METHODOLOGY FOR CALCULATING ENERGY SECTOR JOBS

Final report

For Greenpeace International

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Abbreviations

CMI	Construction, manufacturing and installation
CSP	Concentrating Solar Power
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
IEA	International Energy Agency
ILO	International Labour Organisation
ISF	Institute for Sustainable Futures
KILM	Key Indicators of the Labour Market
kWh	Kilowatt hour
MW	Megawatt
MWh	Megawatt hour
NREL	National Renewable Energy Laboratories (US)
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 published a global energy scenario in 2008. The Energy [R]evolution set out a vision for low-carbon global energy supply and compared it to a Reference scenario, namely the energy projection put forward by the International Energy Agency in the World Energy Outlook 2007 (IEA 2007). The Institute for Sustainable Futures undertook an analysis of the employment effects of the Energy [R]evolution and Reference scenarios in 2009 (Rutovitz and Atherton, 2009).

Greenpeace International are updating the Energy [R}evolution modelling using the 2009 World Energy Outlook projections for the Reference scenario, and producing two [R]evolution scenarios, which they refer to as the basic and advanced [R]evolution scenarios, referred to here as the [R]evolution and Advanced scenarios.

Greenpeace International asked the Institute for Sustainable Futures to update the 2009 methodology to calculate the electricity sector jobs for the three 2010 scenarios, namely the Energy [R]evolution Basic scenario, the Energy [R]evolution Advanced scenario, and the Reference scenario from the IEA World Energy Outlook 2009. The updated methodology is presented in this report.

The Energy [R]evolution modelling makes projections for ten world regions as defined in the World Energy Outlook 2009 (IEA 2009). In addition Greenpeace has produced [R]evolution scenarios for four case study areas: the USA, Canada, Mexico, and the European Union.

Only direct employment 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, and are sometimes taken to include the effects from spending wages earned in the primary industries. Indirect jobs are usually calculated using a multiplier derived from input-output modelling. Indirect jobs have been completely excluded from this analysis owing to the considerable uncertainties involved. However, indirect jobs would certainly increase the numbers of jobs created, perhaps by a factor of two (for example, Bedzek, 2007).

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. It did not attempt to calculate the 'base line' energy efficiency jobs that would occur in the Reference scenario. The 2010 Energy [R]evolution scenarios include a considerable expansion of transport associated electricity consumption, which masks the reduction in stationary energy from the Reference to the [R]evolution scenarios (approximately 28% by 2030). While this could create substantial numbers of jobs, the methodology developed in 2009 only compared total electricity consumption between scenarios. It was not within the scope of this project to develop new methodology to assess the additional energy efficiency jobs created in the stationary energy sector, so no energy efficiency job calculations are included.

2 Methodology overview

The methodology used here was developed for an analysis of the global and regional employment effects of Greenpeace International's global Energy [R]evolution (GPI/ EREC 2008), and a full discussion of the employment factors and decline factors may be found in *Energy sector jobs to 2030, a global analysis* (Rutovitz and Atherton, 2009).

Greenpeace International have produced three scenarios including:

- a business as usual Reference case, based on the IEA World Energy Outlook 2009;
- a Basic [R]evolution scenario; and
- an Advanced [R]evolution scenario.

The energy scenarios are inputs to the employment modelling.

Employment is projected for each of the ten IEA world regions for the Reference scenario and both the [R]evolution scenarios at 2015, 2020, and 2030 by using a series of employment multipliers and the projected electrical generation and capacity.

Employment is also projected for four case study areas, the USA, Canada, Mexico, and the European Union. There are some methodology modifications for the case study areas, which are described in Section 9.

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

The inputs to the employment projections are as follows:

- ***Installed electrical capacity and generation by technology***, from the three scenarios. These are given at 2007, 2015, 2020, 2030, 2040, and 2050, and are extrapolated linearly for years in between.
- ***Employment factors*** which give the number of jobs per MW for each technology in construction and manufacturing, operations and maintenance, and fuel supply. These are the key inputs to the analysis. Employment factors other than for coal mining are adjusted using regional multipliers described below. Separate region-specific factors have been used for coal mining because of the size of the industry and the large variation between regions.
- ***Decline factors***, or learning adjustment rates, for each technology reduce the employment factors by a given percentage per year, to take account of the reduction in employment per MW as technologies mature.
- ***Regional job* multipliers** are used to adjust the employment factors in each region to take account of different stages of economic development. The job multiplier used is the ratio of labour productivity (excluding agriculture) in the OECD compared to the regional labour productivity. Job multipliers change over the study period according to projected changes in GDP per capita.
- ***Local manufacturing percentages and domestic coal and gas production percentages*** are used to determine the proportion of manufacturing jobs, and the proportion of coal and gas production, occurring within each region.

