ENERGY SECTOR JOBS TO 2030: A GLOBAL ANALYSIS

Final report version 2

For Greenpeace International

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Executive summary

Greenpeace International and the European Renewable Energy Council published a global energy scenario, Energy [R]evolution, that sets out a vision for low-carbon global energy supply and compares it to the energy projection put forward by the International Energy Agency (IEA 2007).

This report presents an analysis of the potential job creation associated with the two scenarios to 2030. Only direct employment associated with electricity production is calculated, including jobs in fuel production, manufacturing, construction, and operations and maintenance.

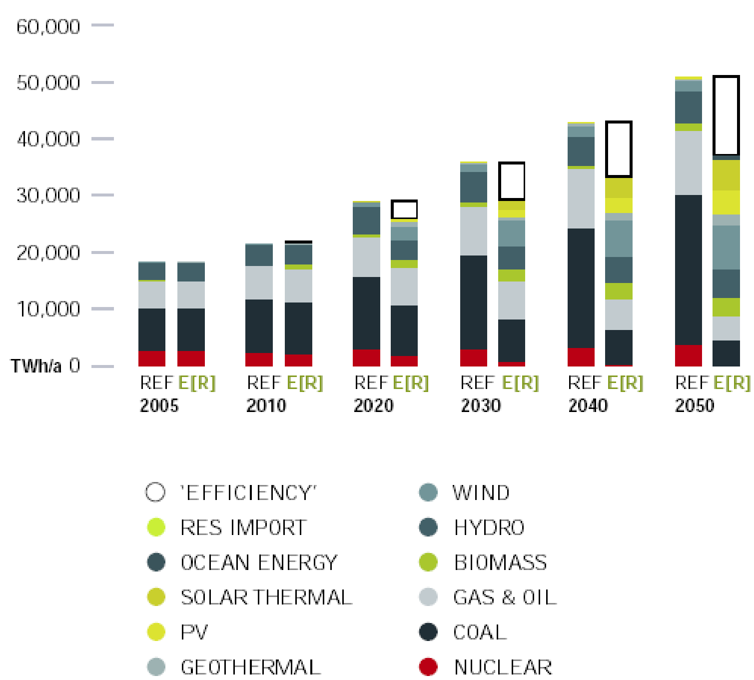
Results are presented for the regions used in both the IEA and Greenpeace projections, namely OECD North America, OECD Europe, OECD Pacific, Africa, Latin America, Middle East, Developing Asia, the Transition Economies, India, and China. Additional detail is given for the G8 countries and the European Union.

There have been many reports in recent years attempting to analyse local, national, or regional job effects of energy scenarios and energy policy. This is the first report that attempts to systematically analyse global job impacts of a low-carbon energy future.

The Energy [R]evolution scenarios

The Energy [R]evolution sets a target reduction of 50% below the 1990 level of greenhouse emissions by 2050, with average per capita emissions of less than 1.3 tonnes per annum. Emissions reductions are achieved through existing technologies, such as energy efficiency, renewable energy and combined heat and power generation. Coal and nuclear power are gradually phased out.

Global electricity generation under the Reference and [R]evolution scenarios



By 2050, the [R]evolution scenario shows a 38% reduction in energy demand, and 77% of global energy supply comes from renewable sources.

Methodology

Employment is projected for the [R]evolution and Reference scenarios at 2010, 2020, and 2030 for each region by using a series of multipliers and the projected electrical consumption. An indicative result for energy efficiency jobs is calculated, although the associated uncertainty is even greater than for energy supply. The inputs to the employment projections for energy are as follows:

- *Installed electrical capacity by technology*
- *Employment factors,* which give the number of jobs per MW for each technology. These are the key inputs to the analysis. Region-specific factors are used for coal mining, but otherwise factors are derived from OECD data and adjusted using regional multipliers.
- *Decline factors*, or learning adjustment rates, for each technology, which reduce the employment factors by a given percentage per year.
- *Regional job multipliers* are used to adjust the employment factors in each region to take account of different stages of economic development.
- *Local manufacturing percentages for renewable energy technologies and percentages for domestic coal and gas production*, in order to assign jobs to the correct regions.
- *Export percentages for renewable technologies, coal and gas:* where equipment, coal or gas is imported, the country of origin is required in order to assign jobs to that region.
- *Energy efficiency employment* is calculated from the reduction in electricity generation in the [R]evolution compared to the Reference scenario, multiplied by a derived factor for jobs per unit of energy.

