INSTITUTE FOR SUSTAINABLE FUTURES

CALCULATING GLOBAL ENERGY SECTOR JOBS

2015 METHODOLOGY UPDATE

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CALCULATING GLOBAL ENERGY SECTOR JOBS: 2015 METHODOLOGY UPDATE

For Greenpeace International

Draft Report

Authors:

Jay Rutovitz, Elsa Dominish, Jenni Downes

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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, equal to 29.3 GJ. It is)
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
TCE	Tonnes of coal equivalent (this is unit of energy rather than weight, and standardises between different grades of coal)
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 five global Energy [R]evolution scenarios, with previous editions in 2007, 2008, 2010 and 2012. 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; International Energy Agency 2011; International Energy Agency 2014).

The Institute for Sustainable Futures (ISF) at the University of Technology Sydney analysed the employment effects of the Energy [R]evolution global scenarios in 2009 and 2012 (Greenpeace International and European Renewable Energy Council 2009; Teske et al. 2012) and published methodology reports in 2009, 2010 and 2012 (Rutovitz & Atherton 2009; Rutovitz & Usher 2010; Rutovitz & Harris 2012a).

For the 2015 Energy [R]evolution study (Teske et al. 2015), ISF has once again completed the employment analysis. Employment factors have been updated wherever possible, as well as other factors such as regional multipliers. Employment data has been obtained for a significantly higher proportion of world coal and gas extraction than in previous analyses.

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 100 – 350% (for example Blanco & Rodrigues, 2009; Bournakis, Cuttica, Mueller, & Hewings, 2005; National Renewable Energy Laboratory, 2010a, 2010b, 2011a; Tourkolias & Mirasgedis, 2011). As in 2012, energy efficiency jobs have not been included in the calculations.

No energy efficiency job calculations are included, as it is beyond the scope of the project to develop a new methodology to calculate these jobs. The Energy [R]evolution scenarios show decline in the **primary** energy demand of 34% relative to the Reference scenario. The methodology used in 2009 to estimate energy efficiency jobs relied on the relative difference in stationary energy, which is no longer an indicator of energy efficiency because of the role of electric vehicles in the Energy [R]evolution scenarios. The 2015 Energy [R]evolution scenarios show an increase in electricity generation of 2% by 2030 relative to the Reference scenario, despite the significant decline in primary energy. This masks the "real" reduction in stationary energy from the Reference to the [R]evolution scenarios, which could create substantial numbers of jobs.

2 Methodology overview

The methodology used for the 2015 study was first developed for the 2009 Energy [R]evolution study which analysed global and regional employment effects. A fuller discussion of the regional adjustment factors and technology decline factors used in the 2009 study 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 2014 (International Energy Agency 2014).
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 2020, 2025 and 2030 by using a series of employment multipliers and the projections for energy use and capacity.

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, 2025 and 2030 calculations, a 'decline factor' for each technology and region 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.
- A set of 'decline factors' for each technology, based on the projected costs for that region in the Reference Scenario.

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 to give the number of energy sector jobs. The calculation is summarised in Figure 1.

Figure 1: Calculation of Energy Supply Jobs: Overview

Manufacturing (for local use) = **MW installed per year in region** x **Manufacturing employment factor** x **Regional job multiplier for year** x **% local manufacturing**

Manufacturing (for export) = **MW exported per year** x **Manufacturing employment factor** x **Regional job multiplier for year**

Construction = **MW installed per year** x **Construction employment factor** x **Regional job multiplier for year**

Operation and Maintenance = **Cumulative capacity** x **O&M employment factor** x **Regional job multiplier for year**

Fuel supply (nuclear) = **Electricity generation** x **Fuel employment factor** x **Regional job multiplier for year**

Fuel supply (coal, gas and biomass) = **Primary energy demand plus exports** x **Fuel employment factor (always regional for coal)** x **Regional job multiplier for year** x **% of local production**

Heat supply = **MW installed per year** x **Employment factor for heat** x **Regional job multiplier for year**

Jobs in region = **Manufacturing** + **Construction** + **Operation and maintenance (O&M)** + **Fuel** + **Heat**

Employment factors at 2020 or 2030 = **2015 employment factor** x **Technology decline factor** [number of years **after 2015**]

2.1 Limitations

Employment numbers for the 2015 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 2015 global analysis are shown in Table 1 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 2-6.

Table 1 OECD employment factors used in the 2015 global analysis

	Construction times	**Construction/ Installation**	**Manufacturing**	**Operations & Maintenance**	**Fuel – PRIMARY Energy Demand**	
	Years	Job years/ MW		Jobs/MW	Jobs/PJ	
Coal	5	11.2	5.4	0.14	Regional	Note 1
Gas	2	1.3	0.93	0.14	Regional	Note 2
Nuclear	10	11.8	1.3	0.6	0.001 jobs/GWh final demand	Note 3
Biomass	2	14.0	2.9	1.5	29.9	Note 4
Hydro-large	2	7.4	3.5	0.2		Note 5
Hydro-small	2	15.8	10.9	4.9		Note 6
Wind onshore	2	3.2	4.7	0.3		Note 7
Wind offshore	4	8.0	15.6	0.2		Note 8
Solar Photovoltaics	1	13.0	6.7	0.7		Note 9
Geothermal	2	6.8	3.9	0.4		Note 10
Solar thermal	2	8.0	4.0	0.6		Note 11
Ocean	2	10.2	10.2	0.6		Note 12
Geothermal - heat	6.9 jobs/ MW (construction and manufacturing)					Note 13
Solar - heat	8.4 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 2014a)
   Regional factors are used for coal fuel employment (see below, Section 3.2).

2. **Gas, oil and diesel**
   Installation and O&M average figures are from 2 - 4 studies and own research (see Section 3.3 for details). Manufacturing data is from the JEDI model (National Renewable Energy Laboratory 2014c). Regional factors are used for gas fuel supply for OECD North America, OECD Europe, OECD Pacific, China, Africa and Eastern Europe/Eurasia and the remaining regions use the weighted average of these.

3. **Nuclear**
   The construction factor is the weighted average of two studies from the UK and one from France (Cogent Sector Skills Council 2010; Cogent Sector Skills Council 2011a; Rutovitz & Razain 2013a). The manufacturing factor is the average of the two UK reports, while the O&M factor is the weighted average of 89GW from all three studies and ISF research for South Korea and Switzerland (Rutovitz & Harris 2012b; Rutovitz & Mikhailovich 2013b). The fuel factor is from Rutovitz & Harris 2012a.

4. **Bioenergy**
   Employment factors for construction, manufacturing and O&M are unchanged from the 2012 analysis. The factors use the average values of studies from Greece, the UK, Spain, USA, and one Europe wide study (Kjaer 2006; Thornley 2006; Thornley et al. 2008; Tourkolias & Mirasgedis 2011; Moreno & López 2008; Thornley et al. 2009). Fuel employment per PJ primary energy is derived from seven studies, all in Europe, including one new study from Netherlands (Domac et al. 2005; Hillring 2002; Thornley 2006; Upham & Speakman 2007; Valente et al. 2011; Kjaer 2006; Rutovitz & Mikhailovich 2013a). There is considerable variation between different estimates of biomass fuel employment, reflecting both practices in different countries and the considerable variation in biomass feed stocks.

5. **Hydro - large**
   Employment factors for construction, manufacturing and O&M are an average of 2 - 6 studies from South Korea, Japan, the US, New Zealand, France and Switzerland. For more details see Appendix 5.