– ***Export percentages for renewable technologies, coal and gas*** are used where equipment, coal or gas is imported. In these cases, the country of origin is required in order to assign jobs to that region. A percentage of globally traded components / coal are assigned to each exporting region.

The calculation of energy supply jobs in each region is summarised in Figure 1.

Figure 1: Calculation of energy supply jobs overview

Manufacturing (for domestic use) = **MW installed per year** x **Manufacturing employment factor** x **regional job multiplier** x **% local manufacturing**

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

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

Operation and Maintenance = **Cumulative capacity** x **O&M employment factor** x **regional job multiplier**

Fuel supply (nuclear, oil, diesel, biomass) = **Electricity generation** x **Fuel employment factor** x **regional job multiplier**

Fuel supply (coal) = **Electricity generation + net coal exports** x **Regional fuel employment factor** x **% of local production**

Fuel supply (gas) = **Electricity generation + net gas exports** x **Fuel employment factor** x **regional job multiplier** x **% of local production**

Jobs in region = **manufacturing** + **construction** + **Operation and maintenance (O&M)** + **fuel**

Jobs in region at 2010 = **Jobs in region**

Jobs in region at 2020 or 2030 = **jobs in region** x **technology decline factor** [number of years **after 2010**]

2.1 Limitations

Employment numbers 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 have not been 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 40 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.
- **Decommissioning:** no estimate has been included for decommissioning of power plant. These jobs would mostly appear in the two [R]evolution scenarios, as a significant capacity of both coal and nuclear capacity is decommissioned within the analysis period.
- **Energy efficiency:** as noted above, no estimate is made of energy efficiency jobs, which could be significantly higher in [R]evolution scenarios than in the Reference case, as stationary electricity consumption is reduced globally by approximately 28%.

3 Employment factors

The factors used in the employment analysis are presented in Table 1: Employment factors used in the 2010 global 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	Note 1
Gas, oil and diesel	2	1.40	0.07	0.05	0.12	Note 2
Nuclear	10	14.4	1.6	0.3	0.001	Note 3
Biomass	2	3.9	0.4	3.1	0.2	Note 4
Hydro	2	10.8	0.5	0.2		Note 5

Wind	2	2.5	12.5	0.4	Note 6
PV	1	29.0	9.3	0.4	Note 7
Geothermal	2	3.1	3.3	0.7	Note 8
Solar thermal	2	6.0	4.0	0.3	Note 9
Ocean	2	9.0	1.0	0.3	Note 10
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.				

Notes on Employment Factors

1. **Coal**
   Construction and manufacturing and operations and maintenance multipliers are from the NREL JEDI model, downloaded 30/4/09. Note that the factors have been altered since the ISF 2009 global analysis as an ambiguity within the NREL model has been clarified. Regional factors are used for coal fuel employment (see below, Section 3.1).

2. **Gas**
   All factors are from NREL JEDI model, downloaded 30/4/09 with default values used for all variables. Note that the factors have been altered since the 2009 global analysis as an ambiguity within the NREL model has been clarified.

3. **Nuclear**
   The construction, manufacturing and installation factor is derived from a Nuclear Energy Institute fact sheet (NEI 2009). The operations and maintenance and fuel factors were derived for the ISF 2009 global energy sector jobs analysis (Rutovitz and Atherton 2009).

4. **Hydro**
   All factors are from a Canadian study (Pembina Institute 2004).

5. **Wind**
   All factors are from the European Wind Energy Association 2009 report (EWEA 2009). Note that offshore wind is not distinguished from onshore wind in the calculations as it was not separated in the energy modelling.

6. **Bioenergy**
   Only bioenergy for power generation is considered in this analysis, which does not include bio-fuels. The combined employment factors for construction and manufacturing are from a Californian study (EPRI 2001). The factor for operations and maintenance and fuel supply comes from a UK study (DTI 2004).

7. **Geothermal**
   Factors used in this study were derived from US geothermal industry data projections for jobs and installed capacity (GEA 2005). Data in the GEA report has been collated from an industry survey and other sources such as environmental impact assessments.

