Employment effects of wind-turbine manufacturing and installation in Europe

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1. Direct and Indirect Employment Effect

The employment effect of wind turbine manufacturing can be addressed by adding the employment of the European manufacturing activities. The production structure of these manufacturers are, however, quite different. Some are basically manufacturing most of the components, including blades whereas others are designing and assembling components purchased from different sub-contractors. Therefore, an inclusion of employment at sub-contractors would be a more correct assessment of the employment effect. Because sub-contractors are the next link in the process from basic raw materials to the finished WT, we can use the employment content in the different industries. This measure is based on National Account statistics and using an input-output methodology. Employment content of output from the "electric machinery" sector thus includes the employment in the sector itself as well as the employment in all sectors supplying components and all the previous links of raw materials processing, etc.

We include for wind turbine manufacturing the direct employment within manufacturers, together with the employment that can be calculated based on the supplies of components measured in value terms and referable to some of the aggregated national account sectors.

1.3 Employment in Wind Turbine Manufacturing

Employment within EU	Total	Austria	Denmark	England	France	Germany	Portugal	Spain
Turbine manufacturing, etc.	30946	720	6624	1150	756	10439	60	11197
Share	100%	2.3%	21.4%	3.7%	2.4%	33.7%	0.2%	36.2%

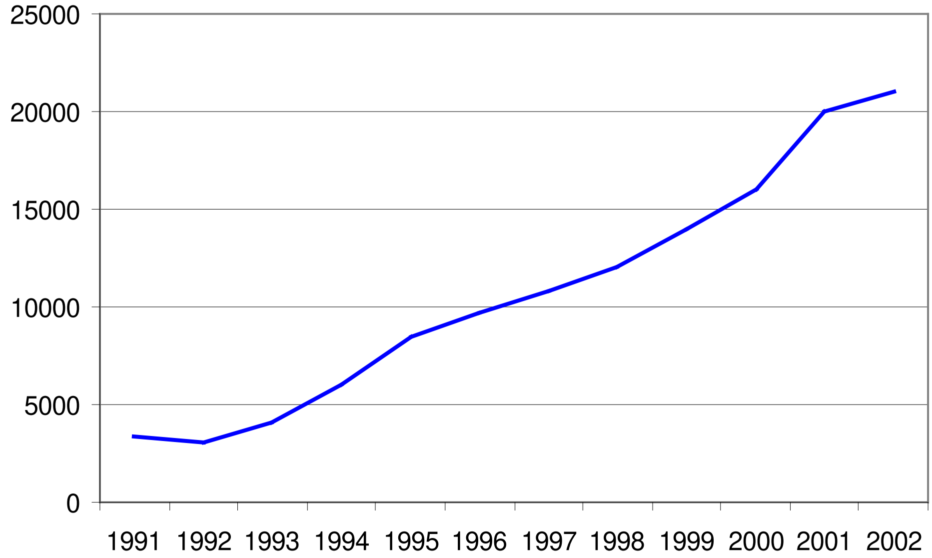
Source: Reporting from National Wind Organisations

Table 1.1: Direct employment in WT manufacturing in Europe for 2002

Employment is concentrated in a few countries of which Germany, Denmark and Spain constitute more than 90%. The share of total employment in manufacturing is on average approximately 0.1% for the EU, but for countries with a large WT manufacturing sector, this share is as high as 1.2% (DK 2002). In Denmark, this specific manufacturing sector thus contributes more to employment than the cement and basic steel production.

Figures for direct employment in Italy and the Netherlands have not been included since they were not reported in the questionnaires, but there is some manufacturing taking place in both of these countries.

Employment has been increasing considerably since the beginning of the 1990's as exemplified by the Danish experience.



Source: Danish Wind Turbine Manufacturers Association, Wind Power Note No. 30, Table 7

Figure 1.1 Direct and indirect employment in the Danish Wind Turbine Sector

The direct and indirect employment in Denmark is estimated to have increased from around 2,900 persons in 1991 to around 21,000 in 2002 (Annual Report 2002, Wind Power notes), which is far more than the increase in any other manufacturing industry. These growth rates will not continue, but this development has brought the sector forward as an important manufacturing sector for the Danish economy and has contributed to reducing unemployment.

In recent years, the growth of employment in WT manufacturing in Germany and Spain has been even higher with nearly a doubling of the employment from 2000 to 2002.

1.4 Employment in Wind Turbine Installation

Apart from the manufacturing of turbines, the installation also contributes considerably to the employment effect in the year of installation. There are differences in employment effect both based on the type of WT, the location and the country of installation. An estimate of the employment related to installation is given in **Source:** Reporting from National Wind Organisations and own calculations
Table 1.2.