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 extremely difficult to obtain, even in established industries such as coal and gas generation, so it is not possible to calibrate the methodology against time series data. However, within the limits of data availability, the figures presented are indicative of employment levels under the two scenarios.

Results

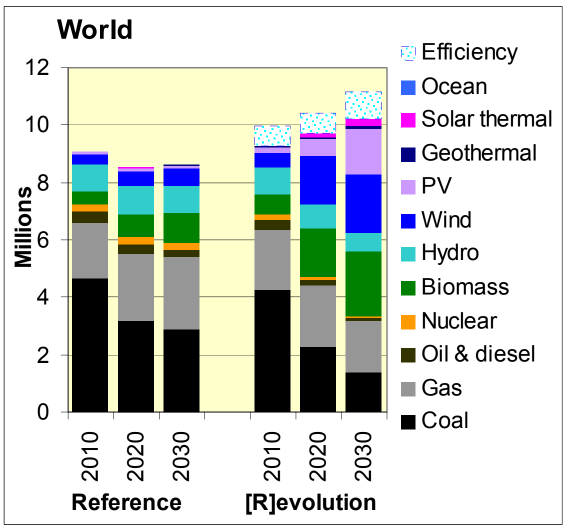
- By 2010 global energy sector jobs in the [R]evolution scenario are estimated at about 9.3 million, 200,000 more than the Reference scenario.
- By 2020, the [R]evolution scenario is estimated to have about 10.5 million jobs, 2 million more than the Reference scenario. More than half a million jobs are lost in the Reference scenario between 2010 and 2020, while 1 million are added in the [R]evolution scenario.
- By 2030 the [R]evolution scenario has about 11.3 million jobs, 2.7 million more than the Reference scenario. Approximately 800,000 new jobs are created between 2020 and 2030 in the [R]evolution scenario, ten times the number created in the Reference scenario.

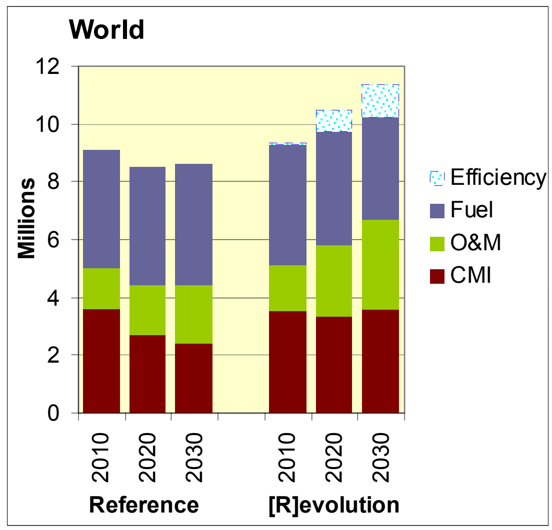
The number of jobs under the [R]evolution and the Reference scenario are shown below, by technology and by type: construction, manufacturing and installation (CMI), operations and maintenance (O&M), fuel supply, and energy efficiency. Combined heat and power generation is included under the fuel type, for example gas or biomass.

There is a decrease in coal power jobs in both scenarios between 2010 and 2020, but strong growth in renewable energy jobs in the [R]evolution scenario leads to a net gain in employment. Growth in gas generation jobs in the Reference scenario is not sufficient to compensate for the losses in coal jobs.