8. **Solar thermal**
All employment factors from European Renewable Energy Council 2008 Renewable Energy Technology Roadmap 20% by 2020, page 16. The new generation of solar thermal power plants is an emerging sector, so the factors used in this study are industry projections for job creation from the technology (EREC 2008).

9. **Solar PV**
The construction factors are the 2010 projections for jobs and installed capacity in the advanced scenario put forward by the European PV Industry Association (EPIA and Greenpeace 2008). The O&M factor used in this study was derived from 2007 German industry data for employment and capacity (BMU 2008a).

Ocean
As with solar thermal, ocean power is an emerging sector and hence very little data is available for jobs associated with ocean power 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, and 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)..
Employment factors were derived for the ISF 2009 global jobs analysis, and these have been used unchanged for this analysis with the exception of coal and gas.

The 2009 analysis used employment factors for construction that were too high, as an ambiguity in the NREL model led to the assumption that 'job years' were in fact jobs for the entire construction period. This has been corrected for this analysis, and the revised factors are presented in Table 1. Notes are given on each technology below.

Only **direct** employment in development, construction, manufacturing, operations and maintenance, and fuel supply is included.

Construction, installation, manufacturing and development (CMI) are all expressed in terms of job years per MW new capacity. Operations and maintenance (O&M) and fuel supply jobs are expressed in terms of jobs per MW and per GWh respectively. Construction and manufacturing jobs occur in the years prior to generation capacity coming on line. The construction times given in Table 1 are used to define the years in which jobs occur. For example, it is assumed that new coal capacity takes 5 years to develop, so 20% of the job years occur in each of the five years prior to coming on line. For wind energy, 50% of the job years occur in each of the two years prior to coming on line. Manufacturing jobs have been assumed to follow the same pattern.[1]

Further detail and a comparison with other factors from the literature on the employment effects of different energy technologies may be found in Rutovitz and Atherton, 2009.

[1] Note this is a refinement from the construction and manufacturing calculations for 2009, which took the average capacity increase over the previous 10 years and multiplied by the jobs years in construction and manufacturing per MW.

Table 1: Employment factors used in the 2010 global 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	Note 1
Gas, oil and diesel	2	1.40	0.07	0.05	0.12	Note 2
Nuclear	10	14.4	1.6	0.3	0.001	Note 3
Biomass	2	3.9	0.4	3.1	0.2	Note 4
Hydro	2	10.8	0.5	0.2		Note 5
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Ocean	2	9.0	1.0	0.3		Note 10
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.					

Notes on Employment Factors

10. **Coal**
Construction and manufacturing and operations and maintenance multipliers are from the NREL JEDI model, downloaded 30/4/09. Note that the factors have been altered since the ISF 2009 global analysis as an ambiguity within the NREL model has been clarified. Regional factors are used for coal fuel employment (see below, Section 3.1).

11. **Gas**
All factors are from NREL JEDI model, downloaded 30/4/09 with default values used for all variables. Note that the factors have been altered since the 2009 global analysis as an ambiguity within the NREL model has been clarified.

12. **Nuclear**
The construction, manufacturing and installation factor is derived from a Nuclear Energy Institute fact sheet (NEI 2009). The operations and maintenance and fuel factors were derived for the ISF 2009 global energy sector jobs analysis (Rutovitz and Atherton 2009).

13. **Hydro**
    All factors are from a Canadian study (Pembina Institute 2004).

14. **Wind**
    All factors are from the European Wind Energy Association 2009 report (EWEA 2009). Note that offshore wind is not distinguished from onshore wind in the calculations as it was not separated in the energy modelling.

15. **Bioenergy**
    Only bioenergy for power generation is considered in this analysis, which does not include bio-fuels. The combined employment factors for construction and manufacturing are from a Californian study (EPRI 2001). The factor for operations and maintenance and fuel supply comes from a UK study (DTI 2004).

16. **Geothermal**
    Factors used in this study were derived from US geothermal industry data projections for jobs and installed capacity (GEA 2005). Data in the GEA report has been collated from an industry survey and other sources such as environmental impact assessments.

17. **Solar thermal**
    All employment factors from European Renewable Energy Council 2008 Renewable Energy Technology Roadmap 20% by 2020, page 16. The new generation of solar thermal power plants is an emerging sector, so the factors used in this study are industry projections for job creation from the technology (EREC 2008).