Employment within EU	Total	Austria	Denmark	UK	France	Germany	Greece	Portugal	Spain	Others
Turbine installation	14649	213	1500	800	340	5771	30	100	4500	1395

Source: Reporting from National Wind Organisations and own calculations

Table 1.2: Employment in WT installation in Europe for 2002

The employment related to installation in other countries has been calculated based on an average employment per MW installed for the countries that has reported in the questionnaires. The variation in employment between the countries are given in Figure 1.2, which reflects the same differences as seen in the cost variation for installation included in the section on prices and costs. Installation seems to require the highest employment figures in the UK – just as is seen for the installation costs. These figures are, however, considerably higher than earlier Danish studies suggest. Here, the employment for installation was found to be in the region of 5 persons per MW in global employment content for 1998. The direct employment in the largest part of installation activity, namely construction, is around 2/3 of the direct and indirect employment multiplicator for the construction sector. Furthermore, the employment content will be reduced as a result of the cost reduction achieved from 1998 to 2002. There are economies of scale in installation works and thus the employment factor used for the countries not included in the figure is 3 persons per MW. This figure is within the range of the averages included in Figure 1.2.

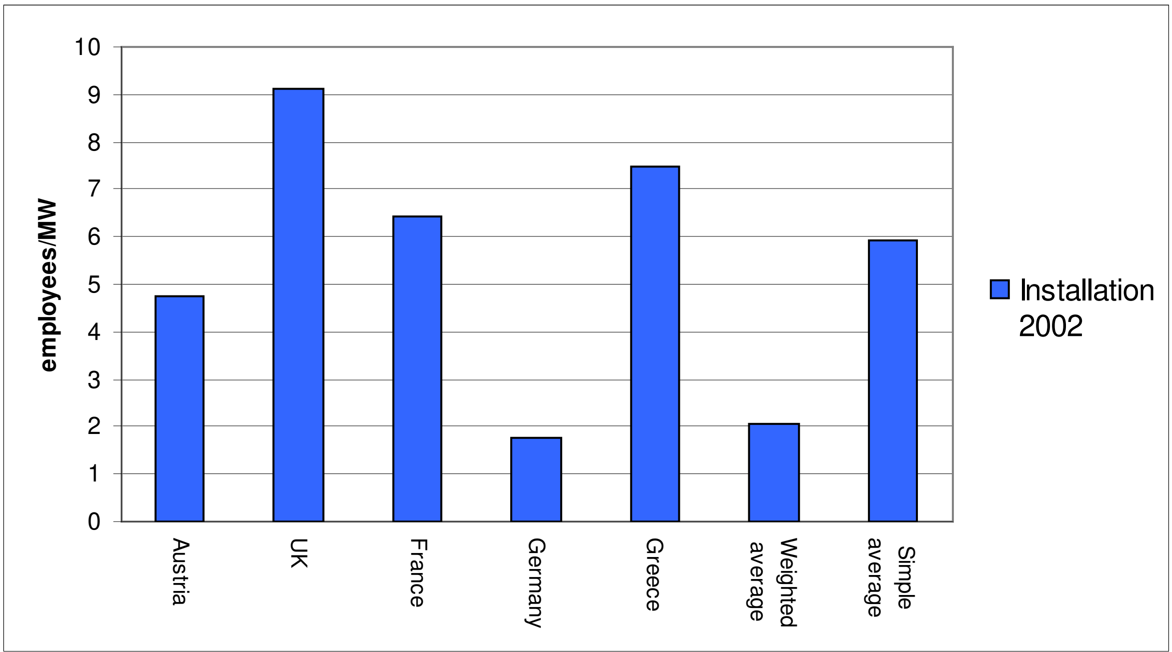


Figure 1.2 Direct employment associated with turbine installation in selected European countries for 2002

The high installation employment in the UK can be partly attributed to the remote siting of wind parks that require quite extensive road and grid infrastructure investments.

1.5 Employment in Maintenance Activities

The employment related to operation and maintenance will increase considerably as the installed capacity increases. However, the present employment related to this activity is still small compared to the employment related to manufacturing and installation.

Employment within EU	Total	Austria	Denmark	England	France	Germany	Greece	Portugal	Spain	Others
Maintenance	2768	60	300	50	44	1010	90	30	966	218

Source: Reporting from National Wind Organisations and own calculations

Table 1.3: Employment in maintenance in Europe for 2002

The employment within maintenance for the group of other countries is calculated based on a conservative value of 0.1 person per MW of installed capacity in each of these countries. Fluctuation given in the employment per MW capacity in Figure 1.3 is quite high, which is partly caused by the difference in the age of the stock of installed turbines and could be partly caused by different composition of wind turbine size and wind park grouping.