Overall, jobs in the [R]evolution scenario jobs increase significantly from 9.3 million in 2010 to 10.5 million by 2020, and reach 11.3 million in 2030. By comparison, there is a global decrease in electricity sector jobs in the Reference scenario. Jobs fall from 9.1 million to 8.5 million by 2020, before climbing back to 8.6 million in 2030.

World jobs by technology and type in 2010, 2020, and 2030





World employment and electricity generation at 2010, 2020, and 2030

WORLD	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	2020	2030	2010	2020	2030
JOBS (millions)						
Coal	4.65 m	3.16 m	2.86 m	4.26 m	2.28 m	1.39 m
Gas	1.95 m	2.36 m	2.55 m	2.08 m	2.12 m	1.80 m
Nuclear, oil and diesel	0.61 m	0.58 m	0.50 m	0.56 m	0.31 m	0.13 m
Renewable	1.88 m	2.41 m	2.71 m	2.38 m	5.03 m	6.90 m
Energy supply jobs	**9.1 m**	**8.5 m**	**8.6 m**	**9.3 m**	**9.7 m**	**10.2 m**
Energy efficiency jobs	0.0 m	0.0 m	0.0 m	0.1 m	0.7 m	1.1 m
TOTAL JOBS	**9.1 m**	**8.5 m**	**8.6 m**	**9.3 m**	**10.5 m**	**11.3 m**

Note: Energy efficiency jobs included are only those over and above efficiency jobs in the reference scenario.

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Abbreviations

CMI	Construction, manufacturing and installation
EREC	European Renewable Energy Council
ESTELA	European Solar Thermal Electricity Association
EWEA	European Wind Energy Association
GPI	Greenpeace International
GW	Gigawatt
GWh	Gigawatt hour
ISF	Institute for Sustainable Futures
MW	Megawatt
MWh	Megawatt hour
NREL	National Renewable Energy Laboratories (US)
O&M	Operations and maintenance

1 Introduction

1.1 Background

Greenpeace International and the European Renewable Energy Council have published a global energy scenario, Energy [R]evolution that sets out a vision for low-carbon global energy supply and compares it to the energy projection put forward by the International Energy Agency (IEA 2007). The Greenpeace report advocates a pathway for low carbon development up to 2050.

This report presents an analysis of the potential job creation associated with the two scenarios to 2030. The analysis includes all the regions modelled in the Energy [R]evolution, and further detail for nine case study areas: the EU 27, the G8 as a whole, and each of the G8 countries.

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" factor derived from input-output modelling. Indirect jobs have been completely excluded from this analysis owing to the considerable uncertainties involved.

There have been many reports in recent years attempting to analyse local, national, or regional job effects of energy scenarios and energy policy. This is the first report that attempts to systematically analyse global job impacts of a low-carbon energy future.

1.2 Report structure

This section of the report provides high-level background on the global renewable energy industry, including an overview of current employment. Section 2 summarises the Energy [R]evolution scenario on which the jobs analysis is based.

Section 3 of the report explains the methodology used to estimate jobs impacts and sections 4 to 7 present the results of the analysis. Section 4 presents global and regional results, section 6 provides case study results and section 7 analyses job impacts by technology. Section 8 presents sensitivity analysis.

1.3 Global installed renewable energy capacity and sector leaders

The information in Sections 1.3 and 1.4 is based on the *2009 Renewables Global Status Report* (REN21 2009). Worldwide, renewable energy experienced strong growth during 2008. Highlights for the year include:

- Wind power grew by around 29% or 27 GW, constituting the largest addition to renewable energy capacity.
- The US, China, India and Germany collectively installed 18.2 GW of wind power.
- Approximately 2 GW of biomass power generation was added in 2008, mainly in Europe. Brazil and the Philippines are the world leaders in biomass power from bagasse (sugar cane trash).

- Grid-connected solar PV was the fastest growing technology, increasing by 70% in 2008.
- Spain installed 2.6 GW of solar PV in 2008, half of the global increase in capacity, making it the leading installer of PV.
- Around 800 utility-scale solar PV power plants were added worldwide bringing total installed capacity to more than 3 GW.
- New concentrating solar thermal power plants came online in Spain and California.
- In the US and Europe, renewable energy contributed more too new capacity during 2008 than conventional, mainly fossil fuel, power sources.