18. **Solar PV**
    The construction factors are the 2010 projections for jobs and installed capacity in the advanced scenario put forward by the European PV Industry Association (EPIA and Greenpeace 2008). The O&M factor used in this study was derived from 2007 German industry data for employment and capacity (BMU 2008a).

19. **Ocean**
    As with solar thermal, ocean power is an emerging sector and hence very little data is available for jobs associated with ocean power 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, and 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).

3.1 Coal fuel supply employment factors

The factor used for coal fuel supply is extremely important because of the dominance of coal in the world's electricity supply and the considerable regional variation in employment per ton. In Australia, for example, coal is extracted at an average of 13,800 tons per person per year (t/p/yr) using highly mechanised processes while in Europe the average production is 1,800 t/p/yr.

China has the lowest average productivity in the world at present, with only 700 t/p/y. However, this is because of the large numbers of people working in very small village or township mines where coal extraction is entirely manual, which have productivity as low as 100 t/p/y). Productivity in large Chinese coal mines is a very different story. Five mines with annual output of 10 million tonnes each have productivity of

30,000 t/p/y (IEA 2007, page 337), double the highest average productivity for any OECD country. The employment factor for new generation in China has been taken as the current level for the US, as this seems the minimum productivity as the dominance of the new ‘super mines’ in Chinese coal supply increases.

Regional factors for coal mining employment were calculated for the 2009 analysis, using 2006/7 coal production and employment data. These have been updated for 2010 by using the current estimates of GDP per capita growth, and are shown in Table 2. These factors are used in the 2010 analysis.

For a detailed discussion of the coal employment factors see Rutovitz and Atherton, 2009.

Table 2: Employment factors used for coal fuel supply

	Employment factor (existing generation)	Employment factor (new generation)
	Jobs per GWh	
World average	0.4	-
OECD North America	0.03	0.02
OECD Europe	0.36	0.17
OECD Pacific	0.05	0.02
India	0.59	0.25
China	0.52	0.02
Africa	0.11	0.07
Transition economies	0.46	0.19
Developing Asia **Latin America** **Middle east**	No employment data available Used world average of **0.4 jobs per GWh for current generation**, as for these regions, and the average employment of 0.0008 per ton x average ton per GWh of electricity from hard coal, to arrive at **0.25 jobs per GWh for new coal generation**.	

From Rutovitz and Atherton, 2009, projected to 2010 using 2009 figures for per capita GDP growth

4 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 2009 World Energy Outlook (IEA 2009) to adjust the regional job multipliers over time.

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 2009). This database holds data for economy wide average labour productivity, calculated as average GDP per 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.

Of a total of 193 countries included in the energy projections for the year 2008, data was available in the KLIM database for 124. However, the regional distribution was uneven as can be seen below in Table 3. While some regions have relatively few countries represented, those with data tend to be the larger energy users within the region.

Table 3 Numbers of countries with labour productivity data

Region	Number of countries in GPI/ EREC	Number of countries with data available on labour productivity
OECD North America	3	3
OECD Europe	23	29
OECD Pacific	4	3
Africa	55	25
China	2	2
Developing Asia	29	14
India	1	1
Latin America	38	16
Middle East	13	12
Transition economies	25	19
Total	**193**	**124**

Average labour productivity for each region is derived from the KILM data. However, this database does not contain forecasts. Instead, a proxy was used, namely growth in GDP per capita. We applied this to the 2008 regional labour productivity data to calculate average labour productivity in 2020 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 IEA 2009. These economic assumptions are key inputs to the IEA scenario and both the [R]evolution scenario.

The ILO database on Key indicators of the Labour Market was updated between 2009 and 2010, and the 2010 analysis uses the later version (edition 6). While this contains more recent data, there is no longer the capacity to disaggregate labour productivity into agricultural and other sectors. In the 2009 analysis, 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.

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 2009 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 4 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 4, such that if productivity or value added per worker is 0.5 times the OECD value, we assume 2x jobs in that region. The resulting multipliers are also presented in Table 5.