6. **Hydro - small**
   Employment factors for construction, manufacturing and O&M are an average of 3-5 studies from Spain, Greece, Netherlands and the US. For more details see Appendix 5.

7. **Wind - onshore**
   Construction and O&M factors are from the average of 6-7 studies and ISF research from UK, Australia, Greece, Germany, New Zealand and the USA. The manufacturing factor is derived using the employment per MW in turbine manufacture at Vestas in 2014 (National Renewable Energy Laboratory 2015a), adjusted for total manufacturing using the ratio used by the EWEA (European Wind Energy Association 2009), as done in previous reports. For details see Appendix 2.

8. **Wind - offshore**
   All factors are an average of a German report (Price Waterhouse Coopers 2012) and the JEDI model (National Renewable Energy Laboratory 2014e). For details see Appendix 2.

9. **Solar PV**
   The employment factors for PV increased from the 2012 analysis, after a significant decrease between 2010 and 2012. The installation factor is the average of eight estimates in Germany, Netherlands, Spain, Greece and the US. The manufacturing factor is taken from module production from the four largest global solar PV companies' annual reports (Trina Solar 2014; Yingli Green Energy 2014; Canadian Solar 2014; JinkoSolar 2013). Balance of system (BOS) is calculated from the cost ratio of BOS to modules in the JEDI model (National Renewable Energy Laboratory 2014f). The O&M factor is an average of six factors from Germany, Spain and the US. See Appendix 4 for details of the different estimates.

10. **Geothermal**
    The factors are unchanged from the 2012 analysis. 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 Rutovitz & Harris 2012a for details.

11. **Solar thermal power**
    Construction and O&M jobs are derived from a weighted average of 31 reported power plants (2570 MW) in the US, Spain, and France. Manufacturing using the same factor as the 2010 report (European Renewable Energy Council, 2008), as the data collected above does not include manufacturing employment. See Appendix 4 for details.

12. **Ocean**
    An average of four studies are used to calculate installation, manufacturing and O&M, with projected manufacturing and construction employment divided equally between the categories (ACIL Tasman 2009; ECONorthwest 2009; Mcgrath et al. 2009; SQW Consulting 2009; Fanning et al. 2014; National Renewable Energy Laboratory 2014d; Batten & Bahaj 2007).

13. **Geothermal and heat pumps**
    One overall factor is used for jobs per MW installed, from a US study (Battocletti & Glassley 2012).

14. **Solar thermal heating**
    One overall factor is used for jobs per MW installed. The global figure is derived from the IEA heating and cooling program report (Mauthner et al. 2015). Local factors are used for OECD Europe, India and China (see Table 2 and Table 5 for more details.

15. **Nuclear decommissioning**
    The employment factors are unchanged from the 2012 analysis. The weighted average decommissioning employment over the first 20 years is derived from one UK study and two German studies (Cogent Sector Skills Council, 2009, 2011b; Wuppertal Institute for Climate Environment and Energy, 2007). See (Rutovitz & Harris 2012a) for more details.

3.1 Regional employment factors

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

- **OECD Americas:** factors for coal fuel supply, gas fuel supply, solar PV, wind – offshore and solar thermal power.
- **OECD Europe:** factors for coal fuel supply, gas fuel supply, wind-offshore, solar thermal power and solar thermal heating.
- **OECD Pacific:** factors for coal fuel supply and gas fuel supply.
- **India:** factors for coal fuel supply and solar thermal heating.
- **China:** factors for coal fuel supply, gas fuel supply and solar thermal heating.
- **Africa:** factors for coal fuel supply, gas fuel supply and biomass fuel supply.
- **Eastern Europe/Eurasia:** factors for coal fuel supply and gas fuel supply.
- **Latin America:** factors for coal fuel supply, nuclear, biomass fuel supply, hydro (small and large) and wind – onshore.
- **Developing Asia:** factors 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	Manufacturing	Operations & Maintenance	Fuel – PRIMARY Energy Demand	Notes
	job years/MW		jobs/MW	jobs/PJ	
Nuclear Latin America	19.6		1.15		Note 1
Biomass Africa				387.3	Note 2
Biomass Latin America				81.1	Note 2
Hydro-large Latin America			0.6		Note 1
Wind-onshore Latin America	6.7	3.4	0.6		Note 3
Wind-offshore OECD North America	8.9	20.5	0.09		Note 4
Wind-offshore OECD Europe	7.1	10.7	0.2		Note 4
Solar PV OECD North America	16.7	12.4	0.6		Note 5
Solar Thermal power OECD average	**8.0**	**4.0**	**0.6**		Note 6
Solar Thermal power OECD Americas	5.3		0.4		Note 6
Solar Thermal power OECD Europe	12.2		1.0		Note 6
SOLAR THERMAL: HEAT World average	**8.4 jobs/ MW** (construction & manufacturing)				Note 7
OECD Europe	15.1 jobs/ MW (construction & manufacturing)				
China	17.1 jobs/ MW (construction & manufacturing)				
India	19.5 jobs/ MW (construction and manufacturing)				

Notes on regional employment factors

1. The Latin America factor for nuclear and large hydro is based on the ISF jobs study for Brazil (Rutovitz 2013).
2. The Africa factor is derived from International Centre for Research in Agroforestry (ICRAF), Woodfuel policy and legislation in Eastern and Southern Africa and a Regional Workshop held at the World Agroforestry Centre, March 4–6, Nairobi, Kenya (Owen et al. 2013). The Latin America factor is from a Brazilian report (ABIB Brazilian Association of Industry Biomass and Renewable Energy 2012).
3. The Latin America factors are based on a Brazilian study which used company interviews to estimate jobs per MW. We use the average value for steel and concrete towers for manufacturing and construction (Simas & Pacca 2015)
4. The OECD North America factor for wind-offshore is based on the JEDI model (National Renewable Energy Laboratory 2014e) and the OECD Europe factor is based on a German study (Price Waterhouse Coopers 2012).
5. The solar PV factors are based on 2 – 5 studies for the US (The World Bank 2011; Comings et al. 2014; EIA USA 2012; National Renewable Energy Laboratory 2014f; Appendix A, National Commission on Energy Policy 2009).
6. The OECD average for solar thermal is the weighted average for 2570 MW in Spain, France and the US. The OECD America figure includes US data (1512 MW) and the OECD Europe figure includes European data (1057 MW). See Appendix 6 for details.
7. The OECD Europe factor is an average of four studies: a Europe wide study (European Solar Thermal Industry Federation 2011), a Netherlands study (Rutovitz & Mikhailovich 2013a), a Switzerland study (Nathani et al. 2013) and a Germany study (total employment from a national report (Federal Ministry for the Environment Nature Conservation and Nuclear Safety 2011), split by electricity and heat by value from an IRENA report (International Renewable Energy Agency 2011)) . The figure for India is from Indian government data (Ministry of New & Renewable Energy & Confederation of Indian Industry 2010). The figure for China is derived from the employment figures from CENREC 2013 data, quoted in the 2015 IRENA report (Ferroukhi et al. 2015) and capacity from the IEA heating and cooling program report (Mauthner et al. 2015) . See Table 6 for further details.

3.2 Coal fuel supply employment factors

Employment factors are derived for each region for coal mining, because coal is currently dominant in the global energy supply, and employment per tonne varies enormously. In Australia and the US, for example, coal is extracted at an average of more than 8,000 tonnes per person per year, while in Europe the average coal miner is responsible for less than 1,000 tonnes per year.