Table 1 and Table 2 show the new capacity added during 2008, and the leading countries in installed capacity in most sectors.

Table 1 Renewable Energy Added and Existing Capacities, 2008 (estimated)*

Electricity generation capacity (GW)	Added during 2008	Existing end of 2008
Large hydropower	25-30	860
Wind power	27	121
Small hydropower	6-8	85
Biomass power	2	52
Solar PV, grid-connected	5.4	13
Geothermal power	0.4	10
Concentrating solar thermal power (CSP)	0.06	0.5
Ocean (tidal) power	~0	0.3

** reproduced from (REN21 2009, Table R1)*

Table 2 Renewable Energy Sector Leaders - Installed Capacity 2008*

TOP FIVE COUNTRIES Existing generation capacity as of end-2008	#1	#2	#3	#4	#5
Renewables capacity (electricity only)	China (76 GW)	United States (40 GW)	Germany (34 GW)	Spain (22 GW)	India (13 GW)
Small hydro	China	Japan	USA	Italy	Brazil
Wind power	United States (~25 GW)	Germany (~24 GW)	Spain (~17 GW)	China (~12 GW)	India (~10 GW)
Biomass power	United States	Brazil	Philippines	Germany Sweden Finland	
Geothermal power	United States	Philippines	Indonesia	Mexico	Italy
Solar PV (grid-connected)	Germany	Spain	Japan	USA	South Korea

** reproduced from (REN21 2009, page 9)*

1.4 Production capacity

2008 saw large increases in renewables manufacturing capacity, although production and expansion plans were impacted at the end of the year by the global financial crisis. Highlights include:

- In the solar PV sector, China overtook Japan as the world's leading producer of PV cells during 2008. Globally, manufacturing capacity in the PV industry was more than 8 GW by the end of 2008. Production during 2008 was 6.9 GW, up from 2.5 GW in 2006.
- The wind power industry in China grew most during 2008 and appeared to be unaffected by the global financial crisis. It is anticipated that by 2010, the Chinese wind industry will have an annual production capacity of 20 GW.
- By the end of 2008 the US was manufacturing 50% of its wind power components domestically, up from 30% in 2007.
- The top 10 wind turbine manufacturers globally were responsible for 85% of total production in 2008.
- The concentrating solar (thermal) power (CSP) industry grew substantially during 2008 with manufacturing facilities opening in the US and Spain.

• TOP FIVE COMPANIES/ COUNTRIES **Annual production in 2008**	**#1**	**#2**	**#3**	**#4**	**#5**
Wind power - top 5 companies	Vestas (Denmark)	GE Wind (USA)	Gamesa (Spain)	Enercon (Germany)	Suzlon (India)
Solar PV - top 5 countries	China (1.8 GW)	Germany (1.3 GW)	Japan (1.2 GW)	Taiwan (0.9 GW)	United States (0.4 GW)

Table 3 shows the world leaders in wind and solar PV production during 2008.

Table 3 Wind & Solar PV Sector Leaders - Production 2008*

TOP FIVE COMPANIES/ COUNTRIES **Annual production in 2008**	**#1**	**#2**	**#3**	**#4**	**#5**
Wind power - top 5 companies	Vestas (Denmark)	GE Wind (USA)	Gamesa (Spain)	Enercon (Germany)	Suzlon (India)
Solar PV - top 5 countries	China (1.8 GW)	Germany (1.3 GW)	Japan (1.2 GW)	Taiwan (0.9 GW)	United States (0.4 GW)

** from REN21, 2009*

Unsurprisingly, countries which have the largest internal markets are generally also leaders in production capacity. Germany, Spain and the US feature as world leaders in production and installed capacity of wind and solar PV. Japan is a leader in PV production and installed capacity, as is India in wind power production and installed capacity. China, the world's leading PV cell manufacturer, does not yet feature as a leader in solar PV installation, but the market in China is growing rapidly.

