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CALCULATING GLOBAL ENERGY SECTOR JOBS: 2012 METHODOLOGY

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For Greenpeace International

Draft report

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Abbreviations

BCM	Billion Cubic Metres
CMI	Construction, Manufacturing And Installation
CSP/ CST	Concentrating Solar Power / Concentrating Solar Thermal
DTI	Department of Trade and Industry (UK)
EIA	Energy Information Administration (USA)
EPIA	European Photovoltaic Industry Association
EREC	European Renewable Energy Council
ESTELA	European Solar Thermal Electricity Association
EWEA	European Wind Energy Association
FTE	Full Time Equivalent
GDP	Gross Domestic Product

GEA	Geothermal Energy Association
GPI	Greenpeace International
GW	Gigawatt
GWh	Gigawatt hour
GW_{th}	Gigawatt thermal
IEA	International Energy Agency
ILO	International Labour Organisation
IRENA	International Renewable Energy Association
ISF	Institute for Sustainable Futures
KILM	Key Indicators of the Labour Market
kW	Kilowatt
kW_{th}	Kilowatt thermal
kWh	Kilowatt hour
MW	Megawatt
MW_{th}	Megawatt thermal
MWh	Megawatt hour
MTCE	Million Tons Coal Equivalent (this is unit of energy rather than weight)
NREL	National Renewable Energy Laboratories (US)
NPP	Nuclear Power Plant
O&M	Operations and Maintenance
OECD	Organisation for Economic Co-operation and Development
PV	Photovoltaic
REN21	Renewables Global Status Report
t/p/yr	Tons Per Person Per Year
TWh	Terawatt hour
UNDP	United Nations Development Programme

1 Introduction

Greenpeace International and the European Renewable Energy Council have published four global Energy [R]evolution scenarios, with previous editions in 2007, 2008, and 2010. The Energy [R]evolution modelling makes projections for the world divided into ten regions as defined by the IEA. In each case, a low-carbon Energy [R]evolution scenario is compared to a Reference scenario based on the latest International Energy Agency (IEA) “business as usual” projection from the IEA World Energy Outlook series (International Energy Agency, 2007, 2011a).

The Institute for Sustainable Futures (ISF) analysed the employment effects of the 2008 Energy [R]evolution in 2009 (Greenpeace International and European Renewable Energy Council, 2009; Rutovitz & Atherton, 2009), and updated the methodology in 2010 (Rutovitz & Usher, 2010).

ISF has undertaken the employment analysis for the 2012 Energy [R]evolution (Teske et al., 2012) which includes a number of changes, namely:

- Nuclear decommissioning is included for the first time,
- Employment analysis is extended to include the heating sector,
- Employment in the three major fuel sectors, coal, gas, and biomass, is now analysed on a primary energy basis (per PJ primary energy) rather than a final energy basis (per GWh electricity).
- Projected productivity improvements in coal production have been included for three regions where rapid development is occurring: China, Russian, and India. .

In addition, the employment factors have been updated and employment data for coal mining has been analysed for a greater proportion of world production.

For this study only direct employment to 2030 is included. Direct jobs are those in the primary industry sector and include jobs in fuel production, manufacturing, construction, and operations and maintenance. Indirect jobs generally include jobs in secondary industries which supply the primary industry sector, which may include, for example, catering and accommodation, while induced jobs are those resulting from spending wages earned in the primary industries. Indirect and induced jobs are usually calculated using input-output modelling. The inclusion of indirect jobs would typically increase job numbers by 50 – 100%, while the inclusion of both indirect and induced jobs could increase job numbers by a 100 – 350% (for example Blanco & Rodrigues, 2009; Bournakis, Cuttica, Mueller, & Hewings, 2005; National Renewable Energy Laboratory, 2010a, 2010b, 2011a; Tourkolias & Mirasgedis, 2011).

Energy efficiency jobs have not been included in the calculations, unlike the analysis in 2009. That analysis included *additional* jobs in energy efficiency resulting from the reduction in electricity consumption between the Reference and the [R]evolution scenarios. The 2012 Energy [R]evolution scenarios see a reduction in electricity generation of only 7% by 2030 relative to the Reference scenario, despite a decline in the relative **primary** energy demand of 21%.The discrepancy is primarily because of the expansion of transport associated electricity consumption because of accelerated uptake of electric vehicles in the Energy [R]evolution scenario. This masks the “real” reduction in stationary energy from the Reference to the [R]evolution scenarios. While this could create substantial numbers of jobs, it was not within the scope of this project to develop an assessment methodology, so no energy efficiency job calculations are included.

2 Methodology overview

The methodology used for the 2012 study was first developed for an analysis of the global and regional employment effects of the 2008 Energy [R]evolution, and a fuller discussion of the regional adjustment factors and technology decline factors may be found in *Energy sector jobs to 2030, a global analysis* (Rutovitz and Atherton, 2009).

The Energy [R]evolution contains two scenarios, namely:

1. A business as usual Reference case, based on the Current Policies scenario in the IEA World Energy Outlook 2011 (International Energy Agency, 2011a).

2. A low carbon scenario which is referred to as the Energy [R]evolution scenario.

These scenarios are inputs to the employment modelling. Employment is projected for each of the ten IEA world regions for both scenarios at 2015, 2020, and 2030 by using a series of employment multipliers and the projected electrical generation, electrical capacity, heat collector capacity, and the primary consumption of coal, gas and biomass (excluding gas used for transport).

Only direct employment is included, namely jobs in construction, manufacturing, operations and maintenance, and fuel supply associated with electricity generation and direct heat provision.

Inputs for energy generation and demand for each scenario include:

- The amount of electrical and heating capacity that will be installed each year for each technology.
- The primary energy demand for coal, gas, and biomass fuels in the electricity and heating sectors.
- The amount of electricity generated per year from nuclear, oil, and diesel.

Inputs for each technology include:

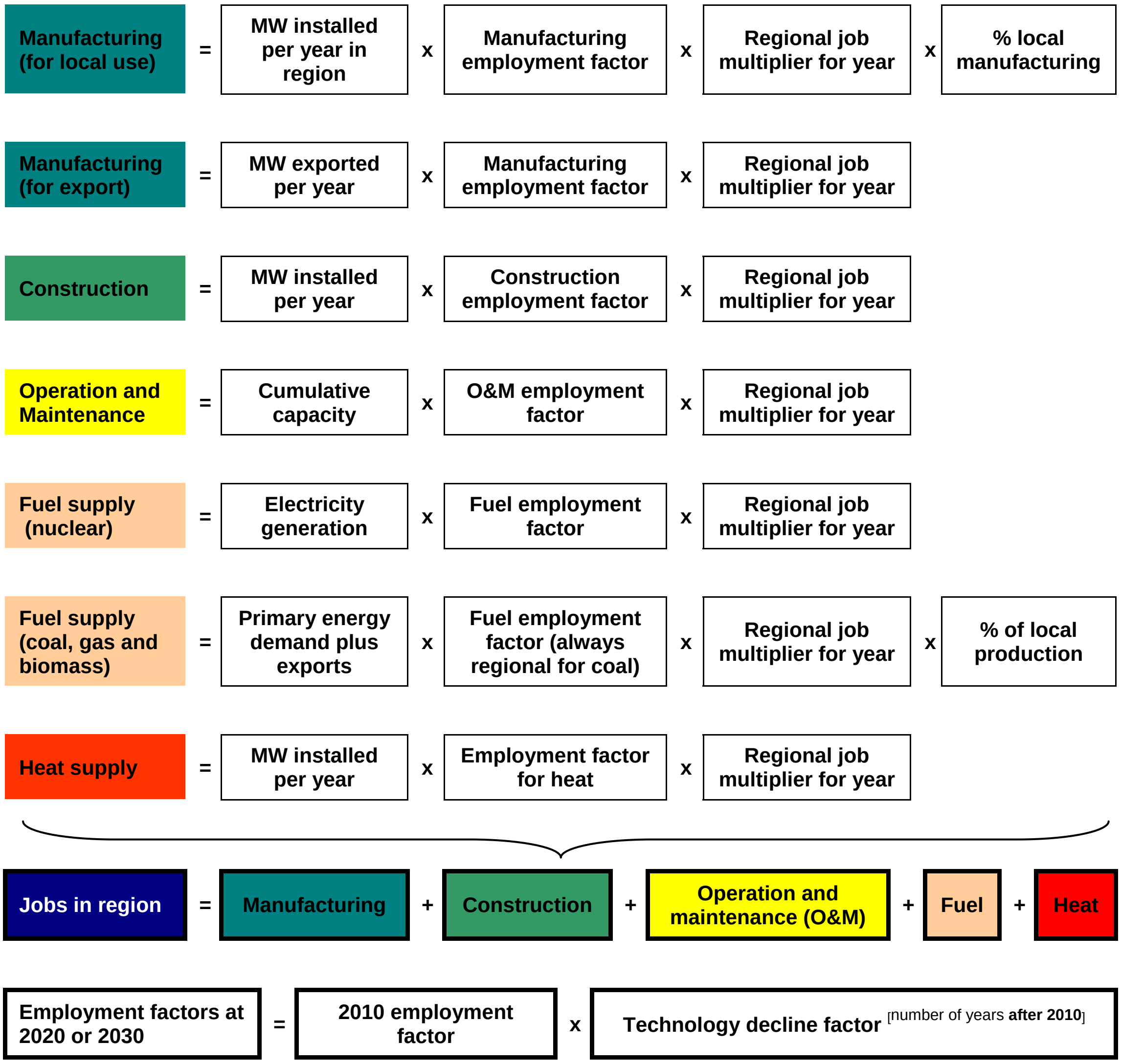
- 'Employment factors', or the number of jobs per unit of capacity, separated into manufacturing, construction, operation and maintenance, and per unit of primary energy for fuel supply.
- For the 2020 and 2030 calculations, a 'decline factor' for each technology which reduces the employment factors by a certain percentage per year to reflect the employment per unit reduction as technology efficiencies improve.

Inputs for each region include:

- The percentage of local manufacturing and domestic fuel production in each region, in order to calculate the number of manufacturing and fuel production jobs in the region.
- The percentage of world trade which originates in each region for coal and gas fuels, and renewable traded components.
- A "regional job multiplier", which indicates how labour-intensive economic activity is in that region compared to the OECD. This is used to adjust OECD employment factors where local data is not available.

The electrical capacity increase and energy use figures from each scenario are multiplied by the employment factors for each of the technologies, and then adjusted for regional labour intensity and the proportion of fuel or manufacturing occurring locally. The calculation is summarised in Figure 1.

Figure 1: Calculation of Energy Supply Jobs: Overview



2.1 Limitations

Employment numbers for the 2012 study are indicative only, as a large number of assumptions are required to make calculations. Quantitative data on present employment based on actual surveys is difficult to obtain, so it is not possible to calibrate the methodology against time series data, or even against current data in many regions. However, within the limits of data availability, the figures presented are indicative of electricity sector employment levels under the two scenarios. However, there are some significant areas of employment which are not included:

- **Replacement**: generating plant require periodic replacement, which has not been included in the analysis. The replacement schedule is approximately twenty years for wind and PV (the renewable technologies which would be most affected owing to their greater penetration), and forty years for coal. However, it is very uncertain what the relative employment creation of replacing generating equipment would be compared to building new capacity. Inclusion of replacement is likely to increase renewable energy jobs proportionately more than coal and gas jobs over the analysis period, as the replacement cycle is somewhat shorter.