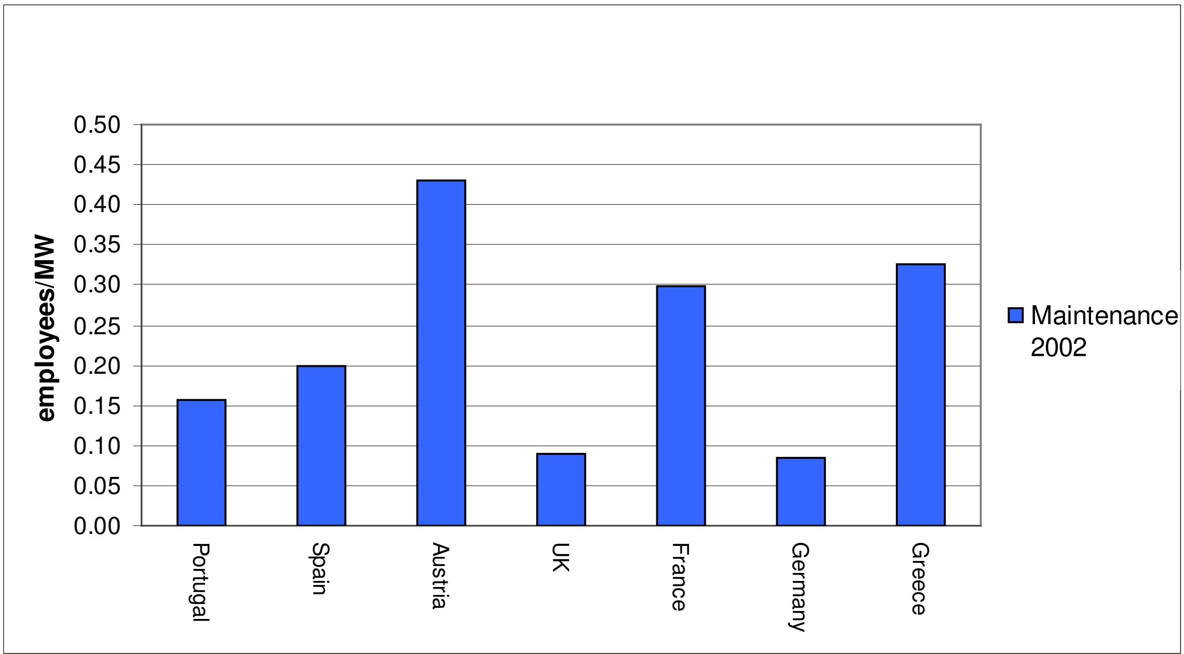


Figure 1.3 Employment in maintenance of wind turbines in selected European countries for 2002

It seems from the figure that maintenance is more employment-intensive in countries with the least installed capacity, namely Austria, France and Greece. It is noticeable that UK has a low maintenance employment compared to other countries whereas the installation-related employment is the highest.

1.6 Indirect Employment in Manufacturing

Assessments for individual countries have produced estimates for indirect employment in those countries.

Individual assessment of Denmark and Germany has been made on indirect employment within each country. For Germany, an indirect employment of approximately 24000 people for 2002 has been estimated and, in Denmark, the figure is reported to be approximately 14500. As a much smaller country, the Danish share of indirect employment must be expected to be less than the German one.

Alternatively, the indirect employment content within different sectors are calculated based on the national account statistics from EUROSTAT.

1.7 Input Structure for Turbine Manufacturing

Firstly, we have to establish the composition of intermediate inputs to the manufacturing of wind turbines. The input structure varies a great deal for the individual manufacturers and thus also for the EU countries. The following is based on the response received from the questionnaires and earlier Danish data:

Input structure Denmark 1995	
	%
Generator	4
Gearbox	12
Rotor	18
Tower	18
Brakes,	1.5
Electronic	4
Nacelle (remainder)	42.5
Total	**100**

Table 1.4 Input structure in the Danish wind turbine-manufacturing sector

The contributing sector of the 25 sector level data from the EU input-output table (see Appendix) have been associated with the production inputs by judgement and based on the Danish study. Only few data for the input structure in manufacturing of wind turbines in the different EU countries are available.

Calculations of indirect employment in manufacturing

All calculations in this section are based on installation of turbines in Europe and not the turnover figures that were unfortunately not available. Turnover has been estimated based on the investment cost for wind turbines given in Volume 2.

	Input structure	**Contributing sector**	**Employment multiplier 1995**	**Employment multiplier 2002**	**Employment 2002**
Generator	4%	Electrical goods	14.22	10.81	1836
Gearbox	12%	Industrial machinery	13.6	10.33	5268
Rotor	18%	Rubber and plastic products	14.27	10.84	8292

Tower	18%	Metal products	19.84	15.08	11528
Brakes,	1.5%	Industrial machinery	13.6	10.33	659
Electronic	4%	Office and data processing machines	10.72	8.15	1384
Nacelle (remainder)	42.5%	Industrial machinery	13.6	10.33	18658
Total	**100%**				**47625**

Source: Input-output tables for EU 1995, EUROSTAT and own calculations

Table 1.5 Calculation of direct and indirect employment for turbine manufacturing

The calculated direct and indirect employment suggests that the direct employment is on a European level 60% of the total direct and indirect employment. This is partly caused by omitting the export part of the turbine manufacturing activity in Europe from the calculations made in this section. However, the figure for the total European manufacturing and installation employment will be closer to 12 persons per MW installed than the 22 persons per MW used elsewhere.