The employment factors and adjustments used for coal in this report are shown in Table 3.

The calculation of the employment factors draws on data from national statistics and company reports, combined with coal production figures from the BP Statistical Review of World Energy, or as stated in the notes to Table 3 below. Data was collected for as many major coal producing countries as possible accounting for 90% of world coal production. The Middle East was the only region with no employment data.

The average PJ per tonne of coal for each region is calculated from BP Statistical Review of World Energy 2015, using data from the country and regional coal production statistics (in million tons of oil equivalent).

China, Russia and India have relatively low productivity at present, with 600-700 tons of coal per worker per year, but annual increases in productivity are very high. The changes in productivity over the last 7 to 15 years were used to derive an average annual improvement, which has been used to adjust the employment factors for likely future increases in productivity over the study period. The derivation of the productivity improvements in China, India, and Eastern Europe/Eurasia is explained in Appendix 7.

Table 3: Employment factors used for coal fuel supply

	Year	**Employment factor** Jobs per PJ	**Productivity** Tons/ person/ year (coal equivalent)	
World average		**39.7**	**875**	Note 1
OECD North America	2013	3.8	8,900	Note 2
OECD Pacific	2014	4.1	8,380	Note 3
Developing Asia	2012-13	6.1	5,600	Note 5
Africa	2013	14.4	2,370	Note 5
Latin America	2013	15.4	2,200	Note 6
OECD Europe	2013	40.1	850	Note 7
India	2013-14	48.3	700	Note 8
Eastern Europe/Eurasia	2013	51.1	670	Note 9
China	2012	56.1	600	Note 10
Middle east	Used world average as no employment data available			

Notes on coal employment factors

1. **World average:**
   Weighted average of below factors

2. **OECD North America:**
   2013 data for US derived from coal mining jobs from Annual Coal Report 2013 (US Energy Information Administration 2013a) and coal production from BP Statistical Review of World Energy 2015 (BP 2015).

3. **OECD Pacific:**
   2014 data for Australia derived from average full time employment in oil and gas extraction for four quarters of 2014 (Australian Bureau of Statistics 2015) and coal production from BP Statistical Review of World Energy 2015 (BP 2015).

4. **Developing Asia:**
   2012-13 data for Indonesia derived from employment and production data from 5 companies corresponding to 38% of Indonesian production (PT Adaro Indonesia 2013; PT Kaltim Prima Coal 2013; PT Berau Coal Energy Tbk 2013; PT Kaltim Prima Coal 2012; PT Indo Tambangraya Megah (ITM) 2014; PT Bukit Asam (Persero) Tbk 2014; PT Indo Tambangraya Megah (ITM) 2013), converted to PJ using production from BP Statistical Review of World Energy 2015 (BP 2015).

5. **Africa:**
   2013 data for South Africa derived from coal mining jobs from national data (Chamber of Mines of South Africa 2014), converted to PJ using coal production from BP Statistical Review of World Energy 2015 (BP 2015).

6. **Latin America:**
   2013 data for Colombia derived from employment and production data from company information corresponding to 39% of Colombian production (Cerrejon 2015), converted to PJ using production from BP Statistical Review of World Energy 2015 (BP 2015).

7. **OECD Europe:**
   2013 data for Poland, Germany, Czech Republic, and Turkey from Eurocoal statistics using primary production of saleable coal. Data corresponds to 88% of OECD Europe production (Euracoal 2012; Euracoal 2013b; Euracoal 2013a; Euracoal 2013c).

8. **India:**
   2014 data from Indian Ministry of Coal annual report (Indian Ministry of Coal 2015a; Indian Ministry of Coal 2015b), converted to PJ using coal production from BP Statistical Review of World Energy 2015 (BP 2015).

9. **Eastern Europe/Eurasia:**
   2013 data for Ukraine from Eurocoal statistics (Euracoal 2013d) and Russia from report on Coal Mining Sector (Emerging Markets Insight 2013). Data corresponds to 68% of OECD Europe production.

10. **China:**
    2013 data for China derived from national statistics (National Bureau of Statistics of China 2013) and production from BP Statistical Review of World Energy 2015 (BP 2015).

3.3 Gas fuel supply employment factors

Gas fuel employment factors per PJ have been included for most regions in the world, as shown in Table 4. In most cases employment data is from national statistics, using the statistical classification for oil and gas extraction, and converting to jobs per PJ using the total production of oil and gas from the BP Statistical Review of World Energy 2015 (BP 2015).

Table 4 Gas fuel employment factors

	Jobs / PJ	Notes/ Sources
World average	**15.1**	**Weighted average of below factors**
OECD North America	4.2	Average of factors from 2012-2014, derived from total employment for gas and oil extraction from US Bureau of Statistics (US Bureau of Statistics 2015) and production from BP Statistical Review of World Energy 2015 (BP 2015)
OECD Europe	**8.6**	**Weighted average of Italy, Netherlands and Norway**
Italy	14.3	Italy factor for 2012 from ENI Annual Report (Eni 2012)
Netherlands	4.4	Netherlands factor for 2009 from Rutovitz & Mikhailovich 2013b.
Norway	9.8	Average of factors for 2011- 2013, derived from employment figures from (Thoen & Johannessen 2011) and production from BP Statistical Review of World Energy 2015 (BP 2015)
OECD Pacific	**7.9**	**Weighted average of Australia and New Zealand**
Australia	8.4	2014 factor derived from average full-time employment in oil and gas extraction for four quarters of 2014 (Australian Bureau of Statistics 2015) and production from BP Statistical Review of World Energy 2015 (BP 2015)
New Zealand	3.2	2012 factor derived from employment data (Department of Labour - New Zealand Government 2010) and production statistics (Ministry of Business Innovation and Employment 2012)
China	58.7	2012 factor derived from national statistics (National Bureau of Statistics of China 2013) and production from BP Statistical Review of World Energy 2015 (BP 2015)
Africa	7.4	2010 Factor derived from employment and production data from the state-owned company Sonatrach (Sonatrach 2010)
Eastern Europe/Eurasia	**17.9**	**Weighted average of Romania and Russia**
Romania	61.6	Average of factors from 2009-2011 (PETROM 2011)
Russia	17.2	Average of factors from 2009-2011 (Zubov 2012)
India, Latin America, Developing Asia and Middle east		Used world average as insufficient employment data available

4 Heat sector methodology and employment factors

The 2015 employment analysis includes a partial estimate of jobs in the heating sector.

The heat sector includes 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 includes fuel jobs (for biomass and fossil fuels), and installation, operation and maintenance, and manufacturing jobs for all types of heating systems.

All the fuel jobs in gas, coal, and biomass are captured via the primary energy demand for that fuel. Thus whether the fuel is used for electricity generation or direct heat supply, or a combined system, the job calculation and job factor is the same. The regional employment factors for coal are shown in Table 3, for gas in Table 4, while the biomass global factor is in Table 1.

Jobs in installation, manufacturing and operations and maintenance are calculated for all CHP systems, regardless of whether geothermal, solar thermal, or fossil fuel are used, as these are included in any case for the electricity sector. However, 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 are included under “heat”. Where the heat supply is via a CHP system, those 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 reporting of jobs by industry sector (manufacturing and construction), 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. Jobs are not allocated to O&M, as O&M jobs in the heat sector are unlikely to be captured in this analysis.