- **Energy efficiency:** as noted in Section 1, no estimate is made of energy efficiency jobs, which could be significantly higher in the Energy [R]evolution scenarios than in the Reference case as there is a relative reduction of 21% in primary energy demand by 2030.

- **Jobs in heat supply:** only a partial estimate is made, as biomass, gas, and coal jobs in this sector include only fuel supply jobs where heat is supplied directly (that is, not via a combined heat and power plant), while jobs in heat from geothermal and solar collectors primarily include manufacturing and installation. Insufficient data meant it was not possible to include a comprehensive assessment for this sector.

3 Employment factors

The employment factors used in the 2012 global analysis are shown in **Error! Reference source not found.** below, with the main source given in the notes. Appendix 1 documents the factors used in the previous analysis, and further detail is provided on specific technologies in Appendices 2-8.

Table 1: OECD employment factors used in the 2012 global analysis

	Construction times	Construction/ installation	Manufacturing	Operations & maintenance	Fuel – PRIMARY energy demand	
	Years	Job years/ MW		Jobs/MW	Jobs/PJ	
Coal	5	7.7	3.5	0.1	Regional	Note 1
Gas	2	1.7	1.0	0.08	22	Note 2
Nuclear	10	14	1.3	0.3	0.001 jobs/GWh final demand	Note 3
Biomass	2	14	2.9	1.5	32	Note 4
Hydro-large	2	6.0	1.5	0.3		Note 5
Hydro-small	2	15	5.5	2.4		Note 6
Wind onshore	2	2.5	6.1	0.2		Note 7
Wind offshore	4	7.1	11	0.2		Note 8
PV	1	11	6.9	0.3		Note 9
Geothermal	2	6.8	3.9	0.4		Note 10
Solar thermal	2	8.9	4.0	0.5		Note 11
Ocean	2	9.0	1.0	0.32		Note 12
Geothermal - heat	3.0 jobs/ MW (construction and manufacturing)					Note 13
Solar - heat	7.4 jobs/ MW (construction and manufacturing)					Note 14
Nuclear decommissioning	0.95 jobs per MW decommissioned					Note 15
Combined heat and power	CHP technologies use the factor for the technology, i.e. coal, gas, biomass, geothermal, etc, increased by a factor of 1.5 for O&M only.					
Oil and diesel	Use the employment factors for gas					

Notes on employment factors

1. **Coal**
   Construction, manufacturing and operations and maintenance factors are from the JEDI model (National Renewable Energy Laboratory, 2011b).
   Regional factors are used for coal fuel employment (see below, Section 3.2).

2. **Gas, oil and diesel**
   Installation and manufacturing factors are from the JEDI model (National Renewable Energy Laboratory, 2011c)
   O&M factor is an average the figure from the 2010 report, the JEDI model (National Renewable Energy Laboratory, 2011c), a US study (National Commission on Energy Policy, 2009) and ISF research (Rutovitz & Harris, 2012).
   Fuel factor per PJ is the weighted average of US, Canadian, and Russian employment in gas production, derived from US and Canadian information (America's Natural Gas Alliance, 2008; IHS Global Insight (Canada) Ltd, 2009; Zubov, 2012a).

3. **Nuclear**
   The construction factor is the average of two studies from the UK and one from the US (Cogent Sector Skills Council, 2010, 2011a; National Commission on Energy Policy, 2009). The manufacturing factor is the average of the two UK reports, while the O&M factor is the average of values from all three studies and ISF research (Rutovitz & Harris, 2012).The fuel factor was derived by ISF in 2009 (Rutovitz & Atherton, 2009).

4. **Bioenergy**
   The values for bioenergy employment factors have all been increased since the 2010 report, with the exception of the operations and maintenance factor, which has been reduced. For details see Appendix 1. Considerable variation occurs between different estimates of biomass employment, reflecting both practices in different countries and the considerable variation in biomass feed stocks.
   Employment factors for construction, manufacturing, and O&M use the average values of studies from Greece, the UK, Spain, USA, and one Europe wide (Kjaer, 2006; Moreno & López, 2008; Thornley, 2006; Thornley et al., 2009; Thornley, Rogers, & Huang, 2008; Tourkolias & Mirasgedis, 2011)
   Fuel employment per PJ primary energy is derived from five studies, all in Europe (Domac, Richards, & Risovic, 2005; EPRI, 2001a; Hillring, 2002; Thornley, 2006; Upham & Speakman, 2007; Valente, Spinelli, & Hillring, 2011)

5. **Hydro - large**
   Construction and manufacturing factors are from a US study (Navigant Consulting, 2009).
   O&M factor is an average of data from the US study (Navigant Consulting, 2009) and ISF research (Rutovitz, 2010; Rutovitz & Harris, 2012; Rutovitz & Ison, 2011).

6. **Hydro - small**
   Installation and O&M factors are the average of the figure used in the 2010 methodology report, which was from a Canadian study (Pembina Insitute, 2004) the JEDI model, a US study and a Spanish study (Moreno & López, 2008; National Renewable Energy Laboratory, 2011d; Navigant Consulting, 2009). The manufacturing is the average of the same studies, with the exception of the Spanish study as it did not include information on manufacturing employment.

7. **Wind - onshore**
   The installation factor used is from the European Wind Energy Association (European Wind Energy Association, 2009), and is the same factor used in previous analyses. The manufacturing factor is derived using the employment per MW in turbine manufacture at Vestas from 2007 – 2011 (Vestas, 2011), adjusted for total manufacturing using the ratio used by the EWEA (European Wind Energy Association, 2009). The O&M factor is an average of eight reports from USA, Europe, the UK and Australia (see Appendix 3 for details)

8. **Wind - offshore**
   All factors are from a German report (Price Waterhouse Coopers, 2012).

9. **Solar PV**
   The employment factors for PV have been reduced quite significantly since the 2010 analysis, reflecting the major reduction in costs for this technology. The installation factor is the average of five estimates in Germany and the US, while manufacturing is taken from the JEDI model (National Renewable Energy Laboratory, 2010a), a Greek study (Tourkolias & Mirasgedis, 2011), a Korean national report (Korea Energy Management Corporation (KEMCO) & New and Renewable Energy Center (NREC), 2012), and ISF research for Japan (Rutovitz & Ison, 2011). See Appendix 4 for the details of the different estimates.

10. **Geothermal**
    The construction and O&M factors are the weighted averages from employment data reported for thirteen power stations totalling 1050 MW in the US, Canada, Greece and Australia (some of them hypothetical). The manufacturing factor is derived from a US study (Geothermal Energy Association, 2010). See Appendix 5 for details.

11. **Solar thermal power**
    Construction and O&M jobs were derived from a weighted average of 19 reported power plants (3223 MW) in the US, Spain, and Australia (see Appendix 6 for details). The manufacturing factor used is unchanged from the 2010 analysis (European Renewable Energy Council, 2008, page 16).

12. **Ocean**
    These factors are unchanged from the 2010 analysis. Ocean power is an emerging sector and hence very little data is available for jobs associated with this technology. The construction factor used in this study is a combined projection for wave and tidal power derived from data for offshore wind power (Batten & Bahaj, 2007). A study of a particular wave power technology, Wave Dragon, provided jobs creation potential for that technology, and the O&M factor used here is based on that report ((Soerensen, 2008)).

13. **Geothermal and heat pumps**
    One overall factor has been used for jobs per MW installed. The figure of 1.7 jobs per MW manufactured comes from the US EIA annual reporting (US Energy Information Administration, 2010), adjusted to a figure to include installation using data from WaterFurnace (WaterFurnace, 2009)

14. **Solar thermal heating**
    One overall factor has been used for jobs per MW installed, as this was the only data available on any large scale. This may underestimate jobs, as it may not include O&M. The global figure comes is derived from the IEA heating and cooling program report (International Energy Agency Solar Heating and Cooling Program, 2011). Local factors have been used for the US, Europe, India and China (see Table 2).

15. **Nuclear decommissioning**
    The weighted average decommissioning employment over the first 20 years from one UK study and two German studies is used (Cogent Sector Skills Council, 2009, 2011b; Wuppertal Institute for Climate Environment and Energy, 2007). See Section 3.3 for more details.

3.1 *Regional employment factors*

Local employment factors are used where possible, and coal employment uses a regional employment factor in nearly all cases. Region specific factors are:

- Africa: solar heating (factor for total employment), nuclear, and hydro – factor for operations and maintenance, and coal – all factors.
- China: solar thermal heating, coal fuel supply.
- Eastern Europe/Eurasia: factor for gas and coal fuel supply.
- OECD Americas: factor for gas and coal fuel jobs, and for solar thermal power.
- OECD Europe: factor for solar thermal power and for coal fuel supply.
- India: factor for solar heating and for coal fuel supply.

The regional factors used are shown in Table 2. Where regional factors are not available, a regional adjustment factor is used for non-OECD regions.

Table 2 Regional employment factors other than coal fuel

	Construction/ installation	**Operations & maintenance**	**Fuel – PRIMARY energy demand**	**Notes**
	job years/ MW	jobs/MW	jobs/PJ	
Coal (Africa)	10.4	0.3		Note 1
Nuclear (Africa)		0.66		Note 1
Hydro-large (Africa)		0.04		Note 1
Solar Thermal power				Note 2
OECD average	**8.9**	**0.5**		
OECD Americas	5.3	0.4		
OECD Europe	15	1		
Gas				Note 3
Global average			**22**	
Eastern Europe/ Eurasia			17	
OECD Americas			26	
Solar thermal – heat				Note 4
Global	**7.4 jobs/ MW (construction and manufacturing)**			
Africa	22 jobs/ MW (construction and manufacturing)			
China	10 jobs/ MW (construction and manufacturing)			
India	19.5 jobs/ MW (construction and manufacturing)			

NOTES

1. All local factors for Africa other than coal fuel are from the ISF jobs study for South Africa (Rutovitz, 2010)

2. The OECD average is the weighted average for 3223 MW in Spain, the US and Australia, while the OECD America figure includes only the US data (1512 MW) and the OECD Europe figure includes only European data (951 MW). See Appendix 6 for details.

3. The OECD America data is for the US and Canada (America's Natural Gas Alliance, 2008; IHS Global Insight (Canada) Ltd, 2009), while the Eastern Europe/ Eurasia data is from Russia (Zubov, 2012a).

4. The global figure for employment per MW in solar thermal heating is derived from the IEA solar heating and cooling program (International Energy Agency Solar Heating and Cooling Program, 2011); the employment for China is from the REN21 update (Renewable Energy Policy Network for the 21st Century, 2011, page 189 note 82) with the collector area from the IEA solar heating and cooling program (International Energy Agency Solar Heating and Cooling Program, 2009). The figure for India is from Indian government data (Ministry of New & Renewable Energy & Confederation of Indian Industry, 2010), and the figure for Africa is from the ISF jobs study for South Africa (Rutovitz, 2010)

3.2 Coal fuel supply employment factors

Employment factors were derived with regional detail for the coal supply industry, because coal is currently dominant in the global energy supply, and employment per ton varies enormously by region. In Australia, for example, coal is extracted at an average rate of 13,800 tons per person per year, while in Europe the average coal miner is responsible for only 2,000 tonnes per year. India, China, and Russia have relatively low productivity at present (700, 900, and 2000 tons per worker per year respectively).

