Pennsylvania	The number of jobs was calculated with the I-O "Renewable Energy Policy Project". The technical coefficients were estimated by means of a survey to 19 wind energy companies in 2001. Indirect employment figures come from the Texas Comptroller's office.	An installed capacity of 10,200 MW in 2015 would entail 11,100 year-long jobs in wind turbine manufacturing and installation, 740 permanent jobs in O&M and supporting areas and around 12,700 indirect jobs. The jobs/MW ratio is 2.48. Choosing wind energy over a comparable amount of natural gas installations would create more than twice as many jobs.
Boettcher et al. (2008)	Employment opportunities and challenges in the context of rapid industry growth.	UK	Current and future jobs are based on the application of a coefficient (labour intensity observed in the sector in the past) corrected by the estimated cost reduction in 2020 and by the local content/export market share. The document does not provide figures on indirect employment.	Current level of employment in the UK wind industry stands at approximately 5000. Of these employees, a large percentage are located in parts of the value chain where business models are local in nature (such as development or construction and installation). Depending on the scenario used, it is estimated that 18,000–52,000 additional full-time workers will be needed in the medium term future. The report also addresses the issue of labour scarcity and shows that British wind energy companies have vacancy levels of above 5%. In certain specialist roles, the shortage is significantly higher.
DWIA (2008)	Sector statistics.	Denmark	Questionnaires to Danish wind energy companies.	In 2006, 23,500 people worked for the wind energy sector (direct and indirect). 13,000 of those people were in direct employment in wind turbine and blade manufacturing companies.
European Commission (2006)	European Commission's 2007 Impact Assessment on the Renewable Energy Roadmap.	EU (27 member states)	I-O tables, based on Green-X, PRIMES and ASTRA models.	Meeting the 20% renewable energy (RE) target in 2020 will entail a net increase of 6,50,000 jobs in the EU, half of which may come from the biomass sector. The increase in RE will favour changes in the composition of the labour market, rather than its size.
European Parliament (2007)	Employment potential of renewable forms of energy and increased efficiency of energy use.	EU	Meta-analysis of past employment studies.	A rapid switch to renewables appears to have an unambiguous benefit in terms of overall employment. The growth of a particular segment of the clean energy business (renewables, energy efficiency or sustainable transport) is often partially dependent on the growth in other parts, because the markets for products and technologies are linked. Workers who lose their jobs in the fossil fuel industry should have the opportunity to retrain for employment in the clean energy industry.
EREC (2007)	New renewable energy target for 2020—a Renewable Energy Roadmap for the EU.	EU (15 member states)	I-O tables, based on Sapphire model.	The wind energy sector will account for around 1,84,000 jobs in 2010 (direct and indirect effects) and 3,18,000 in 2020 (if the 20% RE target is reached).
EWEA (2003)	Survey for Wind Energy- The Facts.	EU (15 member states)	Survey of wind energy manufacturers, supplemented by the use of technical coefficients.	Direct employment in turbine manufacturing en Europe for 2002 accounted for 30,946 people, turbine installation for another 14,649, O&M for 2,768.
EWEA and Greenpeace (2005)	Wind Force, 12. A blueprint to achieve 12% of the world's electricity from wind power by 2020.	World	Meta-analysis of past employment studies.	2.3 million jobs will be linked to the wind energy sector worldwide in 2020, if the 12% target is reached. 4,44,000 jobs in North America; 2,22,000 in Europe; 2,51,800 in South America; 44,400 in Africa, 44,400 in the Middle East; 3,25,600 in Eastern European and

Table 4 (*continued*)