Solar thermal

There was an estimated capacity of 55 GW_{th} solar heating installed worldwide in 2013. Total employment in the sector was estimated as 469,000 jobs (Mauthner et al. 2015). This has been used for the global employment factor used in this analysis of 8.4 jobs per MW installed. This is higher than the factor of 7.4 jobs per MW installed derived from the same source data for the 2011 analysis. This estimate includes all employment i.e. manufacturing, operations and maintenance and installation.

Table 5 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 5 Range of employment factors for solar heat supply

Region	Year	New in 2015	Job years/ MW_{th}	Job years/ collector area (m^2)	Notes/ Sources
Global	**2013**	**Y**	**8.36**	**0.006**	**Solar Heat Worldwide: Markets and Contribution to the Energy Supply 2013 (Mauthner et al. 2015)**
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 a national report (Federal Ministry for the Environment Nature Conservation and Nuclear Safety 2011), split by electricity and heat by value from IRENA report (International Renewable Energy Agency 2011), and the increase in capacity from European Solar Thermal Industry Federation (2011)
Netherlands	2006-2010	Y	17.7		Capacity from Statistics Netherlands and employment from Lako, P., & Beurskens, L. W. M. (2011). (Rutovitz & Mikhailovich 2013a)
Switzerland	2010	Y	15.8		Nathani et al. 2013
India	2010		19.48	0.014	From Ministry of New & Renewable Energy & Confederation of Indian Industry (2010)
China	2013	Y	17.1		Employment figures from CENREC 2013 data, quoted in the 2015 IRENA report (Ferroukhi et al. 2015) and capacity from the report Solar Heat Worldwide (Mauthner et al. 2015)

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. A single factor for installation, manufacturing, and operations and maintenance has been derived from information presented to the International Ground Source Heat Pump Association Conference (Battocletti & Glassley 2012).

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 (2015 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 2014 World Energy Outlook (IEA 2014) to adjust the regional job multipliers for non-OECD regions over time.

The factors shown in Table 6 are applied to OECD employment factors when no local employment factor is available.

Table 6 Regional multipliers to be applied to employment factors

	2015	2020	2030
OECD	1.0	1.0	1.0
Africa	5.7	5.4	4.5
China	2.6	2.1	1.5
Eastern Europe/Eurasia	6.0	5.0	3.6
India	6.9	5.9	3.8
Latin America	3.4	3.3	2.9
Middle East	1.4	1.4	1.2
Non-OECD Asia	2.4	2.3	1.9

Note Growth rates in labour productivity are taken as growth rate in GDP per capita, derived from IEA World Energy Outlook (2014).

Derivation of regional adjustment factors

A regional labour productivity value was calculated for each of the ten analysis regions, primarily using data from the 8th Edition of the Key Indicators of the Labour Market (KILM) database (International Labour Organization 2014), with the most recent data coming from 2012. This database holds data for economy-wide average labour productivity, calculated as average GDP per engaged worker. Additional data on GDP and employment numbers was sourced from the World Development Indicators (World Bank 2015c), and The World FactBook (Central Intelligence Agency (CIA) n.d.).

Countries were grouped according to the Energy [R]evolution regions, 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 7 Numbers of countries with labour productivity data

Region	In energy scenarios for this study	With data available on labour productivity Overall	agricultural
OECD Americas	3	3	3
OECD Europe	26	26	26
OECD Asia-Oceania	4	4	4
Africa[1]	55	26	22
China[2,3]	2	2	2
Non-OECD Asia	31	21	18
India	1	1	1
Latin America	44	23	23
Middle East	12	11	11
Eastern Europe/Eurasia	25	21	18
Total	**203**	**138**	**131**

A total of 203 countries are included in the energy projections for the year 2015. Data on labour productivity was available for 138 countries, and for both labour productivity and agricultural labour productivity for 131 countries, as shown in Table 7. 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 2015 regional labour productivity data to calculate average labour productivity in 2020, 2025 and 2030 for each region. GDP per capita growth was then derived for each of the 10 regions using projected GDP and population growth estimates from the World Energy Outlook (International Energy Agency 2014). These economic assumptions are key inputs to the IEA World Energy Outlook modelling and both the Energy [R]evolution and Reference scenarios.

In the job projections, three sets of productivity data were generated for whole of economy for agricultural, forestry and fisheries workers only, and a third set for whole of economy excluding agricultural, forestry and fisheries.

[1] GDP for Nigeria obtained from www.tradingeconomics.com/nigeria/gdp-per-capita-ppp-constant-2005-international-dollar-wb-data.html
[2] Includes Hong Kong
[3] GDP PPP data in 2011 international dollars converted using information from McCarthy 2013.

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, and therefore increases the job multiplier between developed and developing countries. However, agricultural productivity may not be relevant to the majority of energy technologies, other than bioenergy fuel employment.

It is not possible to disaggregate labour productivity in KILM data, so whole of economy labour productivity was adjusted using the relationship between whole of economy and whole of economy excluding agriculture. Agricultural labour productivity was derived using data on Agriculture contribution to GDP from the World Bank (2015a), or where this was not available from the CIA World Fact book, divided by total jobs in agriculture from the World Bank (2015b) or the KILM database (International Labour Organization 2014, Table 4a).

Productivity data for each region and time period is compared to the OECD region in Table 8 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 8, such that if productivity or value added per worker is 0.5 times the OECD value, we assume that job creation in that region would be twice as high. The resulting multipliers are also presented in Table 6.

Table 8 Regional labour productivity compared to OECD labour productivity

	Whole economy [1]	**Whole economy excluding agriculture**	**Ratio to OECD**	**Factor used to exclude agriculture [2]**
	GDP per worker 2012 (2005 international $ at PPP)			
World	25,600	136,200	0.73	5.3
OECD	68,500	187,600	1.00	2.7
OECD Americas	75,900	200,000	1.07	2.6
OECD Europe	64,600	182,800	0.97	2.8
OECD Asia-Oceania	63,000	162,200	0.86	2.6
Africa	9,300	32,000	0.17	3.4
China[4]	17,000	62,100	0.33	3.7
Non-OECD Asia	9,500	28,000	0.15	3.0
India	8,800	24,600	0.13	2.8
Latin America	21,200	55,200	0.29	2.6
Middle East	41,100	131,900	0.70	3.2
Eastern Europe/ Eurasia	25,400	75,900	0.40	3.0

Note 1 Labour productivity (defined as average GDP per worker) from KILM (8th Ed).

Note 2 The factor used to exclude agriculture is the ratio between 'whole economy' labour productivity and 'whole economy excluding agriculture' productivity.

[4] Includes China and Hong Kong.

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.

An annual decline factor is derived for each region from the cost data used in the Energy [R]evolution modelling.

The overall decline in employment per MW is given for each region in Table 9 below. So, for example, in Africa the employment factor for offshore wind is expected to decline by 22% by 2030.