The calculation of employment per Petajoule (PJ) draws on data from national statistics, combined with production figures from the IEA and other sources. Data was collected for as many major coal producing countries as possible, with data obtained for 89% of world coal production.

In China, India, and Russia, the changes in productivity over the last 7 to 15 years were used to derive an annual improvement trend, which has been used to project a reduction in the employment factors for coal mining over the study period.

In China and Eastern Europe/ Eurasia a lower employment factor is used for increases in coal consumption, as it is assumed that expansion will occur in the more efficient mining areas.

The employment factors and adjustments used for coal in this report are shown in Table 3, and detailed information on actual regional and country employment and productivity are given in Table 4.

Details of the employment per PJ are given in the next section, with the data sources given in Appendix 7. The derivation of the productivity improvements in China, India, and Eurasia is also explained in Appendix 7.

Table 3: Employment factors used for coal fuel supply

	Employment factor (existing consumption) Jobs per PJ	**Employment factor (new consumption)[1]** Jobs per PJ	**Average annual productivity increase 2010 - 2030** %
World average	23		
OECD America	3.9		
OECD Europe	40		
OECD Oceania	3.4		
India	55		5%
China	68	1.4	5.5%
Africa	12		
Eastern Europe/Eurasia	56	26	4%
Developing Asia	Use world average as no employment data available		
Latin America			
Middle east			

NOTE (1): If this column is blank, the same factor is used for existing and new consumption

Table 4 Detailed coal information by region

	Production 2009 Million tons	**Domestic production** %	**Employment** '000s	**Productivity** Tons/ person/ year	**Average energy content** GJ/ ton	**Employment per primary energy** Person years/ PJ
World	7,225					
World (excluding China)	3,233 [1]			2,269	19.4	23
OECD America	**1,061**	**106%**		**11,314**	**22.7**	**4**
USA	983	106%	88	11,200		
CANADA	65	127%	5	13,373		
OECD Europe	**632**	**78%**		**2,027**	**12.3**	**40**
UK	18	-41%	6	3,056		
Greece	57	99%	5	10,865		
Poland	133	98%	130	1,019		
Germany	182	75%	41	4,457		
Romania	29	97%	22	1,315		
France	3	16%	3	1,076		
Spain	8	-52%	5	1,556		
Czech Republic	55	108%	24	2,305		
Slovak Rep	2	-42%	4	615		
OECD Oceania	**463**	**97%**		**11,930**	**24.5**	**3**
Australia	406	293%	34	11,930		
India	**569**	**89%**	**572**	**995**	**18.4**	**55**

	Production 2009	Domestic production	Employment	Productivity	Average energy content	Employment per primary energy
	Million tons	%	'000s	Tons/ person/ year	GJ/ ton	Person years/ PJ
China	**3,240**	**97%**	**5,110**	**634**	**23.3**	**68**
Africa	**259**	**129%**				**12**
South Africa	252	135%	74	3,417		12
Eurasia/ E.Europe	**608**	**121%**		**926**	**19.4**	**56**
Eurasia/ E.Europe excluding Ukraine	554			**2055**	**18.7**	**26**
Russia	323	143%	160	2,027		
Ukraine	54	91%	271	201		
Bulgaria	30	88%	13	2,359		
Slovenia	4	87%	2	2,406		
Latin America	98	256%				
Non-OECD Asia	986	110				
Middle east	2	71%				

NOTE (1): Data in this row is for all countries other than China for which employment data in coal mining is available, and is used to derive the "world average" figure to use in regions without employment data.

Calculation of employment per PJ

Coal employment per ton is calculated for all countries where employment data is available, using 2010 data where. This is converted to employment per PJ on a regional basis, by using the average PJ per ton for that region. Employment data was obtained for 89% of world coal production.

The average PJ per ton for each region was calculated from International Energy Agency 2009 data, using data from the country and regional coal production statistics (in million tons) and from their Coal Information series (which gives data in MTCE (International Energy Agency, 2012).

Regional employment per ton and per PJ was calculated from the countries within each region with employment data.

Three regions had no employment data; Non-OECD Asia, Latin America, and the Middle East. The world average employment per PJ was used for calculations in these regions, but China was excluded from the calculation as productivity within China is very low, and the large scale of production means the low productivity would have a disproportionate influence.

Two regions, China and Eurasia, include an employment per PJ for increased consumption, as it is assumed that increased production will be met from the highly mechanised mining areas.

China is a special case. While average productivity of coal per worker is currently low (700 tons per employee per year), some highly mechanised mines opening in China have productivity of 30,000 tons per worker per year (International Energy Agency, 2007, page 337). It is assumed that any increase in coal production locally will come from the new type of mine, so the lower employment factor is used for additional consumption met domestically.

Employment information was obtained for four countries in Eurasia: Russia, Bulgaria, Slovenia, and the Ukraine. While the Ukraine has productivity per worker of 200 tons/year, the other three countries have productivity of 2000 – 2400 tons/year. It is assumed that any expansion of production will occur at the higher level of productivity.

3.3 Nuclear decommissioning employment factors

There are currently 436 nuclear power plants (NPPs) operating globally with a net installed capacity of 370,499 MW[1]. In April 2012, 85 commercial NPPs, 45 experimental/ prototype reactors and over 250 research reactors had been retired from operation[2]. Decommissioning has begun in Germany and the UK and many older reactors will reach the end of their useful lives over the next 20 years.

Jobs in nuclear decommissioning have been estimated using projections for the UK and Germany. The UK study included a projection of employment needs from 2010 – 2025 to begin decommissioning 10,250 MW of operational NPPs (Cogent Sector Skills Council, 2009).Decommissioning employment in the UK is assumed to include approximately 3000 MW which had been shutdown prior to 2010, calculated using the IAEA PRIS database[3].

The German data is from a case study for a single site of 2200 MW (International Atomic Energy Agency, 2008), and a study of projected employment needs to decommission nearly 25,000 MW over a 70 year period (Wuppertal Institute for Climate Environment and Energy, 2007). The 25,000 MW figure was calculated using the average MW figures from IAEA PRIS[4] and European Nuclear Society[5] for the capacity of the 19 NPPs in operation in 2001 plus NPPs at Würgassen and Mülheim-Kärlich.

The data is summarised in

Table 5. The weighted average employment over the first 20 years is used to calculate jobs in nuclear decommissioning in this study, and includes both direct utility and subcontractor employment associated with decommissioning operations.

This Energy [R]evolution employment scenario study covers the years 2010 – 2030, so decommissioning extends beyond the end of the modelling period. The decommissioning employment profile is uneven, with more employment in the first 10-15 years. Employment per MW dropped by between 40% and 90% after 15 - 20 years in the three studies. This has not been factored into the employment projection, which means that employment in decommissioning is likely to be underestimated at the start of any decommissioning period. However, in any region different sites are likely to be at different stages, so this is unlikely to adversely affect the results.

Nuclear decommissioning may be approached in three ways: immediate dismantling, safe enclosure, and entombment[6]. The German data is for immediate dismantling of reactors, and this is assumed to be the main approach in the UK. If other approaches

[1] http://pris.iaea.org/public/
[2] http://www.world-nuclear.org/info/inf19.html
[3] http://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=GB
[4] http://pris.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=DE
[5] http://www.euronuclear.org/info/encyclopedia/n/nuclear-power-plant-germany.htm

were taken to decommissioning, the employment profile could be different from that presented here.

These projections provide a profile over the most employment intensive period (first 20-30 yrs)of decommissioning detailing both direct utility and subcontractor employment associated with decommissioning operations.

Appendix 8 shows the profile of employment given for the three studies.

Table 5 Nuclear decommissioning

Country	Capacity de-commissioned	Average employment (1st 20 years)	Average time to de-commission
	MW	Jobs/MW	Years
Germany	2200 [a]	0.90 [a]	24 [a]
Germany	24,687 [b]	0.68 [b]	36 [c]
UK	13,280 [d]	1.5 [d]	Not provided
Weighted average	-	0.96	35

Notes

a) International Atomic Energy Agency, 2008 p.59

b) Wuppertal Institute for Climate Environment and Energy, 2007 p.22; IAEA PRIS database[3] ; European Nuclear Society[5].

c) The reference shows 36 years to reach a skeleton staff, which are maintained for a further 32 years, so full decommissioning is projected to take 68 years.

d) Cogent Sector Skills Council, 2009 p.23; Cogent Sector Skills Council, 2011b p.2; IAEA PRIS database[3].

[6] http://www.world-nuclear.org/info/inf19.html

4 Heat sector methodology and employment factors

The heat sector delivery mechanisms include combined heat and power (CHP), district heating systems, direct process heat used in industry and direct space and water heating by end users (mainly relatively small scale residential and commercial systems).

Fossil fuel heating includes coal, oil, gas, and diesel, while renewable heat includes biomass, solar thermal, geothermal, and heat pump systems. Both renewable and fossil fuel heating may be delivered via any of the systems listed above. Employment in this sector include fuel jobs (for biomass and fossil fuels), and installation, operation and maintenance, and manufacturing jobs for all types.

For the 2012 employment analysis a partial estimate of jobs in the heating sector is made for the first time.

All the fuel jobs in gas, coal, and biomass are captured in this analysis and calculated using primary energy demand rather than final energy demand, as in previous years. Thus whether the fuel is used for electricity generation or direct heat supply, or a combined system, the job calculation for fuel is the same. This is an improvement in any case, as it removes the errors that arise from calculating fuel jobs after conversion to electricity, when efficiencies vary considerably between generation systems. The employment factors for each fuel are shown in Table 1 and Table 3.

Jobs in installation, manufacturing, and operations and maintenance are calculated for CHP systems, as these calculations are included in any case for the electricity sector. This is regardless of whether the CHP is geothermal, solar thermal, or fossil fuel. Jobs in installation and maintenance of process heat equipment from fossil fuel and biomass are not included.

Jobs in installation of solar, geothermal and heat pumps for heat provision have been included. Where the heat supply is via a CHP system, jobs are included under the CHP for the relevant technology. Where heat supply is direct, without CHP, jobs are calculated from the increase in solar or geothermal collector capacity each year.

In the sectoral reporting of jobs, solar thermal heat jobs are allocated as follows: 25% to manufacturing and 75% to construction, while geothermal and heat pump employment is allocated 43% to manufacturing and 57% to construction.

Solar thermal

There was an estimated 172 GW_{th} of solar heating in operation worldwide in 2009, with 36.5 GW installed that year. Total employment in the sector was estimated as of 270,000 (International Energy Agency Solar Heating and Cooling Program, 2009). This has been used for the global employment factor of 7.4 jobs per MW installed used in this analysis. This is down from the factor of 10.5 jobs per MW installed that derived from the same source data for 2007. This estimate includes all employment, i.e. manufacturing, operations and maintenance, and installation.