The calculations here might understate employment slightly because of the too high import quota implicit in the employment multiplicators for Europe.

1.8 Indirect employment in WT installation

Again here, the direct employment reported by the national associations varies a great deal and has in a number of cases been quite difficult to estimate. Therefore, a calculation based on the different elements of installation activities has been carried out in order to provide an alternative measure of employment. Firstly, the different elements of installation activities have been estimated from the questionnaires and other sources.

2002	**Found-ations**	**Infrastruc-ture roads, etc.**	**Electrical installations, etc., connections**	**Grid rein-forcement**	**Other installation costs**	**Total installation cost excluding turbine**
France	34%	14%	42%	0%	9%	100%
Denmark (1995)	16%	5%	55%	16%	9%	100%
Spain	23%		54%		23%	100%
Portugal	22%	22%	22%	33%	0%	100%

Table 1.6 Installation costs for wind turbines 2002

The question of divergence in installation cost composition between onshore and offshore wind turbines has not been addressed. If the cost composition is identical for the two locations, the different level of installation costs is without effect on employment per cost unit.

In respect of the cost components, each one must be referred to an National Accounts sector that is supplying the service. As construction is the major contributor to the installation, there will only be minor differences in the employment effect even if the composition of cost differs between the countries. The aggregate employment effect is, however, also dependent on any possible difference in the employment content for each Euro cost. The productivity (labour productivity) varies among the EU countries, especially for non-traded goods, such as construction activities and services. This aspect is not included in the calculations that use EU level statistics for labour content in construction.

Calculation of Indirect Employment in Wind Turbine Installation in Europe

1995 EU data for employment as part of the national accounts has been used.

	Average share of costs 2002 (simple average for those reported)	Contributing sector	Employ-ment multiplier 1995	Employment multiplier 2002	Employment 2002
Foundations	24%	Construction	18.14	13.78	4706
Infrastructure roads etc.	14%	Construction	18.14	13.78	2665
Electrical installations etc., connections	40%	Construction /Industrial machinery	15.87	12.06	6790
Grid reinforcement	16%	Construction	18.14	13.78	3210
Other installation costs	6%	Other market services	57.61	43.78	3780
Total	**100%**				**21150**

Table 1.7 Calculation of direct and indirect employment for turbine installation in Europe for 2002

The basic assumption behind the calculation is that the composition of installation costs as a EU average did not change from 1995 to 2002. For the employment multiplier an assumption of 1.5% increase in labour productivity per year has been made. This implies that the employment multiplier per current cost unit (Euro) decrease by 4% per year.

2. Total Employment in Wind-Turbine Manufacturing, Installation and Maintenance in Europe

The calculations as documented above provide an estimate for employment in the wind industry in Europe, including all the related activities in sub-contractors, etc.

	Employment in wind turbine manufacturing (for home market)	Employment in wind turbine installation	Employment in wind turbine maintenance	Total employment
1998	16725	7400	950	25075
2002	47625	21150	3500	72275
Growth 1998-2002	185%	185%	268%	188%

Source: Own calculations based on installation of wind turbines in Europe and input-output statistics

Table 1.1 Total employment related to wind in Europe for 1998-2002

The figures in the table relating to maintenance employment have been adjusted to include indirect employment as it is estimated that only around 25% of maintenance costs are related to wages. If the manufacturing employment relating to the exporting of turbines had been included, the total employment figures would have been somewhat higher. Finally, it must be added that the global employment relating to wind will be considerably higher than the figures given above, not only as a result of production and installation outside the European region but also due to the indirect employment effect of imported inputs to European wind turbine manufacturing.

Appendix 3.2.A: Calculated Employment in EU Level Sectors

Employment per final demand unit (mio ECU) 1995 EU	Direct	Indirect	Total EU
1 Agriculture, forestry and fishery products	31.66	5.78	37.44
2 Fuel and power products	3.29	19.49	22.79
3 Ferrous and non-ferrous ores and metals	4.93	8.51	13.44
4 Non-metallic mineral products	10.13	4.73	14.86
5 Chemical products	6.12	13.83	19.95
6 Metal products except machinery	**13.11**	**6.73**	**19.84**
7 Agricultural and industrial machinery	**9.75**	**3.85**	**13.60**
8 Office and data processing machines	**9.87**	**0.85**	**10.72**
9 Electrical goods	**9.56**	**4.66**	**14.22**
10 Transport equipment	7.25	2.90	10.14
11 Food, beverages, tobacco	6.37	10.69	17.05
12 Textiles and clothing, leather and footwear	17.89	1.89	19.78
13 Paper and printing products	10.67	8.58	19.25
14 Rubber and plastic products	**9.11**	**5.16**	**14.27**
15 Other manufacturing products	15.12	1.91	17.03
16 Building and construction	**13.33**	**4.81**	**18.14**
17 Recovery, repair services, wholesale, retail	20.62	19.19	39.81
18 Lodging and catering services	19.04	2.37	21.41
19 Inland transport services	14.89	6.84	21.73
20 Maritime and air transport services	6.58	1.25	7.83
21 Auxiliary transport services	6.89	5.11	12.01
22 Communication services	13.60	4.52	18.12
23 Services of credit and insurance institutions	12.02	19.34	31.36
24 Other market services	**12.89**	**44.72**	**57.61**
25 Non-market services	21.30	3.33	24.62
Simple Average	12.24	8.44	20.68