Source	Title	Geographical coverage	Methodology	Main results
				transition economies; 4,44,000 in China; 1,48,000 in East Asia; 2,66,400 in South Asia and 1,48,000 in OECD Pacific approx.
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2006)	Renewable Energy: Employment Effects. Impact of the expansion of renewable energy on the German labour market.	Germany	Comprehensive study using a questionnaire and extensive theoretical models (I-O table). The study presents net results on the overall economy; direct, indirect and induced impacts.	The wind energy sector is responsible for around 64,000 jobs in Germany (2004 data). Half of them are direct jobs. By 2030, around 3,00,000 new jobs will be created in the renewable energy sources sector. The net impact should be between 80,000 and 1,30,000, depending on future energy prices.
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (2008)	Kurz–und langfristige Auswirkungen des Ausbaus der erneuerbaren Energien auf den deutschen Arbeitsmarkt. Interim report.	Germany	Update of the 2006 report (questionnaire+I-O table).	84,300 employees in the wind energy sector by the end of 2007 (direct+indirect).
Kammen et al. (2004)	Putting Renewables to Work: How many jobs can the clean industry generate?	EU and the United States of America	Meta-analysis of past employment studies.	The renewable energy sector generates more jobs per MW of power installed, per unit of energy produced and per US$ of investment than the fossil-fuel based energy sector. The distribution of employment benefits across regions can vary considerably. In the US, a 20% RE share by 2020 could create between 1,76,440 and 2,40,850 new jobs, as compared with a figure of 86,369 in the business as usual scenario. The jobs/MW ratio for wind power ranges between 0.71 and 2.79.
Lehr et al. (2008)	Renewable energy and employment in Germany.	Germany	Comprehensive study, using a questionnaire and extensive I-O tables, INFORGE and PANTA RHEI models.	Gross employment figures in 2004: 63,944 workers. The wind sector lacks skilled personnel, but the situation is expected to improve in 2010. Global market share of wind energy products coming from Germany was 40% in 2004, and is expected to decrease to between 15 and 20% in 2020.
Pedden (2005)	Analysis: Economic Impacts of Wind Applications in Rural Communities.	United States of America	Meta-analysis of 13 studies.	Wind installations have a large direct impact on the economies of the local communities, especially those with few supporting industries. A number of local and construction and operation jobs created by a wind energy installation depends upon the skills available in the local community. The jobs/MW ratio is highly variable: from 0.36 to 21,37.
Pfaffenberger et al. (2006)	Renewable energies—environmental benefits, economic growth and job creation.	EU, with emphasis on Germany	Meta-analysis of previous studies.	All studies predict a growth in gross employment. The net employment impacts are substantially less, and can even be negative. None of the studies have taken into account the recent increase in energy prices, which ought to exacerbate the positive effect of RES on employment.
UNEP, ILO, ITUC (2007)	Green jobs: towards sustainable work in a low-carbon world. Preliminary report.	World	Meta-analysis of previous studies.	The wind energy sector created 3,00,000 jobs in 2006 worldwide. The jobs/MW ratio in manufacturing, construction and installation can be situated between 0.43 and 2.51; 0.27 for O&M and 0.70–2.78 in total.
Whiteley et al. (2004)	MITRE project. "Meeting the targets and putting RE to work". Overview report.	EU (15 member states)	I-O tables, based on Sapphire model.	The wind energy sector will create between 1,62,000 and 3,68,000 new jobs in the EU (net effect; direct, indirect and induced) by 2020, according to the current policies and advanced renewables strategy respectively. After 2010, employment levels will only be maintained if the sector is capable of keeping its leading role and finding new markets outside the EU.

Source: Own elaboration.

be undertaken by the industry itself. The list has been elaborated using data sourced from the questionnaires, the recommendations of the European Wind Energy Technology Platform (www.wind-platform.eu), and our own knowledge.

4.2.1. *Measures to promote worker mobility*

Wind energy companies can be an attractive destination for the skilled technical workers coming from Eastern Europe, who sometimes have difficulties finding suitable positions within their

home countries. If their national markets become attractive enough, such companies will probably create a local branch, but until then the governments or the European Commission may consider actions to help bring such workers into the industry. Wind energy companies could regularly inform public authorities on types of position available in order to facilitate the process. They could also be more active in publicising their vacancies in those member states. The wind energy sector can also absorb part of the former workforce of declining economic sectors. In fact, this has already happened in regions like Nakskov in south-eastern Denmark and Bremenhaven in the north of Germany, both with declining shipping industries which have been replaced by wind turbine manufacturing centres.[3]