Table 4 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	$17,263	1.5	$25,308	0.52
OECD	$47,173	1.0	$48,990	1.00
OECD North America	$54,579	1.0	$56,145	1.15
OECD Europe	$40,806	1.0	$42,775	0.87
OECD Pacific	$45,858	1.0	$47,418	0.97
Africa	$4,697	1.5	$6,981	0.14
China	$10,606	1.7	$18,051	0.37
Developing Asia	$10,776	1.6	$17,564	0.36
India	$7,445	2.3	$17,400	0.36
Latin America	$16,969	1.1	$19,367	0.40
Middle East	$17,237	1.2	$19,899	0.41
Transition economies	$17,166	1.1	$19,616	0.40

Note 1 Labour productivity (defined as average GDP per worker) from ILO KILM 2009.

Note 2 Growth rates in labour productivity taken as growth rate in GDP per capita, derived from World Energy Outlook 2009.

Note 3 The factor used to exclude agriculture is the ratio between 'whole economy' and 'whole economy excluding agriculture' from Rutovitz and Atherton, 2009.

Table 5 Regional multipliers to be applied to employment factors

	2010	**2020**	**2030**

OECD	1.0	1.0	1.0
Africa	6.8	6.4	7.0
China	2.4	1.7	1.0
Developing Asia	2.5	2.0	1.2
India	2.6	2.0	1.0
Latin America	2.5	2.3	2.3
Middle East	2.4	2.2	1.8
Transition economies	2.4	2.1	1.4

5 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 6 below. These declines rates are calculated directly from the cost data used in the Energy [R]evolution modelling (GPI 2010).

The Institute for Sustainable Futures has done research which indicates that costs for renewable technologies (and therefore employment) would fall quicker in the [R]evolution scenario than in the Reference scenario, owing to the accelerated uptake of the technologies (for example, see Usher et al, 2010). However, as the cost data is an input to the Energy [R]evolution modelling, we consider it preferable for consistency to use the decline rates derived by Greenpeace International which are identical for the all three scenarios.

Table 6 Decline rates

	Annual decline in job factors Reference scenario		**Annual decline in job factors [R]evolution scenario**	
	2010-20	2020-30	2010-20	2020-30
Coal	0.3%	0.2%	0.3%	0.2%
Lignite	0.4%	0.2%	0.4%	0.2%
Gas	0.5%	0.5%	0.5%	0.5%
Oil	0.4%	0.4%	0.4%	0.4%
Diesel	0.0%	0.0%	0.0%	0.0%
Nuclear	0.0%	0.0%	0.0%	0.0%
Biomass	0.8%	0.2%	0.8%	0.2%
Hydro	-0.6%	-0.4%	-0.6%	-0.4%
Wind onshore	3.1%	0.1%	3.5%	0.5%
Wind offshore	3.1%	0.1%	3.1%	0.1%
PV	5.9%	5.3%	5.9%	5.3%
Geothermal	3.0%	2.3%	3.0%	2.3%
Solar thermal	1.9%	1.7%	1.9%	1.7%
Ocean	5.6%	2.6%	5.6%	2.6%
Coal CHP	0.3%	0.2%	0.3%	0.2%
Lignite CHP	0.4%	0.2%	0.4%	0.2%
Gas CHP	0.5%	0.5%	0.5%	0.5%
Oil CHP	0.4%	0.4%	0.4%	0.4%
Biomass CHP	0.8%	0.2%	0.8%	0.2%
Geothermal CHP	3.0%	2.3%	3.0%	2.3%

6 Coal trade

Jobs in coal supply have been allocated taking international trade into account. The projected volumes of international trade and world coal production in the Reference scenario are taken from IEA 2009, and shown in Table 8 and Table 9 below.

The proportion of coal imports in the Reference, [R]evolution and Advanced scenarios are shown in Table 7.

The proportion of imports in the Reference scenario is calculated from the tons imported divided by the total tons consumed (imports are shown in Table 8, and domestic production in Table 9).

The proportion of coal imports in the [R]evolution and Advanced scenarios are 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 see if there is net import. Potential coal production is assumed to be constant between the three 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 import.