1.5 Employment in the renewable sector

Data on employment in the electricity sector globally is patchy and disaggregated, even in established industries such as coal generation. Data is more readily available for some sectors, such as wind power, and for some OECD countries. For emerging technologies, such as ocean power, data on employment impacts are hard to find. Similarly, for countries where an industry is nascent, employment data is often absent.

Table 4 gives an indication of levels of renewable energy employment in selected countries, although it is not always clear whether data is for direct jobs only. There is no data available for China, which currently leads the world in installed capacity.

Current estimates for world employment in renewable energy sector other than solar water heating are 1.3 million (REN21 2008, p 7) to 1.7 million (UNEP 2008, p. 295).

Table 4 Renewable electricity employment – selected countries and world

RENEWABLE ENERGY SOURCE	Selected countries	Employment estimates
Wind	United States	16,000 [a]
	Spain	32,906 [b]
	Denmark	21,612 [c]
	India	10,000 [d]
	World estimate	**300,000** [f]
Solar PV	United States	6,800 [a]
	Spain	26,449 [b]
	World estimate	**170,000** [f]
Solar Thermal electricity	United States	800 [a]
	Spain	968 [b]
Biomass power	United States	66,000 [a]
	Spain	4,948 [b]
Hydropower	Europe	20,000
	United States	8,000 [a]
	Spain (small hydro)	6,661 [b]
Geothermal	United States	9,000 [a]
All sectors	**World estimate**	**1.3** [e] **- 1.7** [f] **million**

a 2006 data: Bedzek 2007
b 2007 data: Nieto Sáinz J 2007, in UNEP 2008 Table 11.1-4.
c 2006 data: Danish Wind Industry Association
d 2007 data: Suzlon 2007
e 2006 data: REN21 2008 p7
f UNEP 2008 p295; total for renewable sector minus estimated jobs in solar thermal as these are nearly all in solar water heating.

2 Energy [R]evolution scenarios

Greenpeace International and the European Renewable Energy Council set out a vision for a low carbon global energy supply. They present a low carbon scenario, the Energy [R]evolution and a Reference Scenario. The Reference scenario is the International Energy Association's 'World Energy Outlook 2007' projection, extrapolated from 2030 to 2050.

Energy [R]evolution highlights

- The Energy [R]evolution sets a target reduction of 50% below 1990 level of greenhouse emissions by 2050, with average per capita emissions of less than 1.3 tonnes per annum.
- Under the Energy [R]evolution Scenario, emissions peak at 2015 and decline thereafter.
- Emissions reductions in the Energy [R]evolution Scenario are achieved through existing technology such as energy efficiency, renewable energy and combined heat and power generation. Coal and nuclear power are gradually phased out.
- By 2050, the report projects that a 38% reduction in energy demand can be achieved compared to the Reference Scenario.
- In 2020, the [R]evolution Scenario projects renewable electricity capacity of 2,719 GW, supplying 36% of total electricity production, compared to 22% in the Reference Scenario. Over the entire modelling period, installed renewable energy technologies will grow from 1,000 GW in 2005 to 9,100 GW in 2050, accounting for 77% of electricity generation.

In line with the International Energy Agency, Energy [R]evolution uses a multi-region model to reflect structural differences in energy supply in different regions. The regions modelled are OECD North America, OECD Europe, OECD Pacific, Africa, Latin America, Middle East, Developing Asia, and the Transition Economies (see Appendix 1 for a listing of the countries in each region). India and China are modelled separately. The regional framework is used in this report to model employment effects.

Two key underlying drivers of energy demand are population development and economic growth. The [R]evolution scenario uses the same GDP and population assumptions as the International Energy Agency 2007 projection up to 2030 (the limit of this study).