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

Table 9 Employment factor decline from 2015 – 2030 by technology

	OECD North America	OECD Europe	OECD Pacific	Latin America	China	India	Africa	Middle East	Eastern Europe/Eurasia	Developing Asia
Coal	-	-	-	-	-65%	-25%	-	-	-	-25%
Lignite	-	-	-	-	-65%	-25%	-	-	-	-25%
Gas	6%	6%	7%	5%	4%	5%	5%	5%	5%	5%
Oil	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%
Diesel	-	-	-	-	-	-	-	-	-	-
Nuclear	5%	16%	-13%	-	-35%	-27%	-	-	-	-27%
Biomass	4%	5%	4%	3%	3%	3%	5%	3%	3%	3%
Hydro-large	0%	-6%	0%	-7%	-3%	-6%	-1%	-7%	-3%	-6%
Hydro-small	0%	-6%	0%	-7%	-3%	-6%	-1%	-7%	-3%	-6%
Wind onshore	6%	5%	7%	5%	3%	3%	6%	5%	5%	3%
Wind offshore	25%	23%	24%	23%	23%	23%	22%	23%	23%	23%
PV	41%	41%	41%	41%	41%	41%	41%	41%	41%	41%
Geothermal power	48%	48%	48%	48%	48%	48%	48%	48%	48%	48%
Solar thermal power	9%	17%	9%	12%	10%	10%	14%	12%	9%	10%
Ocean	33%	32%	32%	31%	31%	31%	31%	31%	32%	31%
Coal CHP	4%	5%	4%	4%	2%	4%	5%	4%	3%	4%
Lignite CHP	-	-	-	-	-65%	-25%	-	-	-	-25%
Gas CHP	-	-	35%	36%	-	-	36%	36%	-	-
Oil CHP	33%	33%	27%	29%	33%	33%	29%	29%	33%	33%
Biomass CHP	-	-	29%	30%	-65%	-25%	30%	30%	-	-25%
Geothermal CHP	6%	6%	1%	2%	6%	6%	2%	2%	6%	6%
Hydrogen CHP	-	-	-	-	-	-	-	-	-	-
Geothermal - heat	8%	8%	8%	5%	5%	5%	5%	6%	8%	5%
Solar - heat	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%

7 Coal trade

Jobs in coal supply are allocated taking international trade into account. The Reference case is the Current Policies scenario from the World Energy Outlook 2014 (International Energy Agency 2014). Only detailed projections for international coal trade and coal production are included in the New Policies scenario, so are 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 12 and Table 13.

The proportion of coal imports calculated for the Reference and [R]evolution scenarios for each region are shown in Table 10. The proportion of imports in the Reference scenario is calculated from the PJ imported divided by the total PJ consumed (the actual scale of imports are shown in Table 12, and domestic production in Table 13). 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 10 Proportion of coal imports: Reference and [R]evolution scenarios

	REFERENCE				[R]EVOLUTION			
	2012	2015	2020	2030	2012	2015	2020	2030
OECD North America	-	-	-	-	-	-	-	-
Latin America	-	-	-	-	-	-	-	-
OECD Europe	46%	49%	54%	60%	43%	54%	39%	0%
Africa	-	-	-	-	-	-	-	-
Middle East	75%	80%	84%	87%	71%	83%	88%	95%
Eastern Europe /Eurasia	-	-	-	-	-	-	-	-
India	14%	14%	14%	12%	12%	14%	5%	0%
Non-OECD Asia	-	-	14%	31%	-	14%	-	-
China	3%	3%	3%	3%	2%	3%	-	-
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 10) 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 12). The percentage of net inter-regional trade sourced from each exporting region is shown in Table 11.

Table 11 Proportional allocation of world trade: Reference and [R]evolution scenarios

	2012	2015	2020	2030
OECD Americas	26%	25%	19%	14%
Latin America	14%	16%	16%	14%
Africa	16%	18%	17%	15%
Eurasia/ E Europe	25%	29%	29%	22%
Non-OECD Asia	16%	1%	0%	0%
OECD Oceania	3%	11%	20%	35%
	100%	**100%**	**100%**	**100%**

Table 12 Net Inter-regional hard coal trade, 2012 – 2030, reference scenario (PJ)
Negative values = imports, positive values = exports. MTCE converted to PJ.

	2012	2015	2020	2025	2030
OECD	**-2,843**	**-2,179**	**-1,074**	**1,493**	**4,059**
OECD Americas	3,048	2,912	2,684	2,744	2,805
OECD Europe	**-6,243**	**-6,389**	**-6,632**	**-6,227**	**-5,823**
OECD Oceania	322	1,279	2,874	4,966	7,059
Eastern Europe/ Eurasia	2,901	3,365	4,137	4,299	4,462
Non-OECD Asia	1,876	3,811	3,812	3,813	3,814
China	**-2,579**	**-2,654**	**-2,779**	**-2,920**	**-3,061**
India	**-1,788**	**-1,840**	**-1,926**	**-2,024**	**-2,122**
Middle East	**-88**	**-114**	**-158**	**-175**	**-193**
Africa	1,934	2,097	2,368	2,650	2,932
Latin America	1,671	1,897	2,274	2,541	2,808
World	29,953	32,777	37,485	41,713	45,940

Derived from WEO 2014 Table 5.4 *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 (Table 5.1, page 174). Linear interpolation is used between specified years.

Table 13 Regional production of coal, 2012–2030, coal importing countries (PJ)

	2012	2015	2020	2025	2030	2035
OECD	39,888	39,701	39,390	37,294	35,199	35,082
Europe	7,210	6,638	5,686	4,763	3,839	3,458
China	78,985	80,722	83,616	84,671	85,726	80,275
India	10,903	11,397	12,221	13,584	14,947	17,262
Middle East	29	29	29	29	29	29
Non-OECD Asia	13,804	15,002	16,999	18,464	19,929	

From WEO 2014, Table 5.3 *Coal production by region in the New Policies Scenario*. P183 (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 derived from the New Policies scenario in the World Energy Outlook 2014 (International Energy Agency 2011), and are shown in Table 15 and Table 16. 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.

The proportion of gas imports in the Reference and [R]evolution scenarios are shown in Table 14. 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 15, with the assumption that export regions will increase production in response to demand.

Table 14 Proportion of gas imports: Reference and [R]evolution scenarios

	REFERENCE				[R]EVOLUTION			
	2012	2015	2020	2030	2012	2015	2020	2030
OECD Americas	1%	-	-	-	-	3%	3%	-
Latin America	-	-	-	-	-	-	-	-
OECD Europe	31%	32%	35%	37%	37%	31%	30%	10%
Africa	-	-	-	-	-	-	-	-
Middle East	-	-	-	-	-	-	-	-
Eurasia/ E Europe	-	-	-	-	0%	-	-	-
India	24%	25%	27%	29%	33%	24%	32%	29%
Non-OECD Asia	-	-	-	3%	1%	-	0%	-
China	21%	24%	27%	31%	19%	21%	27%	26%
OECD Oceania	21%	24%	27%	31%	7%	21%	26%	7%

Table 15 Net Inter-regional gas trade, 2009 – 2035, New Policies scenario (PJ)

Negative values = imports, positive values = exports.