Table 7 Proportion of coal imports in the Reference and [R]evolution scenario

	REFERENCE			[R]EVOLUTION			ADVANCED		
	2010	2020	2030	2010	2020	2030	2010	2020	2030
OECD North America	-	-	-	-	-	-	-	-	-
Latin America	-	-	-	-	-	-	-	-	-
OECD Europe	45%	49%	50%	45%	23%	0%	42%	16%	0%
Africa	-	-	-	-	-	-	-	-	-
Middle East	87%	89%	91%	86%	80%	54%	91%	84%	62%
Transition economies	-	-	-	-	-	-	-	-	-
India	16%	22%	24%	14%	5%	0%	13%	0%	0%
Developing Asia	-	-	-	-	-	-	-	-	-
China	1%	2%	3%	-	-	-	-	-	-
OECD Pacific	1%	-	-	-	-	-	-	-	-

The total amount of exports in each scenario is determined by applying the proportion of imports (shown in Table 7) to the GWh of coal generation in each region. The proportional share of world trade assigned to each region is assumed to stay constant, so this is assigned to export regions according to the proportion of total international trade belonging to each region in the IEA Reference scenario projections (shown in Table 8).

Table 8 Net Inter-regional hard coal trade, 2007 – 2030, IEA reference scenario
Negative values = imports, positive values = exports. Million tons of coal equivalent.

	2007	2010	2015	2020	2030
OECD N America	**23**	**22**	**20**	**23**	**30**
OECD Europe	**-203**	**-204**	**-205**	**-200**	**-189**
OECD Pacific	**-14**	**-4**	**14**	**52**	**127**
Asia	-241	-241	-242	-238	-229
Oceania	228	239	256	290	357
E. Europe/Eurasia	**57**	**62**	**69**	**81**	**105**
Russia	61	63	66	80	107
Asia	78	39	-27	-85	-202
China	15	-12	-58	-68	-89
India	-48	-63	-87	-124	-197
Middle East	**-13**	**-13**	**-14**	**-19**	**-29**
Africa	**53**	**64**	**83**	**88**	**97**
Latin America	**42**	**49**	**60**	**60**	**61**
World	**654**	**709**	**801**	**896**	**1085**

From IEA 2009, Table 1.7, with values for 2010 and 2020 calculated assuming linear change.

Table 9 Regional production of coal, 2007 – 2030, IEA reference scenario (million tons of coal equivalent)

	2007	2010	2015	2020	2030
OECD N America	**868**	**866**	**862**	**881**	**918**
OECD Europe	**270**	**249**	**215**	**206**	**189**
OECD Pacific	**318**	**326**	**340**	**373**	**438**
Non OECD	**3128**	**3474**	**4051**	**4513**	**5436**
E. Europe/Eurasia	**361**	**366**	**375**	**409**	**477**
Russia	*209*	*218*	*232*	*266*	*334*
Asia	**2484**	**2799**	**3324**	**3731**	**4546**
China	*1875*	*2138*	*2575*	*2829*	*3336*
India	*300*	*318*	*348*	*445*	*640*
Middle East	**2**	**2**	**2**	**2**	**3**
Africa	**205**	**219**	**241**	**254**	**279**
Latin America	**77**	**89**	**109**	**116**	**130**
World	**4584**	**4916**	**5468**	**5972**	**6981**
European Union	*268*	*245*	*207*	*192*	*162*

From IEA 2009, Table 1.6, with values for 2010 and 2020 calculated assuming linear change.

7 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 IEA 2009, and shown in Table 11 and Table 12.

The proportion of gas imports in the Reference and [R]evolution scenarios are shown in Table 10. These are calculated for the Reference scenario from the billion cubic metres 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 GWh of coal imports for each region. This is assigned to export regions according to the proportion of total international trade belonging to each region in the IEA Reference scenario shown in Table 8, with the assumption that export regions will increase production in response to demand.

Table 10 Proportion of gas imports in the Reference and [R]evolution scenario

	REFERENCE			[R]EVOLUTION			ADVANCED		
	2010	2020	2030	2010	2020	2030	2010	2020	2030
OECD North America	-	-	-	-	-	-	-	-	-
Latin America	-	-	-	-	-	-	-	-	-
OECD Europe	45%	49%	50%	45%	23%	0%	42%	16%	0%
Africa	-	-	-	-	-	-	-	-	-
Middle East	87%	89%	91%	86%	80%	54%	91%	84%	62%
Transition economies	-	-	-	-	-	-	-	-	-
India	16%	22%	24%	14%	5%	0%	13%	0%	0%
Developing Asia	-	-	-	-	-	-	-	-	-
China	1%	2%	3%	-	-	-	-	-	-
OECD Pacific	1%	-	-	-	-	-	-	-	-

Table 11 Net Inter-regional gas trade, 2006 – 2030, IEA reference scenario
Negative values = imports, positive values = exports. Billion cubic metres.