Table 6 shows the range of employment factors derived for solar heating; it should be noted that most of them are considerably higher than the one used.

Regional data has been used where it is clearly identified as such and comes from a large capacity estimate. Thus the analysis for OECD Europe, India, and China use local figures.

Table 6 Range of employment factors for solar heat supply

Region	Year	Job years/ MWth	Job years/ collector area (m2)	Notes/ Sources
Global	**2011**	**7.40**	**0.005**	**International Energy Agency Solar Heating and Cooling Program (2011), page 7**
Europe	2010	13.0	0.009	European Solar Thermal Industry Federation (2011)
Germany	2010	13.79	0.010	Total employment in the solar thermal sector from Federal Ministry for the Environment Nature Conservation and Nuclear Safety (2011), Page 20, the split between heat and power from IRENA (2011), page 17 footnote 3, and the increase in capacity from European Solar Thermal Industry Federation (2011), page 5
India	2010	19.48	0.014	From Ministry of New & Renewable Energy & Confederation of Indian Industry (2010)
Spain	2008	43.75	0.063	Moreno & López (2008), Table 6. Includes O&M of 5 jobs per 1000m^2, converted to jobs years assuming 12 year life for equipment.
Global	2007	10.05	0.007	IEA Solar Heating and Cooling Program (2009), pages 5 and 6
Spain	2007	44.06		8,174 direct jobs in solar thermal heat in 2007 (UNEP, 2008) and 2007 capacity increase of 185.5 MWth (International Energy Agency Solar Heating and Cooling Program, 2009, page 15)
China	2007	40.30		Reported in United Nations Environment Programme (2008), page 115
China	2007	10.08		Total 2007 solar thermal employment from Renewable Energy Policy Network for the 21st Century (2011), page 109, footnote 82. Total collector area from IEA Solar Heating and Cooling Program (2011).
Italy	2006	2.31	0.002	Solar Expo Research Centre (2007)

A conversion factor of 0.7 kW_{th} per m^2 has been used, from International Energy Agency Solar Heating and Cooling Program (2011), page 5.

Geothermal and heat pumps

Geothermal and heat pumps cover a wide range of technologies, including ground source and air sourced heat pumps. Unfortunately, the main data source for this employment factor was the US EIA annual reporting (US Energy Information Administration, 2010) of manufacturing, which does not distinguish employment between the two areas. We have therefore used a combined estimate for jobs per MW.

The figure of 1.7 jobs per MW manufactured from the US EIA annual reporting (US Energy Information Administration, 2010) was used, adjusted to 3 on the basis of the ration between manufacturing and installation employment identified by WaterFurnace (WaterFurnace, 2009).

5 Regional adjustment factors

The available employment factors are for OECD countries or regions, and need adjustment for differing stages of economic development. Broadly, the lower the cost of labour in a country, the greater the number of workers that will be employed to produce a unit of any particular output, be it manufacturing, construction or agriculture. This is because when labour costs are low, labour is relatively affordable compared to mechanised means of production. Low average labour costs are closely associated with low GDP per capita, a key indicator of economic development.

This means that changes to levels of production in any given sector of the economy are likely to have a greater impact on jobs in developing countries than in developed countries. Ideally, employment factors would be derived for both developed and developing countries. In practice, data for developing countries is extremely limited. Instead the derived OECD employment factors are multiplied by a proxy regional adjustment factor. It is important to derive these job multipliers from a relatively complete data set with global coverage. The best available proxy factor is average labour productivity, measured as GDP (or value added) per worker.

Job multipliers are expected to change over the study period (2010 to 2030), as the differences in labour productivity alter with regional economic growth. Fortunately regional economic growth is a key input to the energy scenarios, as it is the major determinant of projected changes in energy consumption. We therefore use the projected change in GDP per capita derived from GDP growth and population growth figures from 2011 World Energy Outlook (IEA 2011) to adjust the regional job multipliers over time.

The factors shown in Table 7 are applied to OECD employment factors when no local employment factor is available.

Table 7 Regional multipliers to be applied to employment factors

	2015	2020	2035
OECD	1.0	1.0	1.0
Africa	4.3	4.2	4.6
China	2.6	1.9	1.0
Eastern Europe/Eurasia	2.4	2.1	1.5
India	3.6	2.8	1.5
Latin America	2.9	2.7	2.4
Middle East	2.9	2.8	2.5
Non-OECD Asia	3.0	2.3	1.4

Derivation of regional adjustment factors

A regional labour productivity value was calculated for each of the ten analysis regions using data from the International Labour Organisation Key Indicators of the Labour Market (KILM) database (ILO 2012). This database holds data for economy wide average labour productivity, calculated as average GDP per engaged worker.

Countries were grouped according to the Energy [R]evolution regional categorisation, and labour productivity data for each country was used to calculate weighted average productivity for the region, with weighting proportional to the total workforce.

Table 8 Numbers of countries with labour productivity data

Region	Number of countries in GPI/ EREC	Number of countries with data available on labour productivity
OECD Americas	4	4
OECD Europe	23	23
OECD Asia-Oceania	4	4
Africa	55	19
China[7]	2	2
Non-OECD Asia[8]	29	13
India	1	1
Latin America	38	14
Middle East	13	10
Eastern Europe/Eurasia	25	25
Total	**194**	**115**

Of a total of 193 countries included in the energy projections for the year 2010, data was available in the KILM database for 112. However, the regional distribution was uneven as can be seen above in Table 8. While some regions have relatively few countries represented, those with data tend to be the larger energy users within the region.

The KILM data does not contain forecasts. Instead, a proxy was used, namely growth in GDP per capita. This was applied to the 2010 regional labour productivity data to calculate average labour productivity in 2015, 2020 and 2035 for each region. GDP per capita growth was then derived for each of the 10 regions using projected GDP and population growth estimates from IEA 2011. These economic assumptions are key inputs to the IEA World Energy Outlook modelling and both the Energy [R]evolution and Reference scenarios.

The ILO database on Key Indicators of the Labour Market was updated in 2012 (Edition 7), with the most recent data coming from 2010. In the job projections, three sets of productivity data were generated, for the whole of economy, for agricultural, forestry and fisheries workers only, and a third set for whole of economy excluding agricultural, forestry and fisheries.

In developing regions, the value for average GDP production per agricultural worker is considerably lower than the value for the rest of the economy. When agricultural value added is included, it lowers the economy wide labour productivity figure in developing regions, and therefore increases the job multiplier between developed and developing countries. However, agricultural productivity is not relevant to the majority of energy technologies.

[7] Includes China and Hong Kong.
[8] Includes countries in other categories: China, Hong Kong (China) and India.

As it was not possible to disaggregate labour productivity in the newer version of KILM, the whole economy labour productivity was derived, and then adjusted using the relationship between whole economy and whole economy excluding agriculture from the 2010 analysis (Rutovitz and Atherton, 2009). The regional multiplier used is therefore likely to underestimate bioenergy fuel employment.

Productivity data for each region and time period is compared to the OECD region in Table 9 below, where OECD is presented as 1.0 and all other regions as a ratio to OECD. Regional job multipliers are obtained from the ratios in Table 9, such that if productivity or value added per worker is 0.5 times the OECD value, we assume 2 x jobs in that region. The resulting multipliers are also presented in Table 7.

Table 9 Regional labour productivity compared to OECD labour productivity

	Whole economy GDP per worker (1990 US$ at PPP)	**Factor used to exclude agriculture**	**Whole economy excluding agriculture** GDP per worker (1990 US$ at PPP)	**Ratio to OECD**
World	18,886	1.5	27,564	0.6
OECD	47,781	1.0	49,606	1.0
OECD Americas	55,016	1.0	56,847	1.1
OECD Europe	42,439	1.0	44,181	0.89
OECD Asia-Oceania	45,069	1.0	47,006	0.95
Africa	5,499	2.1	11,521	0.23
China[9]	12,813	1.5	19,058	0.38
Non-OECD Asia[10]	10,992	1.5	16,798	0.34
India	8,401	1.7	13,920	0.28
Latin America	15,173	1.1	17,002	0.34
Middle East	16,922	1.0	17,185	0.35
Eastern Europe/Eurasia	18,119	1.1	20,819	0.42

Note 1 Labour productivity (defined as average GDP per worker) from ILO KILM (2012).

Note 2 Growth rates in labour productivity taken as growth rate in GDP per capita, derived from IEA World Energy Outlook (2011).

Note 3 The factor used to exclude agriculture is the ratio between 'whole economy' labour productivity and 'whole economy excluding agriculture' productivity.

[9] Includes China and Hong Kong.
[10] Includes countries in other categories: China, Hong Kong (China) and India.

6 Adjustment for learning rates – decline factors

Employment factors are adjusted to take into account the reduction in employment per unit of electrical capacity as technologies and production techniques mature. The learning rates assumed have a significant effect on the outcome of the analysis.

The annual decline in employment used in this analysis is given in Table 10 below. These declines rates are calculated directly from the cost data used in the Energy [R]evolution modelling (Teske et al., 2012).

Table 10 Employment factor decline rates by technology

	Annual decline in job factors		
	2010-15	2015-2020	2020-30
Coal	0.3%	0.3%	0.5%
Lignite	0.4%	0.4%	0.4%
Gas	0.5%	0.5%	1.0%
Oil	0.4%	0.4%	0.8%
Diesel	0.0%	0.0%	0.0%
Nuclear	0.0%	0.0%	0.0%
Biomass	1.6%	1.1%	0.7%
Hydro-large	-0.6%	-0.6%	-0.9%
Hydro-small	-0.6%	-0.6%	-0.9%
Wind onshore	3.6%	2.8%	0.2%
Wind offshore	3.1%	7.2%	4.5%
PV	5.3%	6.4%	4.9%
Geothermal power	3.5%	5.4%	7.3%
Solar thermal power	5.6%	5.1%	2.8%
Ocean	4.8%	6.5%	7.0%
Coal CHP	0.3%	0.3%	0.5%
Lignite CHP	0.3%	0.3%	0.5%
Gas CHP	0.9%	1.0%	1.0%
Oil CHP	0.4%	0.4%	0.8%
Biomass CHP	2.0%	2.2%	2.2%
Geothermal CHP	2.6%	3.2%	4.5%
Nuclear decommissioning	2%	2%	2%
Geothermal - heat	0.0%	0.9%	0.9%
Solar thermal heat	Uses decline factor for solar thermal power		

The factor for nuclear decommissioning has been taken as the average decline across all other technologies.

7 Coal trade

Jobs in coal supply have been allocated taking international trade into account. The Reference case is the Current Policies scenario from the World Energy Outlook 2011 (International Energy Agency, 2011a). There are only detailed projections for international coal trade and coal production in the New Policies scenario, so these have been adjusted upwards according to the difference in coal production between the New Policies and Current Policies projections. The adjusted projections are shown in Table 13 and Table 14.

The proportion of coal imports calculated for the Reference and [R]evolution scenarios for each region are shown in Table 11. The proportion of imports in the Reference scenario is calculated from the PJ imported divided by the total PJ consumed (imports are shown in Table 13, and domestic production in Table 14). It is assumed that coal production in coal importing regions is constant between the Current Policies and New Policies scenarios, and that the increase in coal production in the Current Policies scenario is met from coal exporting regions.