1. Employment Prediction and Methodology

The history of employment related to wind energy in the EU is a very positive story. Employment has been growing very rapidly in recent years and the sector has thus contributed to reducing unemployment in the EU.

A broader understanding of employment in the wind energy sector is, however, not straightforward as there is great uncertainty about what to include in this employment. Here, we have chosen to use a notion of direct and indirect employment and to separately examine the manufacturing of turbines, the installation of turbines in Europe and the employment within maintenance. The use of different terms and the applied methodology is described in the section below.

The objective has been to examine the magnitude of the employment in the sector directly producing wind turbines and the employment associated with the production of inputs to turbine manufacturing. This is not a calculation of the employment created by wind turbine manufacturing, as parts of the employment in the wind turbine sector today would certainly have been employed in other activities had the wind sector not existed. A similar approach would be to evaluate the net employment effect by deducting the employment associated with alternative electricity producing technologies from the employment associated with wind-based electricity production. This approach would result in a net employment lower than the gross employment associated with wind based electricity production. The net effect is, however, assumed to be of a considerable size as the wind power capacity needed would be much higher than the conventional capacity and the employment content is somewhat higher in wind turbine manufacturing and installation.

The other extreme is that some might add that this input-output story does not address the economy's wide employment effects of wind turbines. The argument is based on the fact that the income generated in the sector via wages paid and rents extracted from the sector will contribute to demand for other goods that again will generate employment. However, such arguments should lead to the inclusion of the question how the wind turbine development is being financed. The funds used for wind turbine investment might have been invested in other electricity producing equipment, or in totally different sectors. These investments would have created jobs just like in the wind sector and the net effect could have been both higher and lower depending on the labour intensity of the activities in which investment takes place. One way of addressing these more complex economic linkages is to use macroeconomic general equilibrium models. However, these models do very seldom include details of wind turbine manufacturing and the sectors from where the different components are supplied. At the same time these models produce quite different results of employment effect as a result of different model structure, theoretical orientation and the actual parameter values and forecasts fed into the model.

Therefore, the conclusion in this work has been to focus the analysis on the employment in activities directly producing wind turbines or supporting and supplying to the wind sector. This is not an attempt to address the employment created by the wind turbine sector, or give a figure for *the net employment* effect.

Direct and Indirect Employment

The direct employment in the analysis is the employment within the manufacturing companies that mainly produce for wind-turbines. The companies producing intermediates (parts) for the wind turbine industry is treated as indirect employment if this is only a minor part of their activities. This means that wind turbine manufacturers and the component manufacturers, having this as their main activity (blade manufacturers), are both included in direct employment.

There is another important distinction between the national and the global employment content of wind turbine manufacturing. Direct and indirect employment at national level does not include the employment associated with imports. For small open economies, this means that there will be a large difference between the national and global employment content. For a larger country, or for the entire EU, the difference between national and global employment content will be lessen as the trade flows among the countries are consolidated and the effect included in indirect employment at the EU level. If direct and indirect employment effects for the EU countries are added, this figure will be less than the direct and indirect employment calculated at the EU level.

2. Input-Output Methodology

The calculation of employment is based on the input-output methodology used in economics. The basic idea is to include the effects from suppliers of inputs (raw materials, etc.) to have a better measure of the effect of some activities; in this case, wind turbine manufacturing. Direct employment in manufacturing activities having wind turbine related products as their main output is seen as the first part of a link of employment effects. The secondary links are the employment associated with the production of component and raw materials used in the processing of wind turbines. These secondary effects continue with the employment used for extracting raw materials needed for products that are later used as components in wind turbines. The secondary effects become less and less the further back in the production chain we go.

The employment used is the number of employees per output unit in economic terms.

Example:
1 MW installed capacity at the price of 1 mill. Euro
0.75 mill. Euro of wind turbine output in 2002 (the rest is installation costs etc.):

Direct employment + indirect employment: 0.75 mill Euro x 7.94 employee per mill Euro
+ level 1 input: (input from sector "industrial machinery" x industrial machinery employment coefficient per mill. Euro output) + input from sector 2 x employment coefficient + input sector 3 ….
+ level 2 inputs: (input from sector 2 to sector "electric machinery" x employment coefficient in sector 2 per mill Euro output in sector 2….