	2007	2010	2015	2020	2030
OECD N America	**-36**	**-33**	**-27**	**-38**	**-61**
OECD Europe	**-250**	**-259**	**-273**	**-325**	**-428**
OECD Pacific	**-117**	**-114**	**-109**	**-103**	**-91**
Asia	-131	-134	-138	-144	-157
Oceania	14	20	29	41	66
E. Europe/Eurasia	**176**	**187**	**204**	**239**	**309**
Russia	193	196	201	221	260
Asia	**35**	**12**	**-26**	**-82**	**-193**
China	-4	-17	-39	-65	-117
India	-10	-13	-18	-29	-52
Middle East	**63**	**82**	**113**	**145**	**210**
Africa	**105**	**108**	**113**	**151**	**228**
Latin America	**16**	**12**	**4**	**11**	**25**
World	**677**	**708**	**760**	**863**	**1069**
European Union	-312	-332	-365	-415	-516

From IEA 2009, Table 12.3, values for 2010 and 2020 calculated assuming linear change.

Table 12 Regional production of gas, 2006 – 2030, IEA reference scenario
(billion cubic metres)

	2006	2010	2015	2020	2030
OECD N America	777	782	791	819	831
OECD Europe	294	288	279	260	222
OECD Pacific	53	61	75	104	128
E. Europe/Eurasia	858	875	903	958	1097
Russia	646	649	655	688	760
Asia	354	384	434	480	555
China	69	82	104	127	125
India	29	41	60	66	80
Middle East	357	408	493	569	812
Africa	206	225	257	303	414
Latin America	143	150	162	185	254
World	3042	3174	3395	3678	4313
European Union	214	196	167	139	103

From IEA 2009, Table 12.1, values for 2010 and 2020 calculated assuming linear change.

8 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 13.

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

Local manufacturing percentages vary from 100% manufacturing within Europe for each period, to 30% of manufacturing occurring within Africa in 2010, rising to 70% by 2030. Local percentages are applied to all renewable technologies, and to the Reference and [R]evolution scenarios, at the same proportion. The only exception is that a specific value for solar thermal technologies is applied in the OECD North America, as mirrors are currently imported from Germany.

Where equipment is imported, it is allocated among exporting regions as shown in Table 13. Import and export percentages, and current export regions, are set according to current practice. Local manufacturing generally increased over time.

Table 13 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%	-	-	-	-
OECD North America	**100%**	**100%**	100%	100%	-	-	-
OECD Pacific	30%	50%	50%	50%	-	25%	25%
Developing Asia	30%	50%	70%	50%	-	25%	25%
India	70%	100%	100%	50%	-	-	50%
China	70%	100%	100%	50%	-	-	50%
Africa	30%	30%	50%	50%	10%	20%	20%
Latin America	30%	50%	70%	50%	50%	-	-
Middle East	30%	30%	30%	50%	-	25%	25%
Transition economies	30%	50%	70%	50%	-	25%	25%

Note: Local manufacturing is applied across all technologies, with the exception of solar thermal in OECD N America. Only 50% and 70% of manufacturing for solar thermal is allocated to the OECD N America in 2010 and 2020, but by 2030 all manufacturing is assumed to occur locally.

9 Employment case studies

Greenpeace has also produced a Reference scenario, a basic [R]evolution scenario, and an Advanced [R]evolution scenario for the USA, Canada, Mexico, and the European Union (EU27). In order to produce employment projections for the case studies, ISF derived some additional inputs, and made some modifications to the global methodology described above. These changes are:

- Classification of the OECD employment factors into “mainly US / Canada”, “mainly Europe”, and “both”. These were then modified using regional or country multipliers to adjust for different productivity levels in the OECD. The country multipliers are derived using the same methodology as used in the global analysis. This means, for example, that the US, which has higher labour productivity, and is assigned lower job creation per unit of generation than Europe.
- Derivation of import percentages and export GWh for coal and gas for each of the countries and the EU27.
- Making reasonable estimates for domestic manufacturing of renewable technologies for each of the three countries and the EU27.

International trade - coal

To derive the percentage of imported coal used in each scenario at 2010, 2020, and 2030, we use country data for primary use and the proportion of coal produced domestically in 2007 from the country balance sheets of the International Energy Agency Coal Information 2008 (IEA 2008). These are projected forward using the growth in primary consumption from the Reference scenario in each case. These are combined with the projections for net international trade for the USA and OECD North America in the World Energy Outlook 2009 (IEA 2009), assuming that the proportion of coal production in each country in OECD North America remains constant (i.e. Mexico continues to produce 13% of the region’s coal). The resulting import percentages are shown in Table 14.