Table 11 Proportion of coal imports: Reference and [R]evolution scenarios

	REFERENCE				[R]EVOLUTION			
	2010	2015	2020	2030	2010	2015	2020	2030
OECD North America	-	-	-	-	-	-	-	-
Latin America	-	-	-	-	-	-	-	-
OECD Europe	43%	48%	53%	61%	43%	43%	14%	0%
Africa	-	-	-	-	-	-	-	-
Middle East	53%	63%	70%	74%	53%	67%	74%	93%
Eurasia/ E Europe	-	-	-	-	-	-	-	-
India	17%	26%	31%	41%	17%	24%	0%	0%
Non-OECD Asia	-	-	-	-	-	-	-	-
China	4%	6%	8%	5%	4%	0%	-	-
OECD Pacific	-	-	-	-	-	-	-	-

The proportion of coal imports in the [R]evolution scenario is calculated by first adjusting the amount of coal consumed according to the ratio of coal use in the Reference scenario to coal use in the [R]evolution scenario. This is subtracted from the regional coal production for the relevant year to identify net import regions. Potential domestic coal production is assumed to be constant between the Reference and the [R]evolution scenarios, so coal is only assumed to be imported if the adjusted consumption is more than production. The revised figure for imports is divided by the coal production plus imports to determine the percentage imported.

The total amount of exports in each scenario is determined by applying the proportion of imports (shown in Table 11) to the PJ of primary coal demand in each region. The proportional share of world trade assigned to each region is assumed to stay constant, and is assigned to export regions according to the proportion of net inter-regional trade belonging to each region in the IEA projections (shown in Table 13). The percentage of net inter-regional trade sourced from each exporting region is shown in Table 12.

Table 12 Proportion of coal exports: Reference and [R]evolution scenarios

	2010	2015	2020	2030
OECD Americas	10%	12%	13%	12%
Latin America	14%	13%	13%	14%
Africa	14%	14%	13%	14%
Eurasia/ E Europe	22%	20%	18%	17%
Non-OECD Asia	34%	34%	34%	22%
OECD Oceania	6%	8%	9%	21%
	100%	100%	100%	100%

Table 13 Net Inter-regional hard coal trade, 2009 – 2035, reference scenario, PJ
Negative values = imports, positive values = exports. Million tons of coal equivalent.

	2009	2010	2015	2020	2030	2035
OECD	**-3,517**	**-3,417**	**-2,920**	**-2,422**	**702**	**2,264**
OECD Americas	1,114	1,227	1,791	2,355	2,626	2,762
OECD Europe	**-5,305**	**-5,407**	**-5,916**	**-6,425**	**-6,578**	**-6,655**
OECD Oceania	674	760	1,187	1,615	4,643	6,157
Eurasia/E.Europe	2,550	2,633	3,049	3,465	3,660	3,758
Non-OECD Asia	3,810	4,039	5,181	6,324	4,945	4,256
China	**-2,579**	**-2,920**	**-4,622**	**-6,324**	**-4,553**	**-3,667**
India	**-1,788**	**-2,170**	**-4,079**	**-5,987**	**-10,869**	**-13,310**
Middle East	**-29**	**-33**	**-50**	**-67**	**-83**	**-91**
Africa	1,641	1,721	2,122	2,523	3,105	3,395
Latin America	1,583	1,665	2,077	2,489	3,063	3,350
World	22,069	23,292	29,407	35,521	42,536	46,043

2009, 2020, and 2035 derived from WEO 2011 Table 11.8 *Inter-regional hard coal net trade by country in the New Policies Scenario* (MTCE converted to PJ, and increased according to the ratio of inter-regional trade in the New Policies and Current policies scenarios). Linear interpolation is used between specified years.

Table 14 Regional production of coal, 2007–2035, coal importing countries (PJ)

	2009	2010	2015	2020	2030	2035
OECD	41,119	41,407	42,848	41,080	37,544	35,082
Europe	7,298	7,146	6,389	5,686	4,279	3,458
China	64,390	66,177	75,116	76,552	79,425	80,275
India	10,228	10,473	11,694	13,042	15,738	17,262
Middle East	29	29	29	29	29	29

From WEO 2011, Table 11.7 *Coal production by region in the New Policies Scenario*. P420 (MTCE converted to PJ). Linear interpolation is used between specified years.

8 Gas trade

Jobs in gas supply have been allocated after taking international trade into account. The projected volumes of international trade and world gas production in the Reference scenario are taken from the New Policies scenario in the World Energy Outlook 2011 (International Energy Agency, 2011a), and are shown in Table 16 and Table 17.These have not been adjusted to reflect the fact that the Reference case uses the Current Policies Scenario, as primary demand for gas is only 4% higher in the Current Policies scenario (International Energy Agency, 2011a, pages 544, 545).

The proportion of gas imports in the Reference and [R]evolution scenarios are shown in Table 15. These are calculated for the Reference scenario from the PJ imported divided by the total consumed (i.e., gas production plus gas imports).

The proportion of gas imports in the [R]evolution scenario is calculated by first adjusting the amount of gas consumed according to the ratio of gas use in the Reference scenario to gas use in the [R]evolution scenario. The revised figure for consumption is divided by the gas production to determine the proportion of imports in the [R]evolution scenario. Potential gas production is assumed to be constant between the two scenarios in gas importing regions, so the proportion imported increases in the [R]evolution scenario in some cases.

The proportion of domestic gas production is used to calculate a value for PJ of gas imports for each region. This is assigned to export regions according to the proportion of total inter regional trade belonging to each region in the IEA Reference scenario shown in Table 16, with the assumption that export regions will increase production in response to demand.

Table 15 Proportion of gas imports: Reference and [R]evolution scenarios

	REFERENCE				[R]EVOLUTION			
	2010	2015	2020	2030	2010	2015	2020	2030
OECD Americas	2%	2%	2%	2%	2%	-	-	-
Latin America	-	-	-	-	-	-	-	-
OECD Europe	46%	51%	57%	52%	46%	46%	44%	25%
Africa	-	-	-	-	-	8%	10%	-
Middle East	-	-	-	-	-	-	-	-
Eurasia/ E Europe	-	-	-	-	-	-	-	-
India	23%	28%	31%	11%	23%	36%	46%	24%
Non-OECD Asia	-	-	-	-	-	2%	-	-
China	14%	29%	35%	3%	14%	18%	25%	-
OECD Oceania	80%	73%	63%	63%	80%	84%	84%	81%

Table 16 Net Inter-regional gas trade, 2009 – 2035, Reference scenario (PJ)
Negative values = imports, positive values = exports.

	2009	2010	2015	2020	2030	2035
OECD Americas	-580	-585	-606	-627	-586	-691
Latin America	694	718	838	958	701	1,317
OECD Europe	-8,982	-9,307	-10,930	-12,553	-9,076	-17,421
Africa	4,603	4,937	6,605	8,273	4,651	13,278
Middle East	2,672	2,792	3,389	3,986	2,700	5,778
Eurasia/ E Europe	4,759	5,114	6,889	8,663	4,808	13,988
India	-479	-557	-947	-1,337	-484	-2,507
Non-OECD Asia	-	-	-	-	-	-
China	-273	-582	-2,125	-3,669	-276	-8,299
OECD Oceania	-10,393	-10,273	-9,670	-9,067	-10,502	-7,258

From International Energy Agency, 2011a, Figure 4.7 page 168, linear interpolation between 2009 and 2035. Converted from BCM to PJ using regional values for 2009 gas production in energy units from IEA energy statistics (www.iea.org).

Table 17 Regional production of gas, 2009 – 2035, IEA reference scenario (PJ)

	2009	2010	2015	2020	2030	2035
OECD Americas	30,396	30,510	31,083	32,076	34,558	35,589
Latin America	5,996	6,245	7,494	8,993	9,979	10,611
OECD Europe	10,949	10,856	10,390	9,645	8,267	7,597
Africa	7,785	8,208	10,327	12,710	15,847	17,555
Middle East	16,073	16,820	20,559	22,627	27,347	30,156
Eurasia/ E Europe	28,874	29,871	34,855	36,696	43,636	45,899
India	1,791	1,901	2,452	3,036	4,087	4,671
Non-OECD Asia	15,409	16,121	19,682	22,780	27,759	30,308
China	3,320	3,645	5,272	6,874	9,842	11,326
OECD Oceania	2,362	2,570	3,608	5,325	6,270	6,829

From International Energy Agency, 2011a, page 165, linear interpolation for 2010 value. Converted from BCM to PJ using regional values for 2009 gas production in energy units from IEA energy statistics (www.iea.org.

9 Employment in renewable energy manufacturing

The proportion of manufacturing that occurs within each region varies around the world. In order to calculate employment, percentages have been assigned in each region for 2010, 2020, and 2030. These are shown in Table 18.

It is assumed that all manufacturing for fossil fuel, biomass, hydro and nucleartechnologies occurs within the region.

Local manufacturing percentages vary from 100% manufacturing within Europe and China for each period, to 30% of manufacturing occurring within Africa in 2010, rising to 50% by 2030. These percentages are applied to all renewable technologies except biomass and hydro, and to the Reference and [R]evolution scenarios.

Where equipment is imported, it is allocated among exporting regions as shown in Table 18. Import and export percentages, and current export regions, are set according to current practice. Local manufacturing generally increased over time.

Table 18 Proportion of local manufacturing and import / export, all regions

	Proportion of manufacturing within the region			Region where equipment is imported from			
	2010	2020	2030	OECD Europe	OECD North America	India	China
OECD Europe	100%	100%	100%	0%	-	-	-
OECD Americas	**50%**	**100%**	**100%**	50%	-	-	50%
OECD Asia-Oceania	50%	60%	80%	50%	-	25%	25%
Non-OECD Asia	30%	50%	70%	50%	-	25%	25%
India	70%	100%	100%	50%	-	-	50%
China	100%	100%	100%	-	-	-	-
Africa	30%	30%	50%	50%	10%	20%	20%
Latin America	30%	70%	100%	50%	50%	-	-
Middle East	30%	30%	30%	50%	-	25%	25%
Eastern Europe/Eurasia	30%	50%	70%	50%	-	25%	25%

Note: These percentages are applied to wind, solar PV, solar thermal power, geothermal power, and ocean (wave and tidal) technologies. .

Appendix 1 Employment factors used in 2010 analysis

	Construction times	Construction/ installation	Manufacturing	Operations & maintenance	FUEL
	years	job years/ MW		jobs/MW	jobs/GWh
Coal	5	6.2	1.5	0.1	Regional
Gas, oil and diesel	2	1.40	0.07	0.05	0.12
Nuclear	10	14.4	1.6	0.3	0.001
Biomass	2	3.9	0.4	3.1	0.2
Hydro	2	10.8	0.5	0.2	
Wind	2	2.5	12.5	0.4	
PV	1	29.0	9.3	0.4	
Geothermal	2	3.1	3.3	0.7	
Solar thermal	2	6.0	4.0	0.3	
Ocean	2	9.0	1.0	0.3	
CHP	Combined heat and power technologies use the factor for the fuel type, i.e. coal, gas, biomass, geothermal, etc, increased by a factor of 1.3. Construction times are not increased.				