	2012	2015	2020	2030
OECD Americas	-611	-1,132	-2,001	-153
Latin America	603	419	113	-377
OECD Europe	-8,633	-9,105	-9,892	-12,743
Africa	3,506	3,119	2,474	3,054
Middle East	4,713	4,022	2,870	2,337
Eurasia/ E Europe	6,824	7,048	7,422	8,709
India	-641	-941	-1,442	-2,714
Non-OECD Asia	1,810	1,403	726	-302
China	-1,546	-3,285	-6,183	-9,576
OECD Oceania	-5,806	-5,166	-4,100	-1,885

Derived from Net inter-regional trade (PJ), dervied from Table 4.5 Natural gas production by region in the New Policies Scenario (bcm) Page 149 WEO 2014 and Table 4.2 Natural gas demand by region in the New Policies Scenario (bcm)

Table 16 Regional production of gas, 2009 – 2035, IEA new policies scenario (PJ)

	2012	2015	2020	2030
OECD Americas	33,807	35,970	39,575	44,618
Latin America	6,484	6,824	7,389	10,066
OECD Europe	10,481	10,127	9,538	8,483
Africa	8,030	8,355	8,897	13,120
Middle East	19,943	20,551	21,564	28,124
Eurasia/ E Europe	32,912	33,548	34,609	38,793
India	1,508	1,649	1,885	3,129
Non-OECD Asia	10,405	10,829	11,536	12,554
China	4,034	4,939	6,447	10,028
OECD Oceania	2,413	3,402	5,052	6,032

9 Employment in energy sector manufacturing

The proportion of renewable energy manufacturing that occurs within each region varies around the world. In order to calculate employment for this study, percentages have been assigned in each region for 2010, 2020, and 2030. These are shown in Table 17.

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

Local renewable energy 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 17. Import and export percentages and current export regions are set according to current practice.

Table 17 Proportion of local renewable energy manufacturing and import / export, all regions

	Proportion of renewable energy manufacturing within the region			Region where renewable energy equipment is imported from			
	2010	2020	2030	OECD Europe	OECD North America	India	China
OECD Europe	100%	100%	100%	0%	-	-	-
OECD Americas	**70%**	**100%**	**100%**	50%	-	-	50%
OECD Asia-Oceania	50%	60%	60%	0%	-	-	-
Non-OECD Asia	30%	50%	70%	40%	-	30%	30%
India	80%	100%	100%	50%	-	-	50%
China	100%	100%	100%	-	-	-	-
Africa	30%	30%	50%	50%	10%	10%	40%
Latin America	50%	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 and 2012

Table 18 Employment factors used in the 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.

Table 19 Employment factors used in the 2012 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
Gas	2	1.7	1.0	0.08	22
Nuclear	10	14	1.3	0.3	0.001 Jobs/GWh final demand
Biomass	2	14	2.9	1.5	32
Hydro-large	2	6.0	1.5	0.3	
Hydro-small	2	15	5.5	2.4	
Wind onshore	2	2.5	6.1	0.2	
Wind offshore	4	7.1	11	0.2	
PV	1	11	6.9	0.3	
Geothermal	2	6.8	3.9	0.4	
Solar thermal	2	8.9	4.0	0.5	
Ocean	2	9.0	1.0	0.32	
Geothermal - heat	3.0 jobs/ MW (construction and manufacturing)				
Solar - heat	7.4 jobs/ MW (construction and manufacturing)				
Nuclear decommissioning	0.95 jobs per MW decommissioned				
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	Employment factors for gas are used				

Further details can be found in Rutovitz & Harris 2012a.

Appendix 2 Wind employment factors – additional information

ONSHORE WIND

Report			**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)
2012 analysis			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).
Current report			**3.2**	**4.7**	**0.3**	**Construction and O&M from the average of 6-7 studies below. Turbine manufacturing Vestas 2014 scaled to all manufacturing using EWEA (2009) ratio of turbine to total manufacturing.**
Region/ country	**Year**	**New in 2015**	**Construction** Person years/MW	**Manufacturing** Person years/MW	**O&M** Jobs/ MW	**Notes and data sources**
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)
Greece	2011		6.1	*(2.7)*	0.4	From Tourkolias & Mirasgedis, (2011) Table 3 and Table 8
Germany	2011	Y			0.64	Employment from O'Sullivan et al and installed capacity from German Federal Ministry of Economic affairs and Energy
New Zealand	2012	Y	2.6		0.15	Leung-Wai, J. & Generosa, A. (2012)
OECD	2014	Y		(4.7)		Turbine manufacturing Vestas 2014 scaled to all manufacturing using EWEA (2009) ratio of turbine to total manufacturing.
US	2014	Y	1.0	*(9.1)*	0.1	JEDI model (National Renewable Energy Laboratory 2015b)
US	2014	Y	6.0		0.4	From IO model based on JEDI & other data (Comings et al. 2014)

OFFSHORE WIND

Report			**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)
2012 analysis			7.1	10.7	0.2	Price Waterhouse Coopers (2012)
Current report			**8.0**	**15.6**	**0.2**	**Average of 2 studies below.**
Region/ country	**Year**	**New in 2015**	**Construction** Person years/MW	**Manufacturing** Person years/MW	**O&M** Jobs/ MW	**Notes and data sources**
US	2014	Y	8.9	20.5	0.09	JEDI model (National Renewable Energy Laboratory 2014e)
Germany	2012		7.1	10.7	0.2	Price Waterhouse Coopers (2012)

Appendix 3 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)
2012 analysis		10.9	6.9	0.3	Average of 6-8 factors
Current report		**13.0**	**6.5**	**0.7**	**Construction average of 8 factors listed below. Manufacturing from module production from four of the largest global companies annual reports; balance of system calculated from cost ratio of BOS to modules in the NREL Jedi model 2014. O&M average of 6 factors listed below.**
Germany	2007, 2008	10.7			One company, total installation 3.09 MW [Reisinger Sonnenstrom: http://www.reisinger-sonnenstrom.de/menu/01-sonnenstrom-team.htm](http://www.reisinger-sonnenstrom.de/menu/01-sonnenstrom-team.htm)
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)
Netherlands	2010	12.6			National reporting of employment from Statistics Netherlands (2010)
Greece	2011	11.2	*(6.0)*		From Tourkolias & Mirasgedis, (2011) Table 3 and Table 8
Germany	2011			0.3	Employment from O'Sullivan et al and installed capacity from German Federal Ministry of Economic Affairs and Energy
US	2011,		*(15.1)*		Calculation based on average of 2011 an 2012 data from EIA Solar

Region/ country	**Year**	**Construction** Person years/MW	**Manufacturing** Person years/MW	**O&M** Jobs/ MW	**Notes and data source**
	2012				photovoltaic cell/module manufacturing activities (2012)
Spain	2013	6.4	*(21.4)*	1.7	Llera, E., Scarpellini, S., Aranda, a., & Zabalza, I. (2013)
US	2014	18	*(9.8)*	0.2	JEDI model (National Renewable Energy Laboratory 2010a)
US	2014	21		1.2	Average of small and large PV From IO model based on JEDI and other data (Comings et al. 2014)
Global	2014		6.5		Module production factor calculated from four largest global companies annual reports (does not include inverters or BOS) (Trina Solar 2014; Yingli Green Energy 2014; Canadian Solar 2014; JinkoSolar 2013); balance of system calculated from cost ratio of BOS to modules in the JEDI model (National Renewable Energy Laboratory 2014f)

Appendix 4 Solar thermal employment factors – additional information

Report			Construction Person yrs /MW	O&M Jobs/ MW	Construction period Years	MW	Notes and data source
2010 analysis			**6.0**	**0.3**			
2012 analysis			**8.9**	**0.5**	**2.0**	**3223**	**Weighted average of 19 reported power plants (3223 MW) in the US, Spain, and Australia**
Europe 2012 (weighted average)			14.7	1.0		951	Weighted average of 10 reported power plants (951 MW) in the US, Spain, and Australia
US 2012 (weighted average)			5.3	0.4		1512	Weighted average of 8 reported power plants (1512 MW) in the US, Spain, and Australia
Current report			**8.0**	**0.6**		**2570**	**Weighted average of 31 reported power plants (2570 MW) below**
Europe 2015 (weighted average)			12.2	1.0		1057	Weighted average of 22 reported power plants in Spain, and 1 in France (1057 MW)
US 2015 (weighted average)			5.3	0.4		1512	Weighted average of 8 reported power plants (1512 MW)
Region/ country	**Year**	**New in 2015**	**Construction** Person yrs /MW	**O&M** Jobs/ MW	**Construction period** Years	**MW**	**Notes and data source**
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
Spain	2011		12.0	0.8	2.5	50	Aldiere (Granada) www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=3