Table 14 Percentage of coal imported, USA, Canada, Mexico, and the EU27

	REFERENCE			[R]EVOLUTION			ADVANCED		
	2010	2020	2030	2010	2020	2030	2010	2020	2030
USA	-	-	-	-	-	-	-	-	-
Canada	-	-	-	-	-	-	-	-	-
Mexico	37%	45%	55%	37%	0%	0%	37%	0%	0%
EU27	44%	49%	51%	44%	25%	0%	44%	18%	0%

International trade - gas

To derive the percentage of imported gas used in each scenario at 2010, 2020, and 2030, we use the projections for natural gas production by country from the IEA World Energy Outlook 2009 (IEA 2009), and the projections for natural gas consumption from the US Energy Information Administration Reference Case Projections (US Energy Information Administration 2010). The results are shown below in Table 15.

Table 15 Percentage of gas imported, USA, Canada, Mexico, and the EU27

	REFERENCE			[R]EVOLUTION			ADVANCED		
	2010	2020	2030	2010	2020	2030	2010	2020	2030
USA	15%	9%	7%	15%	29%	23%	15%	15%	-
Canada	-	-	-	-	13%	-	-	11%	-
Mexico	23%	34%	50%	23%	18%	-	23%	11%	-
EU27	63%	75%	83%	63%	60%	54%	63%	60%	53%

International trade – renewable energy

The proportion of renewable technologies which are manufactured within the country was estimated using general knowledge, as it was beyond the scope of this project to obtain detailed data. The assumptions used are shown below in Table 16.

Table 16 Proportions of domestic manufacture of renewable technologies

	Proportion of manufacturing within the region			Region where equipment is imported from			
	2010	2020	2030	EU 27	USA	India	China
USA technologies	100%	100%	100%	-	-	-	-
except solar thermal	50%	50%	100%	100%	-	-	-
Canada technologies	30%	30%	30%	50%	50%	-	-
except wind	30%	40%	50%				
and hydro	100%	100%	100%				
Mexico	0%	0%	0%	33%	33%	-	33%
EU27	100%	100%	100%	-	-	-	-

Country and regional adjustment

Job multipliers have been used in the same way as for the regional analysis for Mexico (see Section 4), and are applied to all the employment factors. The multiplier declines over the study period, as Mexico demonstrates more rapid growth in GDP per capita than the OECD average.

For the USA, Canada, and the EU27, regional multiplies are used to adjust specific employment factors. Table 17 shows the regions to which employment factors primarily apply. Where factors are from the US or Canada, regional adjustment is carried out for the EU27, and *vice versa*. The regional multiplier is applied to all employment factors in the analysis for Mexico.

Table 17 Regions where employment factors originate

	Based on data for US and Canada	Based on data for Europe	Applies to the US, Canada and the EU27
Coal	YES		
Gas, oil and diesel	YES		
Nuclear			YES
Biomass			YES
Hydro	YES		
Wind		YES	
PV		YES	
Geothermal			YES
Solar thermal			YES
Ocean			YES

The multipliers are the inverse ratio of labour productivity in the relevant country to the OECD average. The economy excluding agriculture values have been used. The projections for GDP per capita are obtained from the IEA World Energy Outlook (IEA 2007), and the values for labour productivity are from the KILM database (ILO 2009). The derived job multipliers are shown in Table 18.

Table 18 Multipliers to be applied to employment factors in case study countries

JOB MULTIPLIERS	2010	2020	2030
USA	0.7	0.7	0.8
Canada	1.0	1.0	1.2
Mexico	2.2	2.2	1.7
EU27	1.1	1.1	1.2

Coal fuel supply

Factors for employment in coal fuel supply are calculated for each country, and are shown in Table 19.

Table 19: Employment factors for coal supply, G8 and EU27

Employment per GWh	Coal fuel factor (existing consumption)	Coal fuel employment (new consumption)
USA	0.027	0.02
Canada	0.032	0.02
Mexico	0.40 (no employment data available so uses world average)	0.25 (no employment data available so uses world average adjusted to exclude lignite)
EU27	0.39	0.18

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