Note that fuel jobs are expressed in jobs per GWh electricity, not in jobs per PJ primary energy. Further details can be found in Rutovitz & Usher (2010).

Appendix 2 Biomass employment factors – additional information

Region/ country	Year	Construction Person years /MW	Manufacturing	O&M Jobs/ MW	Construction time Years	MW	Notes and data sources
2010 analysis		3.9	0.4	3.1	0.2		
Current report		**14.0**	**2.9**	**1.5**	**0.3**	**32.2**	**Average values taken from 11 studies in Europe and the USA. Jobs per GWh_e converted to jobs/PJ primary energy using a conversion efficiency of 25%**
Greece	2011	19.7	5.3	3.1			Direct employment in manufacturing from a detailed I/O study for Greece. Figure is calculated from Table 8, which assumes all manufacturing occurs outside Greece, and Table 3, which includes manufacturing. (Tourkolias & Mirasgedis, 2011)
Spain	2008	4		0.14			Figure for biomass electricity. (Moreno & López, 2008, Table 6)
Spain	2008	25		0.14			Figure for biogas (Moreno & López, 2008, Table 6)
		20		1.23			Figures for biomass **power only** supply (wood, straw, or miscellaneous) (Thornley et al., 2008)
UK	2007			1.1	0.26	18	Figures for biomass **power only** supply (Derived from Thornley, 2006)
UK	2007	24		2.3	0.38	26	Figure for **CHP** - wood, straw, miscellaneous. (Derived from Thornley, 2006)
UK				2.69			CHP - wood, straw, miscellaneous (Thornley et al., 2008)
UK	2007				0.22	15	250 kW - 25 MW, 192 plant, both PO and CHP (Upham & Speakman, 2007, Table 2b)
USA	2001	3.9	0.4	3.1			CMI from EPRI, 2001b, O&M and fuel from Department for Trade and Industry (UK), 2004

Region/ country	**Year**	**Construction** Person years /MW	**Manufacturing**	**O&M** Jobs/ MW	**Construction time** Years	**MW**	**Notes and data sources**
Europe	2006	1.6		1.3		84	Derived from (Kjaer, 2006)
Croatia	2005					12	Reported in Domac et al., 2005
Slovenia	2005					16	Reported in Domac et al., 2005
Croatia	2005					40	Reported in Domac et al., 2005
Bosnia Herzegovina	2005					52	Reported in Domac et al., 2005
Sweden	2002					45	Various different biomass fuels, including straw, forest residues, SRC Average value reported in Hillring, 2002, Table 1
Sweden	2002					47	Additional wood fuels per PJ, 5 regions of Sweden. Reported in Hillring, 2002, Table 2
Italy	2011					30	(Valente et al., 2011)
Sweden	2002					1.5	By products from forest industry, reported in Hillring, 2002, Table 1
Developing countries	2005					252	Large scale forestry, reported in Domac et al., 2005

Appendix 3 Wind employment factors – additional information

Region/ country	Year	Construction Person years/MW	Manufacturing Person years/MW	O&M Jobs/ MW	Notes and data sources
2010 analysis		2.5	12.5	0.4	European Wind Energy Association (2009)
Current report		**2.5**	**6.1**	**0.2**	Construction from European Wind Energy Association (2009). Manufacturing from employment per MW at Vestas 2007 – 2011 (Vestas, 2011), adjusted to total manufacturing using ratio from EWEA 2009. O&M Average of 8 estimates listed for OECD (excludes estimate for Caribbean).
USA	2006		7.5		Renewable Energy Policy Project (2006), page13
	2008	13.0		0.2	Moreno & López, 2008, Table 6
USA	2009	1.5		0.13	National Commission on Energy Policy, 2009, Appendix A (Bechtel report)
Germany	2009			0.20	O&M employment from Ulrich, Distelkamp, & Lehr (2012), MW installed end 2008 from (European Wind Energy Association, 2010)
UK	2010	1.12		0.36	16% of 6000 FTE's are in direct employment in construction in UK large onshore wind; estimated annual increase of 860 in 2009. 21% of 6000 FTE's are in O&M, UK installed capacity April 2010 3.5GW. (Renewable UK, 2011 page 8)
Australia	2010	2.5		0.16	Rutovitz, J., Ison, N., Langham, E. and Paddon, M. (2011)
USA	2010	0.9	11.2	0.1	JEDI model (National Renewable Energy Laboratory, 2010b)
Australia	2010	11.2		0.15	Modelled by SKM MMA (Clean Energy Council, 2010)
Greece	2011	6.1	2.7	0.4	From Tourkolias & Mirasgedis, (2011) Table 3 and Table 8
	2011		6.1		Turbine manufacturing average of Vestas 2007 - 2011 scaled to all manufacturing using EWEA (2009) ratio of turbine to total manufacturing.
Caribbean	2012			0.87	Weighted average of four wind projects from (Kammen & Shirely, 2012)

OFFSHORE WIND

Region/ country	**Year**	**Construction** Person years/MW	**Manufacturing** Person years/MW	**O&M** Jobs/ MW	**Notes and data source**
2010 analysis		4.8	24.0	0.4	European Wind Energy Association (2009)
Current analysis Germany		**7.1**	**10.7**	**0.2**	Price Waterhouse Coopers (2012)
UK	2010	1.85			41% of 3100 FTE's are in direct employment in UK offshore wind with installed capacity of 688MW (Renewable UK, 2011 page 10)
UK	2010			0.77	17% of 3100 FTE's are in direct employment in UK offshore wind with installed capacity of 688MW (Renewable UK, 2011 page 10)

Appendix 4 Solar PV employment factors – additional information

Region/ country	Year	Construction Person years/MW	Manufacturing Person years/MW	O&M Jobs/ MW	Notes and data source
Global EPIA estimate	2011	23.0	7.0		Global average of 30 jobs for construction, manufacturing and installation from European Photovoltaic Industry Association and Greenpeace (2011) page 70, split between manufacturing and installation using the EPIA 2008 ratio (European Photovoltaic Industry Association and Greenpeace, 2008)
2010 analysis		29.0	9.3	0.4	Derived from European Photovoltaic Industry Association and Greenpeace (2008)
Current report		**10.9**	**6.9**	**0.3**	**Average of listed factors below (not including global data from EPIA or factors used in 2010 analysis).**
Japan	2008		7.6		Derived from Yamamoto & Ikki (2010)
US	2009			0.5	Local direct employment estimated to be generated by a 75 MW solar PV project in Kittitas County in the United States (The World Bank, 2011, page 29)
Germany	2009			0.2	Derived from Mulenhoff (2010)
Germany	2009	12.6			Based on country total annual increase of 2000 MW and Kunz (2010)
US	2009	11.3			National Commission on Energy Policy, 2009, Appendix A (Bechtel report)
South Korea	2010		3.1		Employment figures for total country manufacturing (Korea Energy Management Corporation (KEMCO) & New and Renewable Energy Center (NREC), 2012)
Greece	2011	11.2	6.0		From Tourkolias & Mirasgedis, (2011) Table 3 and Table 8
US	2011	9	11	0.2	JEDI model (National Renewable Energy Laboratory, 2010a)
Germany	2007, 2008	10.7			One company, total installation 3.09 MW Reisinger Sonnenstrom: http://www.reisinger-sonnenstrom.de/menu/01-sonnenstrom-team.htm

Appendix 5 Geothermal employment factors – additional information

Region/ country	Year	**Construction** Person years /MW	**Manufacturing** Person years /MW	**O&M** Jobs/ MW	**Build time** Years	MW	Notes and data sources
2010 analysis		3.1	3.3	0.7			From Geothermal Energy Association (2005) Geothermal industry employment: survey results & analysis.
Current report		**6.8**	**3.89**	**0.36**			**Construction and O&M weighted average of employment for 10 power plants, total 1050 MW. Manufacturing from Geothermal Energy Association (2010), page 10 and 11**
US	2012	5.5		0.2	4.0	260	Imperial Valley, California. (Geothermal Energy Association, 2012)
US	2011			0.4		235	CalEnergy's Black Rock geothermal project. Employment up to 642 during construction, 57 O&M (Geothermal Energy Association, 2011b, page 5), plant size 159 MW (Geothermal Energy Association, 2011a, page 27)
US	2012			0.5		159	Patuna Project in Nevada to come online 2012 www.renewableenergyworld.com/rea/news/article/2012/01/geothermal-heating-up-in-nevada-despite-frigid-industry-climate
US	2009	8.8			2.8	60	Generic 50 MW geothermal plant (US Department of Energy, 2009, page 34)
US	2010	11.35	3.89	0.35	2.5	50	Generic plant (Geothermal Energy Association 2010, page 10 and 11)
US	2011	10.0		0.3		50	Blue Mountain "Faulkner 1" power plant (Geothermal Energy Association, 2011, page 19)
US	2011			0.7		50	EnergySource's Hudson Ranch: up to 230 FTE during construction and 34 O&M (Geothermal Energy Association, 2011b, page 5), plant size 49.9 MW (Geothermal Energy Association, 2011a, page 27)
US	2009?	16.7		0.3		48	Generic 30 MW plant (Good Company Associates, n.d.)

Region/ country	**Year**	**Construction** Person years /MW	**Manufacturing** Person years /MW	**O&M** Jobs/ MW	**Build time** Years	**MW**	**Notes and data sources**
US	2011	12.5		0.5		30	Neal Hot Springs geothermal plant 26 MW (Geothermal Energy Association, 2009); note that the 2012 report stated 33 MW, but we assume the jobs predictions were done for the 2009 figure. Employment from Geothermal Energy Association (2011a), page 19.
USA	2006	3.2		0.6		26	Generic 24 MW geothermal plant in US. (Nevada Geothermal Power Inc., 2006)
Australia	2009	9.3		0.2		24	Green Earth Energy Data for 10.7 MW plant (ACIL Tasman 2009, Table 2, page 5)
Australia	2009	6.0		0.2		50	ACIL Tasman (2009), Table 2, page 5

Appendix 6 Solar thermal employment factors – additional information

Region/ country	Year	**Construction** Person years /MW	**O&M** Jobs/ MW	**Construction period** Years	MW	Notes and data source
2010 analysis		6.0	0.3			
Current report		**8.9**	**0.5**	**2.0**	**3223**	**Weighted average of 19 reported power plants (3223 MW) in the US, Spain, and Australia.**
Europe (weighted average)		**14.7**	**1.0**		951	Weighted average of 10 reported power plants (951 MW) in the US, Spain, and Australia.
US (weighted average)		**5.3**	**0.4**		1512	Weighted average of 8 reported power plants (1512 MW) in the US, Spain, and Australia.
Australia	2011	9.3		2.5	760	Construction employment for single CST plant (Beyond Zero Emissions, 2011, Appendix A p.32)
Spain	2009	8.0	1.2	2.5	50	EL REBOSO II 50-MW Solar Thermal Power Plant (El Reboso II), Sevilla (La Puebla del Río) www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=49
Spain	2009	12.0	0.8		49.9	Helios I (Helios I), Arenas de San Juan, Villarta de San Juan, Puerto Lápice (Ciudad Real) www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=47
Spain	2010	15.1			532	Protermo Solar & Deloitte, 2011, Figure 10 p.32; Figure 41 p.78
Spain	2010	7.0	0.6	1.5	50	Alvarado I, (Badajoz) www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=5
Spain	2010	18.0	0.9		50	Arcosol 50 (Valle 1), San José del Valle (Cádiz) www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=12
Spain	2010	19.0	0.9	2.0	50	Central Solar Termoelectrica La Florida (La Florida), Badajoz (Badajoz) www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=27
Spain	2010		1.2	2.0	50	Ibersol Ciudad Real (Puertollano) www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=18