The calculation could continue indefinitely, but instead, we use the input-output methodology of calculating the inverse matrix and multiplying by the employment coefficients. The employment coefficient is the direct employment in the sector per output in the sector.

, We have in this case calculated the direct and indirect employment effect from the National Account Statistics of Eurostat for 1995. By using input-output methodology, we calculate the necessary production increases in 20 sectors of the economy to produce 1 additional mill. Euro of output for each of the 20 sectors. Then, these production changes are multiplied by the direct employment in each of the 20 sectors per Euro million of output.

To reach 2002 levels of employment multipliers, the calculated figures for 1995 have to be projected. This can be done individually for the multipliers of all sectors, for example, by using trends in multipliers, or by assuming "productivity" increases. This last approach was chosen here.

National Versus EU Employment

One important aspect is the distinction between national and global employment effect. If considered nationally, the employment effect would include the direct employment effect; but all the indirect effects would exclude the part of inputs that are being imported. Thus, the smaller the country, the larger is the imported share of production inputs. In this way, the indirect employment effect is less for small open economies. If it is a larger country, or a group of countries such as the EU, the indirect employment effect is larger as a much higher fraction of the inputs to the sector will have an origin within the EU.

Then, if all the countries added the national (direct and indirect) employment effect, the sum of these would still be less than (direct and indirect) effect for the entire EU as this also includes employment effect of the intra regional trade flows.

Using Input-Output for Projections of Employment

The input-output methodology used for projections of employment allows the use of different assumptions on developments in productivity for different sectors as well as possible shifts in the composition of inputs from other sectors in the manufacturing of wind turbines.

The productivity and composition changes are closely linked to assumptions that can be made about the overall cost reduction of manufacture of wind turbines. There must be consistency between the assumptions made on cost reductions and the reduction in employment per MW.

3. Projection/Prediction Parameters

In order to make consistent projections of employment, there are a number of parameters that have to be addressed. This includes both activity parameters as well as parameters of technological progress.

Turnover or Indicators for This (output in MW)

The total turnover for the wind turbine manufacturing in the EU is to be projected. One method is to use the installation forecast for MW globally and then add a European market share of manufacturing (see below). Secondly, there need to be a conversion from MW installation to turnover in Euro. 1 MW installed capacity might equal 1 mill. Euro today, but the cost reductions should reduce this figure by at least 2% a year (according to experience curve and cumulated installation). These figures are in fixed price terms, which means that the cost of wind turbines decrease by 2% annually compared to the price of other goods and services.

However this also includes an assumption of an unchanged mix of wind turbine categories between those with low investment cost relative to production and those with higher investment cost per MW, but higher production per installed MW. In some cases, this can be observed as the larger machines having higher investment cost per MW, but lower investment cost per produced kWh.

Share of Production Taking Place in Europe

As the European market dominates both in terms of annual installed capacity and in terms of manufacturing activity, the installation has been equal to European production and then some additional production for exports could be added. The share of production taking place in Europe will in the future be reduced and this development should be addressed by making explicit assumptions. Even though market shares are still high for the European producers, a larger fraction of manufacturing will take place locally at the markets where they are to be installed.

Labour Productivity

Apart from the cost reductions per MW, there will be increases in labour productivity. In the long-term, a 2% annual increase in labour productivity (employment per output unit in fixed prices) is a reasonable assumption for the European economies. This also reduces the future employment effect per MW of installed wind capacity.

Input Composition in wt Manufacturing

Finally, the composition of inputs in wind turbine manufacturing can be addressed. In many cases, there will not be the necessary amount of information to separately project this parameter. Thus, only overall cost reductions will be projected and equally distributed on all inputs. This implies constant technical coefficient in the IO system.

4. Sensitivity – Main Parameters

For all projections, there is a need to identify the most important parameters with respect to their possible variation and their impact on the final result for employment in Europe.

Wind Turbine Market Growth and Regional Distribution

The projection of the wind turbine market is the main assumption for employment as it is clearly the driver for production and thus employment. This is also a projection parameter associated with some uncertainty. The market size in 15 years from now has a possible variation of a factor 10 and is thus the most important parameter for projecting employment in the sector.

Productivity/Cost Reductions

The sensitivity of employment projections to the assumption of cost reductions is less obvious than the sensitivity to market projection. In the longer term, the assumption about technological progress and cost reductions are, however, of a considerable accumulated size and has a large impact on employment forecasts. With experience curves suggesting a 15% cost reduction per electricity output and a 10% cost reduction for turbine costs for every doubling of installed capacity, these cost reductions must partly attribute to reductions in the use of labour input in the production of turbines. Moreover, the installation of turbines will become less labour intense.

The link between cost reductions and accumulated installation makes the cost reductions sensitive to wind market development in addition to the uncertainty that relates to the experience curve itself. Cost reduction that reduce labour input in manufacturing is the reduction in cost per installed MW and not relative to electricity production. Therefore, it is the 10% cost reduction mentioned above that is the relevant figure here. If market growth corresponds to a doubling of installed capacity in five years, then cost reductions per installed MW will decline by approximately 2% per year. This figure might just as well be 1% or 3% depending on market expansion and the "real" experience curve.