4.2.2. Measures aimed at the educational system

There is room to improve the educational system at university and pre-university levels, particularly in activities related to O&M, site management, the transportation of heavy material, and health and safety rules. The European Wind Energy Technology Platform (www.windplatform.eu) has proposed creating a "European Wind Energy Training Centre", with correspondents in various member states and local partnerships with universities. The creation of an EU-wide certification system could also be a valuable initiative (see, for instance, the objectives of the EU-funded windskills project, which aims to establish a European Qualification Profile for the key onshore and offshore process assignments) and the vocational training that is given to unemployed people could focus more on expanding sectors like wind energy.

4.2.3. Dissemination measures

It is crucial that both potential workers and the young generations are aware of the opportunities that the sector offers. Information on the possibilities need to start being spread during secondary education. This task could be led by wind energy companies through job fairs and university employment offices, but it also requires the complicity of the educational system. Unemployment offices, training centres and universities should inform their applicants about fast-growing sectors. In some cases, these centres/universities may lack experienced teachers for emerging areas of work: a training course for the teachers would then be appropriate.

5. Summary and conclusions

This article has provided an updated and comprehensive analysis of the jobs that are directly attributable to the wind energy sector in the European Union, not only an overall total, but also jobs divided by member states, by activity and by gender. The article sheds some light on the alleged scarcity of qualified workers.

The findings can be summarised as follows:

- Wind energy companies in the EU currently employ around 104,350 people. This represents a growth of 226% with respect to 2003.
- Jobs are now more widely spread across the EU than they were 5 years ago, reflecting the emergence of new wind energy markets. France, Italy, Ireland and Portugal are especially dynamic. Eastern European countries also benefit from the liberalisation of their electricity markets and their lower labour costs, but the full impact will only be apparent in the next three to four years, when the changes are consolidated.
- There is a clear link between the number of MW installed and employment, but the two do not run in parallel. While many wind-related jobs, notably development, O&M and specialised services tend to be provided by local companies, the decision to establish large manufacturing and operation centres depends on factors such as market size, proximity to one of the three traditional leaders (Denmark, Germany or Spain), national regulation, quality and cost of the labour force, and so on. The usefulness of the jobs/MW indicator is nonetheless limited by the definition of wind-energy-related jobs and by import–export relations.
- Manufacturers and component manufacturers make up the lion's share of direct jobs in wind energy (59% approx.). Service companies are the third largest category, followed by project developers.
- Wind energy is a predominantly male business (78% of reported employment). This outcome is in line with the characteristics of the European labour market, where men make up most of the workforce in engineering, production and construction.
- Employment in wind energy appears to be counter-cyclical and does not follow the general decline of the energy sector in Europe. A transfer of parts of the workforce from traditional energy sectors towards wind energy has already been observed in some regions of Germany and Denmark.
- The scarcity of suitable candidates for the wind energy industry especially affects the positions that require a high degree of experience and responsibility. The positions that are most difficult to fill in are those related to O&M, project management and aerodynamics, computational, fluid dynamics engineering. While the quality of the university system does not seem to be at the root of the problem, secondary and vocational training centres do not offer enough courses on these subjects. The standardisation of qualifications and a better information system—starting at secondary school—could help to ease the situation and facilitate the transfer of workers towards the areas where they are needed.

Our main conclusion is that wind energy represents an attractive source of employment in Europe. Since a number of activities (construction, O&M, legal and environmental studies) are best dealt with at local level, there will always be a positive co-relation between the location of the wind farm and the number of jobs it creates. The decision of where to locate large manufacturing centres, however, seems to rely on other, often microeconomic factors, and this is where regional and municipal authorities have a role to play. Another relevant point is that wind energy employment is following the opposite trend to the general energy sector, particularly coal extraction and electricity generation, and measures that encourage the transfer of workers from general energy to wind energy will be highly beneficial from both social and economic point of view.

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[3] More details can be found at: http://www.windpower.org/en/core.htm and http://www.windenergie-agentur.de/english/

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Appendix A. Supplementary materials

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