Region/ country	Year	Construction Person years /MW	O&M Jobs/ MW	Construction period Years	MW	Notes and data source
Spain	2011	12.0	0.8	2.5	50	Aldiere (Granada) www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=3
Spain	2011	12.0	0.8	0.5	50	Extresol-1 (EX-1) www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=10
Spain	2011	40.2	2.3	2.0	20	Gemasolar Thermosolar Plant (Gemasolar), Fuentes de Andalucía (Andalucía (Sevilla)) www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=40
US	2009		1.4	0.6	5	Kimberlina Solar Thermal Power Plant (Kimberlina) www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=37
US	2010	5.4	0.3	2.0	280	Solana Generating Station (Solana) www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=23
US	2011	13.6	1.8	1.5	110	Crescent Dunes Solar Energy Project, Tonopah, Nevada. www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=60
US	2011	4.8	0.3	2.2	250	Abengoa Mojave Solar Project, Harper Dry Lake, California www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=57
US	2011	4.3	0.2	4.0	250	Genesis Solar Energy Project, Blythe, California www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=54
US	2011	4.8	0.2	3.0	392	Ivanpah Solar Electric Generating Station (ISEGS) www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=62
US	2011	4.7	0.4	1.5	75	Nevada Solar One (NSO), Boulder City, Nevada www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=20
US	2011	3.0	0.3	2.5	150	www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=61

Note: manufacturing employment uses the same factor as the 2010 report, 4 jobs in manufacturing per MW (European Renewable Energy Council, 2008, page 16), as the data collected above does not include manufacturing employment.

Appendix 7 Coal employment - further information

Table 19 Data sources - coal production and energy content

Region/ Country	Data	Data source
World, OECD America, OECD Europe, OECD Oceania, India, Non-OECD Asia, Africa, Middle East, Eurasia/ Eastern Europe, Latin America, USA, Canada, France, Australia, South Africa.	2009 coal production data 2009 % of domestic production	International Energy Agency, 2012
All regions, including China and India	2009 coal production in MTCE	International Energy Agency, 2011b
Russia	Coal production data	Zubov, 2012b
China	2010 coal production	BP, 2011
UK, Greece, Poland, Germany, Romania, Spain, Czech Republic, Slovak Republic, Ukraine, Bulgaria, Slovenia	2010 coal production data	European Association for Coal and Lignite, 2011

Table 20 Data sources – coal employment

Country	Data source
Russia	Zubov, 2012b
India	Ministry of Coal (India), 2011, pages 2,3,69,77,108
USA	Energy Information Administration, 2011
Canada	Statistics Canada, 2010
China	Zhang, 2012
Australia	Australian Bureau of Statistics, 2010
South Africa	Chamber of mines of South Africa, 2010, page 12
UK, Greece, Poland, Germany, Romania, Spain, Czech Republic, Slovak Republic, Ukraine, Bulgaria, Slovenia	European Association for Coal and Lignite, 2011

Productivity projection for coal mining – China

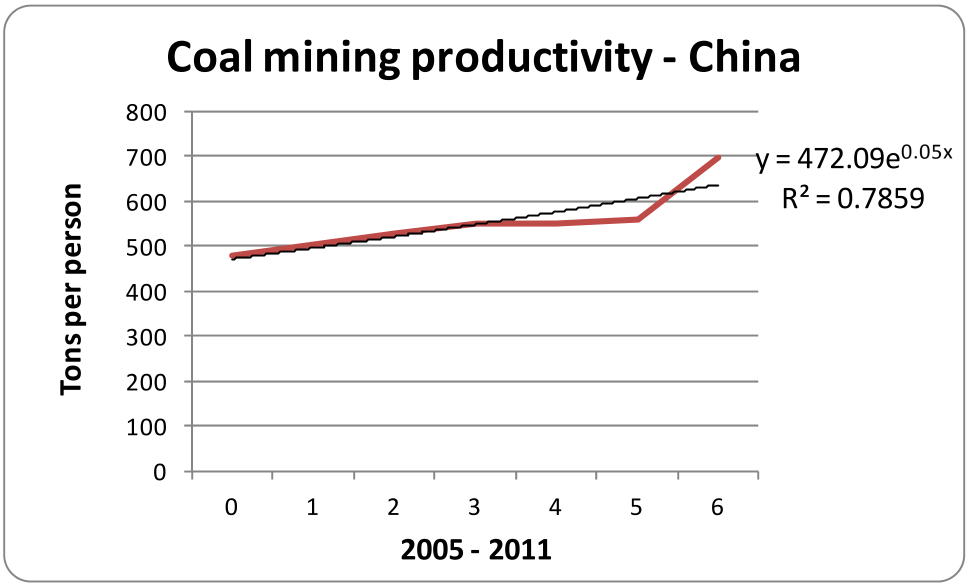
The table and graph shows the historic production in China, with production data from BP ((BP, 2011), employment data for 2007 – 2011 from China Coal Resource (Zhang, 2012), with 2005 from Mr Kevin Tu (Tu, 2012).

The current trend in productivity improvement has been extrapolated to productivity in 2015, 2020, and 2030. This gives the following productivity increases, which have been used in calculations of employment in coal fuel supply:

- **2010-2015** – annual productivity improvement of 6.8%
- **2015-2020**– annual productivity improvement of 5.1%
- **2020-2030** – annual productivity improvement of 5.1%

Table 21 Historic and projected productivity for coal mining in China

YEAR	PRODUCTION Million tons	EMPLOYMENT	Tons per person
2005	2349.5	4,284,856	480
2007	2691.6	4,597,000	528
2008	2802	4,741,000	551
2009	2973	5,003,000	552
2010	3240	5,110,000	561
2011	2349.5	5,311,000	696
PROJECTION FROM 2005 – 2011 TREND			
2015			778
2020			999
2030			1,648



Productivity projection for coal mining – India

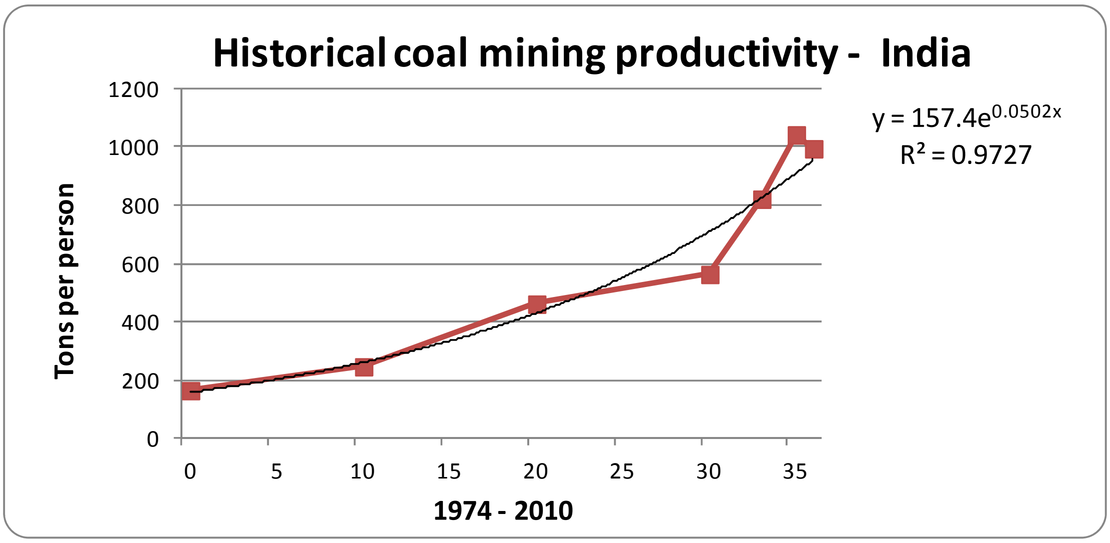
The table and graph shows the historic productivity and projection for coal mining in India. Data is from the Ministry for Coal (Ministry of Coal (India), 2005, 2007, 2011).

The current trend in productivity improvement has been extrapolated to productivity in 2015, 2020, and 2030. This gives the following productivity increases, which have been used in calculations of employment in coal fuel supply:

- **2010-2015** – annual productivity improvement of 4.4%
- **2015-2020**– annual productivity improvement of 5.1%
- **2020-2030** – annual productivity improvement of 5.1%

Table 22 Historic and projected productivity for coal mining in India

YEAR	Tons per person
1974	164
1984	246
1994	461
2004	563
2007	822
2009	1042
2010	995
PROJECTION FROM 974 - 2010 TREND	
2015	778
2020	999
2030	1,648



Productivity projection for coal mining – Russia

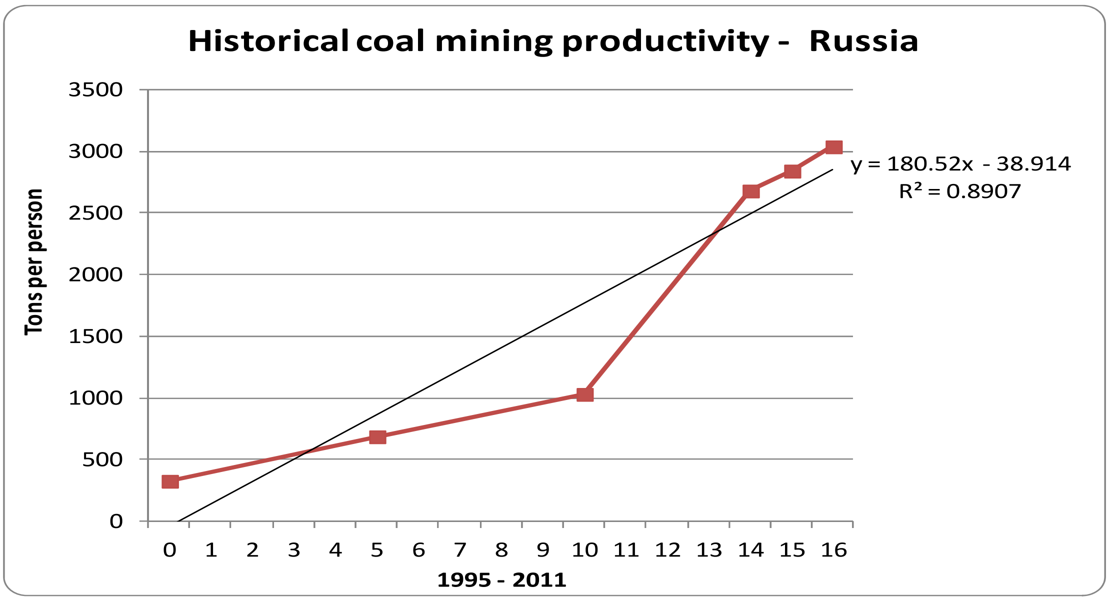
The table and graph shows the historic productivity and projection for coal mining in Russia. Data for employment from 1995 – 2005 is from the UNECE Ad Hoc Group of Experts on Coal in Sustainable Development (Klimov, 2003), for 2009 – 2011 from Ignatov and Company (Zubov, 2012b). Production data is from the IEA ((International Energy Agency, 2011b).