European production share

This parameter will change as the future wind development will become more widespread and the European share of total installation will decline. Even though European producers will maintain a high market share, a larger part of their manufacturing activity will take place also outside Europe. These foreseeable changes are very difficult to project and depend on both market forces/demand and strategic developments/reorganisation of the wind turbine-manufacturing sector. The most likely development is that the European producers global market share will slowly decline and that a larger proportion of their activities will take place outside Europe. The impact will be to reduce the growth of European employment within the wind turbine manufacturing sector. The parameter of European market share and location of production facilities is thus an important parameter for sensitivity analyses.

If long-term projections are made, the assumption of market share is very uncertain. Outcomes of 20% market share, or 80% market share, are possible situations in 15 or 20 years from now.

4. Scenarios for Employment in the Wind Turbine Sector

Based on scenarios for the future development of wind in Europe and globally, it is possible to identify corresponding employment scenarios.

5. Projection of Employment based on Wind Energy Installation in Europe and Globally

Based on the assumptions for parameters, etc. described in task 3.3 above, it is possible to develop a scenario for European employment in the wind sector. Here, a very simple scenario with the majority of composition parameters unchanged will be presented.

The scenario has its origin in the projection included in WindForce 12, 2003. The projection of European and global installation levels are used.

- Annual installation will increase to approximately 150.000 MW in 2020 of which 15.000 is in Europe.

- The European share of global manufacturing is assumed to decline to 25% in 2020.

- Turbine manufacturing input is assumed to have constant composition in Europe.

- Installation activity assumed to have constant composition (no change from increased Offshore expansion).

- Assumption on overall technological progress: (cost reduction) Cost reduction will be assumed at a rate of 2% annually.

- Assumption on installation employment productivity development. The assumption here is 2% growth in labour productivity for both manufacture and installation.

In this scenario where a great deal of employment increase will come from expansion of markets outside Europe it will mainly be increases in manufacturing employment that is responsible for overall employment growth.

Manufacturing

Global installation of 150 000 MW in 2020 and a European share of 25% including those for the European market would require

1 mill € per MW in 2002 reduced by 1/1.02^18 = Total investment cost in 2020 of 26256 mill €, of which 75% will be the wind turbine that is produced in Europe (installation will not generate employment in Europe apart from that included below). Wind turbine manufacturing in Europe will be 19692 mill. €.

The employment multiplier from 2002 of 10.82 employee per mill € of activity has to be reduced by the general productivity increase of 2% annually.

The resulting employment in wind turbine manufacturing will then be 7.58 x 19692 = 149200 employees.

Installation

In 2020, 15.000 MW will be installed in Europe. The installation employment from 2002 has to be adjusted for the general increase in labour productivity and the separate increases that has contributed to lowering the total costs of installed wind turbines. This means that the cost reduction is assumed at similar level for the manufacturing and installation of turbines.

Following this, the employment multiplier for installation in 2002 has to be adjusted. We assume that the composition between the components of installation activity is unchanged from Table 1.7, and that the employment multipliers for the contributing sectors all follow the same trend with 2% annual reduction.

15000 MW at a cost of 1 mill € per MW in 2002 reduced by 1/1.02^18 = Total investment cost in 2020 = 10502 mill €

Installation constitutes an unchanged share of 25% of this amount and the employment multiplier for installation is 14.89 in 2002 reduced with the annual productivity increase of 2% result in a multiplier for 2020 of 10.42 per mill € of installation activity

Direct and indirect employment in European wind turbine installation for 2020 is then 27400.

Maintenance

In 2020 an accumulated 230.000 MW will be installed in Europe. With the conservative value of 0.1 employees per MW in 2002 used in task 3.2, this would mean a considerable increase in employment for maintenance. The employment content also has to be adjusted for the general productivity increase of 2% annually. In maintenance, only the general productivity increase is assumed and no additional cost reductions.

With these assumptions, the employment in operation and maintenance in Europe in 2020 is 16100.

Employment Scenario Results

For the scenario described above, the employment has been increased considerably from the employment in 2002. The total employment related to the wind sector in Europe will be 192700 in this scenario based on a considerable expansion of wind energy. This is more than a doubling of the employment in the European sector in today. However, a major part of employment growth will take place in the markets where the installation activity is at its highest. The employment effect in these countries will probably be even higher than in Europe due to lower productivity and wages.

5. Development & Innovation

Development and innovation have contributed to the fast progress of the wind turbine-manufacturing sector. One of the reasons is the ability to adopt technological progress/technology from other sectors and modify these technologies to be used in the wind turbine technology.