Region/ country	Year	New in 2015	Construction Person yrs /MW	O&M Jobs/ MW	Construction period Years	MW	Notes and data source
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
Spain	2011	Y	12.0	1.2		50	Helioenergy 1, Écija (Sevilla) http://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=210
Spain	2011	Y	10.0		3.1	50	Lebrija 1, Lebrija, (Sevilla) http://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=17
Spain	2011	Y	12.0	0.8	2.5	50	Manchasol-1, Alcazar de San Juan (Ciudad Real) http://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=7
Spain	2011	Y	7.0	0.6	2.1	50	Palma del Río I, Palma del Río (Córdoba) http://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=16
Spain	2011	Y	18.0	0.8	2.5	49.9	Termesol 50, San José del Valle (Cádiz) http://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=13
Spain	2012	Y	10.0	1.0		50	Aste 1A, Alcázar de San Juan (Ciudad Real) http://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=215
Spain	2012	Y	10.0	1.0		50	Astexol II, Olivenza (Badajoz) http://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=229
Spain	2012	Y		1.2	1.8	25	Borges Termosolar, Les Borges Blanques (Lleida) http://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=242
Spain	2012	Y	6.0	0.8		50	La Africana, Posadas (Córdoba) http://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=236
Spain	2012	Y	12.0	0.9		50	Morón, Morón de la Frontera (Seville) http://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=227
Spain	2012	Y	12.0	0.9	2.1	50	Olivenza 1, Olivenza (Badajoz) http://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=228
Spain	2012	Y	9.0	0.8		50	Solacor 1, El Carpio (Córdoba) http://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=223
Spain	2013	Y	14.0	1.7		50	Solaben 1, Logrosán (Cáceres) http://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=230
France	2015	Y	12.5	1.0	1.9	12	Alba Nova 1, Ghisonaccia (Corsica Island) http://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=221
US	2009			1.4	0.6	5	Kimberlina Solar Thermal Power Plant (Kimberlina) www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=37

Region/ country	**Year**	**New in 2015**	**Construction** Person yrs /MW	**O&M** Jobs/ MW	**Construction period** Years	**MW**	**Notes and data source**
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 1: Manufacturing employment uses the same factor as the 2012 report, 4 jobs in manufacturing per MW (European Renewable Energy Council, 2008, page 16)

Note 2: An additional project in France (Augustin Fresnel 1, Targassonne (Pyreneans)) was excluded as it is a prototype.

Appendix 5 Hydro employment factors – additional information

LARGE HYDRO

Report			Construction Person years/MW	Manufacturing Person years/MW	O&M Jobs/ MW	Notes and data source
2010 analysis			10.8	0.5	0.2	(Pembina Institute 2004)
2012 analysis			6.0	1.5	0.3	Construction and manufacturing from Navigant Consulting. (2009). O&M average of data from South Korea, Japan, South Africa (Institute research) and Navigant Consulting (2009)
Current report			**7.4**	**3.5**	**0.2**	Average of 2 - 6 studies listed below
Region/ country	**Year**	**New in 2015**	**Construction** Person years/MW	**Manufacturing** Person years/MW	**O&M** Jobs/ MW	**Notes and data sources**
US	2009		6.0	1.5	0.14	Using mid-range of estimates for new facilities in existing dams. (Navigant Consulting 2009)
South Korea	2010				0.62	(Rutovitz & Harris 2012b)
Japan	2010				0.11	(Rutovitz & Ison 2011)
New Zealand	2010	Y	3.3			(Meridian Energy Limited 2010)
France	2012	Y			0.16	(Rutovitz & Razain 2013b)
Switzerland	2013	Y			0.2	(Rutovitz & Mikhailovich 2013b)
US	2014	Y	12.9	5.5	0.02	(National Renewable Energy Laboratory 2014b)

SMALL HYDRO

Report			Construction Person years/MW	Manufacturing Person years/MW	O&M Jobs/ MW	Notes and data source
2010 analysis			10.8	0.5	0.2	(Pembina Institute 2004)
2012 analysis			15.0	2.4	0.0	Average of 3-4 studies from Canada, Spain and the US
Current report			**15.7**	**5.8**	**5.8**	**Average of 3-5 studies listed below**
Region/ country	**Year**	**New in 2015**	**Construction** Person years/MW	**Manufacturing** Person years/MW	**O&M** Jobs/ MW	**Notes and data sources**
Spain	2008		18.6		1.4	(Moreno & López 2008)
US	2009		29.5	10.0	2.5	Using mid-range of estimates for Micro hydro from (Navigant Consulting 2009)
Greece	2011		13.3	1.3	16.7	Direct employment in manufacturing, from a detailed I/O study for Greece, using Greece's 2005 IO table. Figure is calculated by taking: Table 3 (construction figure assuming all first level expenditure is domestic) minus Table 8 (assumes main elements of necessary equipment for development of the various RES projects will be purchased outside Greece). (Tourkolias & Mirasgedis 2011)
Netherlands	2012	Y			2.7	(Vuik et al. 2012)
US	2014	Y	1.7	21.4	1.1	(National Renewable Energy Laboratory 2014d)

Appendix 6 Nuclear employment factors – additional information

Report	Construction Person years/MW	Manufacturing Person years/MW	O&M Jobs/ MW	Fuel jobs/GWh final demand	Notes and data source
2010 analysis	14.4	1.6	0.3		(Pembina Institute 2004)
2012 analysis	13.7	1.3	0.3	0.001	Weighted average of 2 – 3 studies from US and UK
Current report	11.8	1.3	0.60	0.001	Weighted average of 2 - 5 studies listed below. Fuel from (Rutovitz & Harris 2012a)

Region/ country	Year	New in 2015	Construction Person years/MW	Manufacturing Person years/MW	O&M Jobs/ MW	Notes and data sources
South Korea	2010				0.36	(Rutovitz & Harris 2012b)
UK	2010		12.2	1.1	0.26	(Cogent Sector Skills Council 2010)
UK	2011		14.6	1.4	0.21	(Cogent Sector Skills Council 2011a)
France	2011	Y	11.6		0.71	(Rutovitz & Razain 2013a)
Switzerland	2013	Y			0.51	(Rutovitz & Mikhailovich 2013b)