The current trend in productivity improvement has been extrapolated to productivity in 2015, 2020, and 2030. This gives the following productivity increases, which have been used in calculations of employment in coal fuel supply for Eurasia/ Eastern Europe:

- **2010-2015** – annual productivity improvement of 4.4%
- **2015-2020**– annual productivity improvement of 5.1%
- **2020-2030** – annual productivity improvement of 5.1%

Table 23 Historic and projected productivity for coal mining in Russia

YEAR	Tons per person
1995	325
2000	686
2005	1030
2009	2680
2010	2841
2011	3037
PROJECTION FROM 1995 - 2011 TREND	
2015	3571
2020	4474
2030	6279



Appendix 8 Nuclear decommissioning employment profile

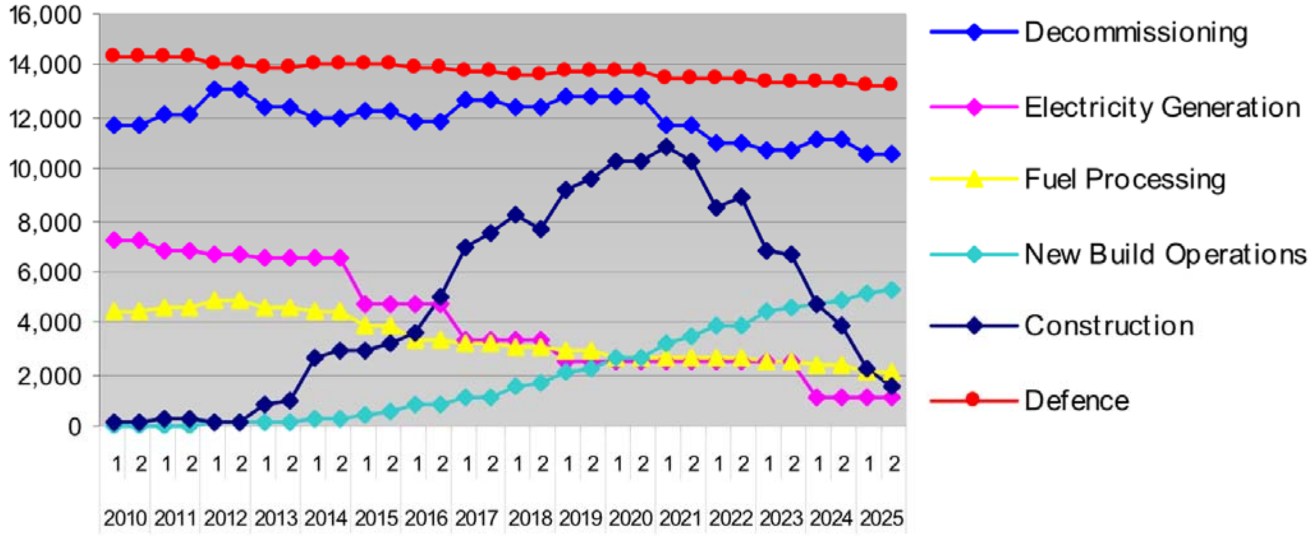
Table 24 UK NPPs operational and shutdown as at 2010

Plant	*Year of Shutdown*	*Size (MW)*
Dounreay DFR	1977	15
WINDSCALE AGR	1981	36
Berkeley	1989	332
Hunterston A	1990	346
WINFRITH SGHWR	1990	100
TRAWSFYNYDD	1991	470
Dounreay PFR	1994	250
Hinkley Point A	2000	534
Bradwell	2002	292
Calder Hall	2003	240
Chapel Cross	2004	240
Dungeness A	2006	460
Sizewell A	2006	490
Oldbury	2010	460
Wylfa	2010	890
Heysham 1	2014	1205
Hartlepool	2014	1310
Hunterston B	2016	860
Hinkley Point B	2016	1,310
Dungeness B	2018	1040
Heysham 2	2023	1195
Torness	2023	1205
	Total	**13,280**
Sizewell B	Post 2025	1188

Source: (Cogent Sector Skills Council, 2009 p.23); (Cogent Sector Skills Council, 2011b p.2); IAEA PRIS database[3]

Figure 2 shows the projected workforce demand for Cogent's 16 GWe generation scenario. The projected decommissioning industry employment was used with the cumulative MW of NPPs decommissioned prior to 2010 and during the projection to 2025 to calculate a figure for average employment per MW of generation decommissioned.

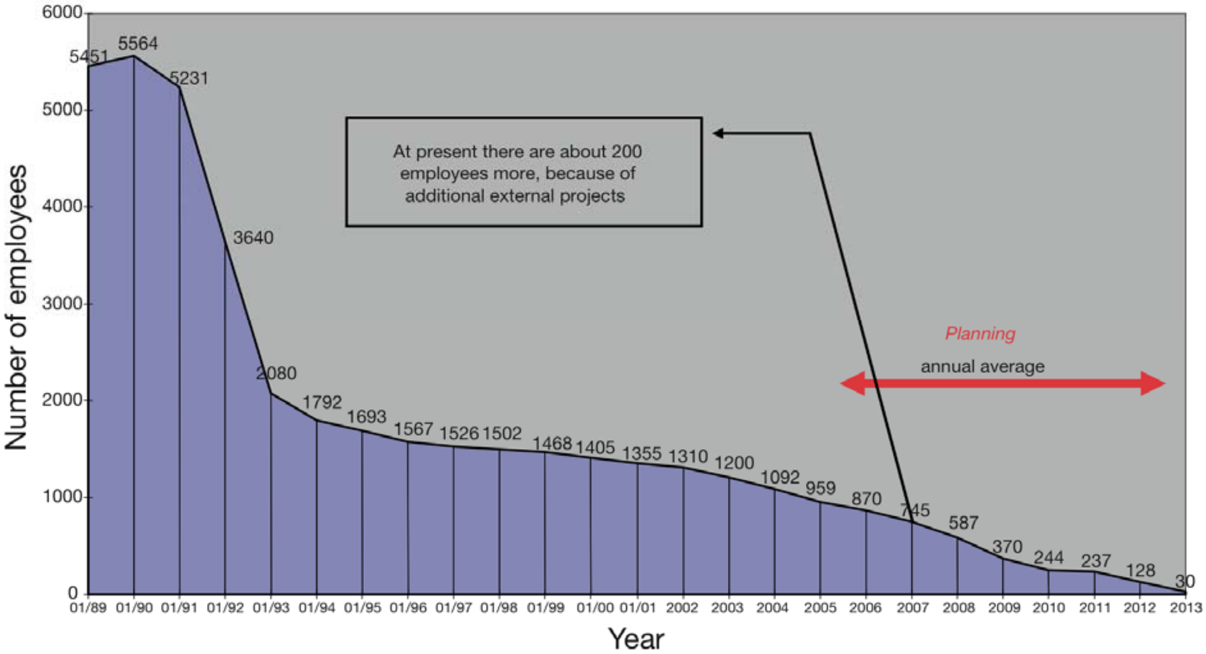
Figure 2 UK projections for nuclear workforce in decommissioning 2010-2025



Source: Cogent Sector Skills Council (2011), page 2.

Figure 3 shows projected employment for the decommissioning of five 440 MW(e) NPP units and all construction works the Greifswald NNP site in Germany. Direct dismantling of the facilities on-site (i.e. no safe enclosure period) was assumed. Annual employment over the first 20 years was divided by the 2200 MW decommissioned and averaged to obtain a figure for average employment per MW decommissioned.

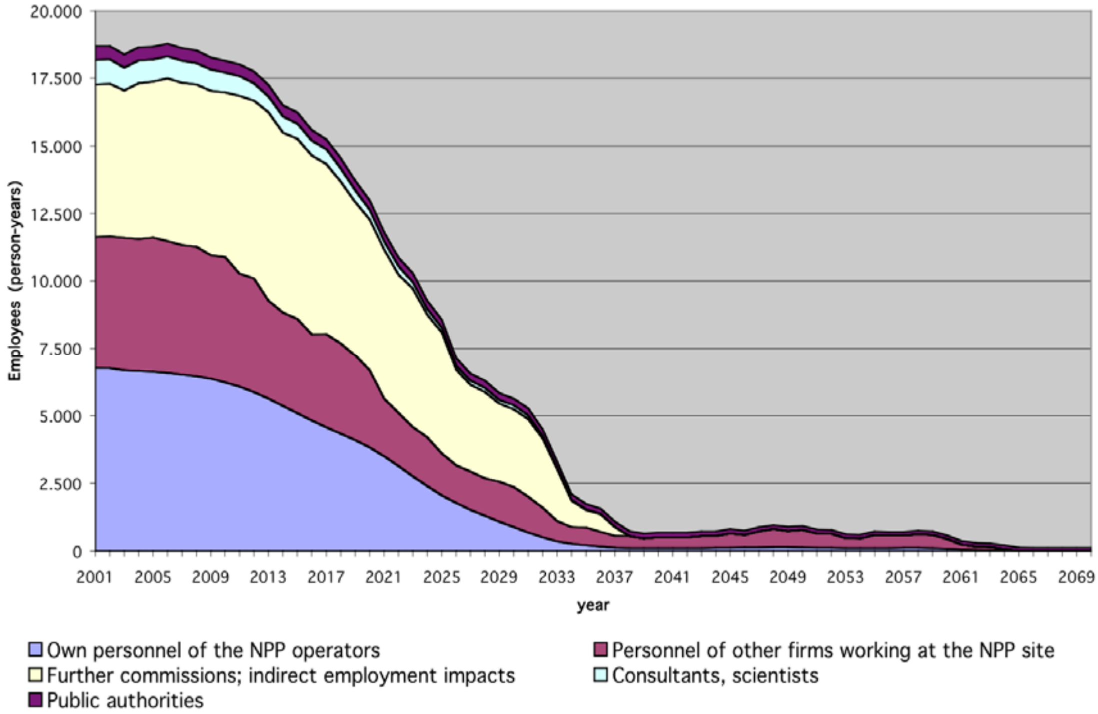
Figure 3 German case study: Employment over the decommissioning period for five 440 MW(e) NPP units in Greifswald.



Source: (International Atomic Energy Agency, 2008) FIG. II–3, Page 59

Figure 4 shows the decommissioning employment for 19 NPPs in Germany in operation in 2001, plus Würgassen and Mülheim Kärlich (direct dismantling assumed), including direct employment and subcontractors. The total generation capacity of the 21 NPPs decommissioned was used to calculate employment per MW of decommissioned NPP.

Figure 4 German employment projection for decommissioning of 21 NPPs



Source: (Wuppertal Institute for Climate Environment and Energy, 2007) Fig. 3, Page 22.

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