The innovation spill over from the wind turbine industry to other sectors has been more modest. In Denmark, one example is the development of small-scale machine-manufacturers to larger companies based on their activities in the wind industry. These small companies often characterised as "smiths" have expanded their expertise with the technology developed for the wind industry. As these companies have often been located outside the traditional business centres, this development has been seen as very positive to a broad industrial development of societies.

Along with the manufacturing of wind turbines, a range of specialised service suppliers for transport, installation, maintenance and insurance has developed.

One promising field of common use of technological progress is within aerodynamics where the use of new materials and the cost reductions is a common target for developers of blades and with the aeronautic industry.

A EU funded research project examining the Experience Curves is (Neij et. al., 2003) analysing the possibility of using experience curve forecasts from one renewable energy source to describe possible developments within other energy sectors (renewable energy). This is based on the idea that some of the technological innovations found for one energy technology (wind energy) can be applied in the development of other technologies.

The turbines manufactured from the mid 80s and until the late 90s mainly were constructed using standard components, the only major exception being the blades, which of course were designed and constructed for specific turbine use. But in the late 90s the turbines were grown that large in size and manufactured in such large numbers, that special components started being designed and manufactured only for turbine use.

In the following a few examples will be given with regard to issues, where turbine development is paving the way for new innovations within the wind industry itself or within related industries, serving as sub suppliers.

Ball bearings

As mentioned above components as ball bearings used for wind turbines were until recently mainly standard products from the ball bearing suppliers. But when going into 2 MW turbines and more it became necessary to produce special large ball bearings for these large turbines. Of course this makes it possible to design these bearings to the specific requirements by wind turbines.

Another niche area in this industry is the bearings that support the pitch-regulated wings. Because of the very small rotation angle of these components used in wind turbines compared to the use in other kinds of machinery, the loads on these bearings are very high. To keep the wear out small specific bearings are being developed that perform well within small rotation angles.

Blades

In the up scaling of the turbines the weight of components as blades, nacelles and towers are of outmost importance. To keep the loads down it is necessary to keep the weight down. This is especially important for the blades and the longer the blades the more the need for lightweight materials. Initially the blades were manufactured using glass fibre materials and in up scaling the turbines it has been possible to reduce the weight mainly by improving the design. But to manufacture blades longer than 40-50m (2-3 MW turbines) requires the use of reinforced composites. Among these are glass fibres reinforced with carbon fibres in general one of the most common techniques, but also hybrid versions using glass fibres and wood are used. Finally, a number of new technologies are taken into use in the production of blades and within this area quite different production techniques are used by different manufacturers

Gearboxes

As for ball bearings also the gearboxes used in turbines were until recently standard components mainly produced as a spin off of other needs in the mechanical industry. But the large numbers of turbines produced nowadays and the requirements from up scaling the turbines also here have pushed the development of specific gearboxes for turbine use. The specific production of lighter and more compact gearboxes is a fairly new phenomenon, again initiated by the need for lighter materials to reduce the weight of the nacelle and thus the loads on larger turbines.

Direct drive

As a number of existing turbines have experiences technical difficulties with gearboxes there has been a strong push towards developing direct drive turbines, which operates with out any gearbox. The direct drive approach requires the use of multipole generators especially designed for turbine use. As larger turbines require increasing sizes of these multipole generators specific research is presently being carried out to reduce the weight and size of these components, e.g. by applying magnets using superconductors.

Installations of offshore turbines

The installation of offshore turbines is a challenging task that in a number of occasions requires new approaches taken into use. To transport and erect the turbines specially designed and constructed vessels are developed, that can carry two or more turbines from the nearest harbour to the offshore site and erect the turbine towers, nacelles and rotors. These vessels are continuously being improved to carry more turbine components, thus reducing the time for

However, these examples are all closely related to the wind-turbine sector itself. The spill over to other sectors should not be neglected. This area of technology spill over from the progress made in the development of wind energy deserves more research activity.

References

Krohn, S (1998) Creating a Local Wind Industry: Experience from Four European Countries

Neij, L.; Dannemand Andersen, P.; Durstewitz, M.; Helby, P.; Hoppe-Kilpper, M.; Morthorst, P.E., (2003) Experience curves: A tool for energy policy assessment. (Lund University, Department of Technology and Society, Environmental and Energy Systems Studies, Lund (SE), 2003) (IMES/EESS Report, 40) 139 p.

Employment in Wind in Denmark (in Danish), Wind Power Note No 2, Danish Wind Turbine Manufacturers Association, 1995

The Energy Balance of Modern Danish Wind Turbines, Wind Power Note No 16, Danish Wind Turbine Manufacturers Association, 1997

The Input-Output Tables: Eurostat Data Shop Handbook, Eurostat 2000

Renewable Energy Sector in the EU: Its Employment and Export Potential, Report to DG Environment, ECOTEC, Birmingham UK 2002

Wind Force 12: A Blueprint to achieve 12% of the Worlds Electricity From Wind Power by 2020, European Wind Energy Association/Greenpeace, May 2003