Appendix 7 Coal employment – productivity projection

Productivity projection for coal mining – China

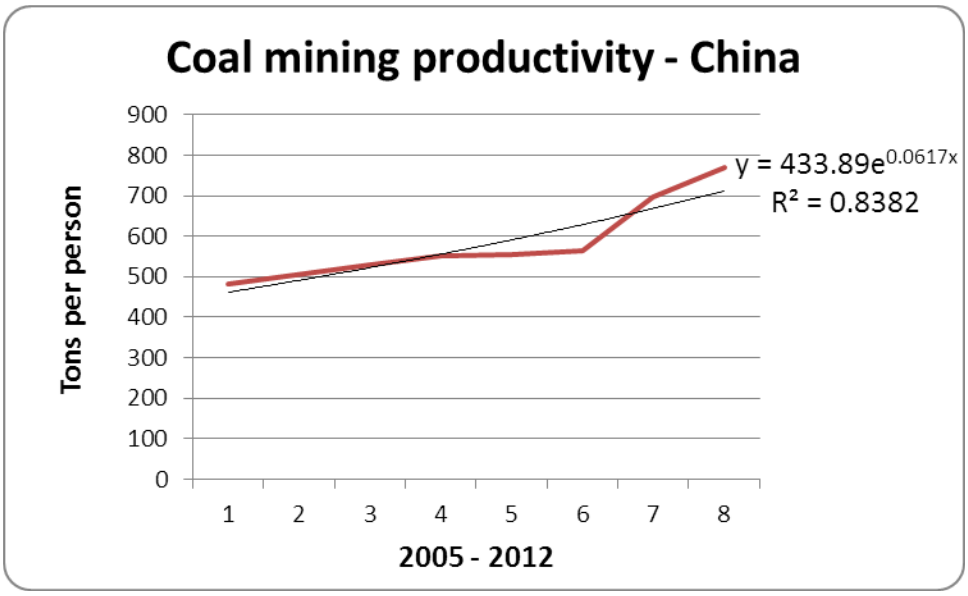
The table and graph below show the historic production in China, with production data from BP (BP 2011), employment data for 2007 – 2011 from China Coal Resource (Zhang 2012), with from the China Labour Statistics Yearbook (2013) converted to PJ using coal production from BP Statistical Review of World Energy (BP 2015).

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 China:

- **2012-2015** – annual productivity improvement of 13%
- **2015-2020**– annual productivity improvement of 6%
- **2020-2030** – annual productivity improvement of 6%

Table 20 Historic and projected productivity for coal mining in China

YEAR	PRODUCTION Million tons	EMPLOYMENT	Tons per person
2005	1636	4,284,856	382
2007	1929	4,597,000	420
2008	2076	4,741,000	438
2009	2197	5,003,000	439
2010	2279	5,110,000	446
2011	2924	5,311,000	551
2012	2675	4,399,000	608
PROJECTION FROM 2005 – 2011 TREND			
2015			910
2020			1,239
2030			2,296



Productivity projection for coal mining – India

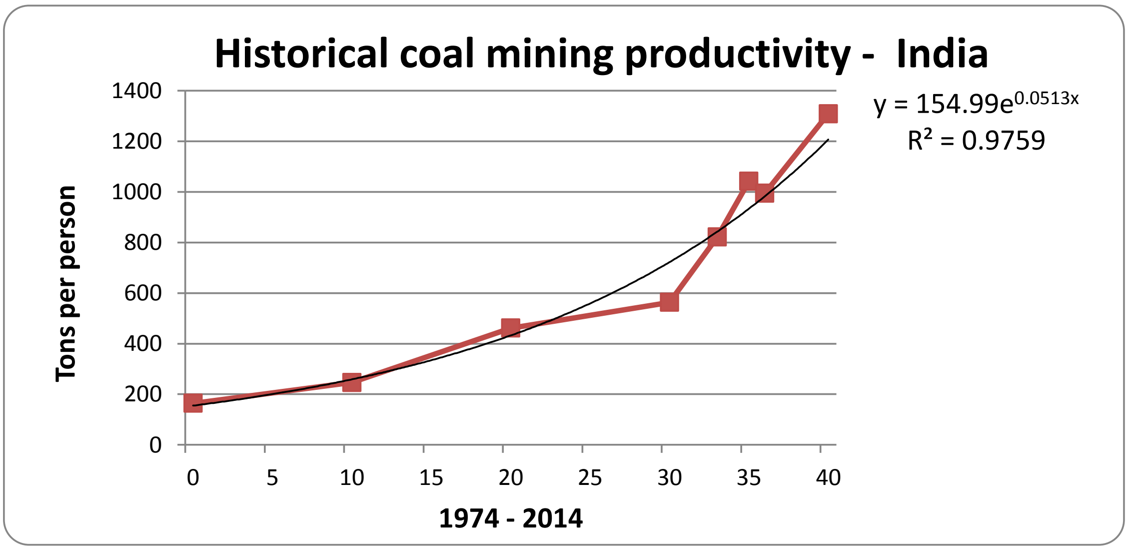
The table and graph below shows the historic productivity and projection for coal mining in India. Data is from the Indian Ministry for Coal 2014.

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 India:

- **2010-2015** – annual productivity improvement of 5%
- **2015-2020**– annual productivity improvement of 5.3%
- **2020-2030** – annual productivity improvement of 5.3%

Table 21 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
2014	1309
PROJECTION FROM TREND	
2015	1270
2020	1641
2030	2741



Productivity projection for coal mining – Russia

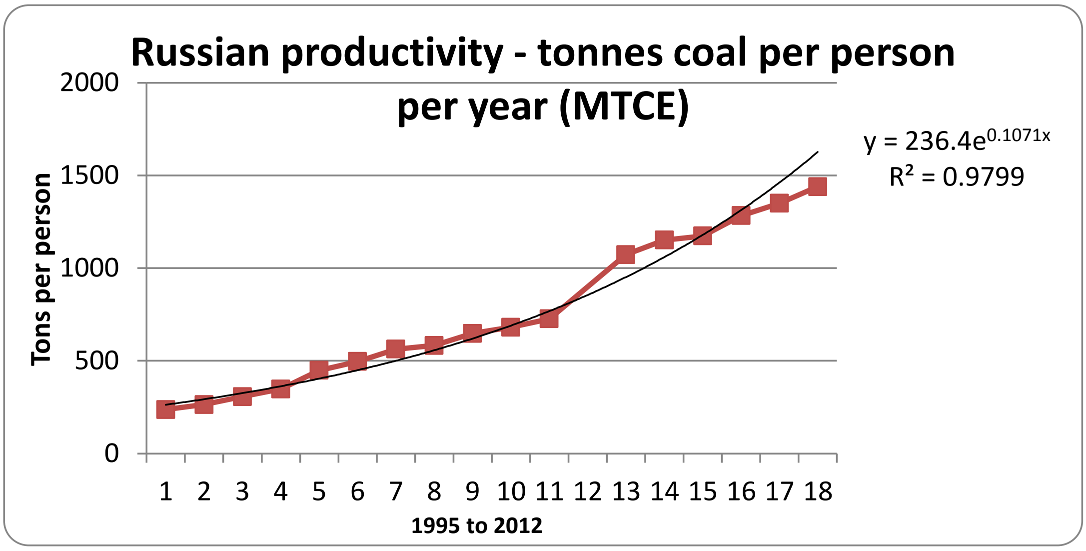
The table and graph shows the historic productivity and projection for coal mining in Russia. Data for employment from 1995 – 2005 is from the UNECE Ad Hoc Group of Experts on Coal in Sustainable Development (Klimov 2003) and for 2007 – 2012 from Emerging Markets Insight 2013. Production data is from the BP Statistical Review of World Energy (BP 2015).

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 10%
- **2015-2020**– annual productivity improvement of 10%
- **2020-2030** – annual productivity improvement of 10%

Table 22 Historic and projected productivity for coal mining in Russia

YEAR	Tons per person
1995	237
1997	306
1999	449
2001	563
2003	648
2005	726
2008	1151
2009	1174
2011	1350
2012	1439
FORWARD PROJECTION	
2015	**2241**
2020	**3828**
2030	**11172**



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