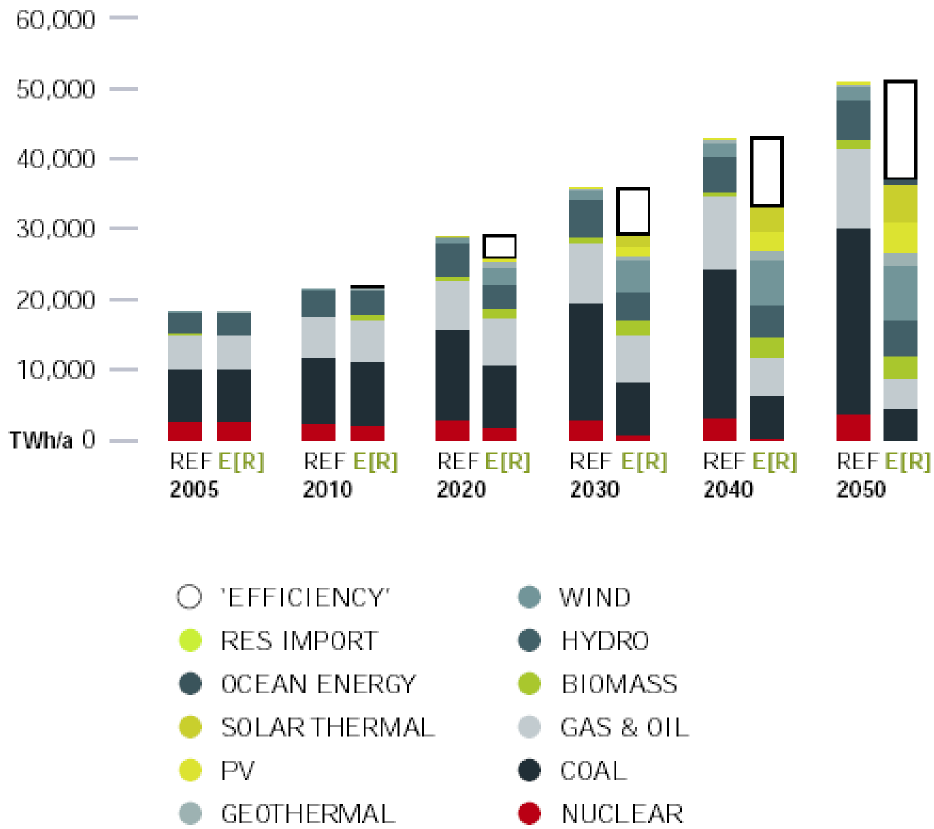
The third key driver of future global energy demand is energy intensity i.e. how much energy is required to produce a unit of GDP. This is a key point of difference between the [R]evolution and the Reference Scenario. The [R]evolution scenario decouples energy consumption from economic growth through efficiency measures, so energy intensity under the [R]evolution scenario is significantly lower than the Reference scenario. Thus energy efficiency displaces a significant share of electricity consumption.

The [R]evolution Scenario also proposes significant shifts in electricity supply. By 2050, 'new' renewables such as wind, solar thermal energy and solar PV will supply 60% of world electricity, with 77% in total coming from renewable energy sources.

Figure 1 shows electricity supply, including the portion of consumption displaced by energy efficiency, for the two scenarios up until 2050. Full details of the scenarios can be found in the Greepeace/ European Renewable Energy council report (GPI/EREC 2008)

This analysis of employment effects only looks at the period to 2030.

Figure 1 Global development of electricity generation under the Reference and [R]evolution scenarios



3 Methodology

3.1 Methodology overview

Employment is projected for the [R]evolution and Reference scenarios at 2010, 2020, and 2030 for each region by using a series of multipliers and the projected electrical consumption. Only direct employment is included in this analysis, namely jobs in construction, manufacturing, operations and maintenance, and fuel supply associated with electricity generation.

An indicative result for energy efficiency jobs is calculated, although the associated uncertainty is even greater than for energy supply.

The inputs to the employment projections for energy are as follows:

- ***Installed electrical capacity by technology***, for each region, at 5 or 10 yearly intervals. The energy projections are for two scenarios, the Reference and the [R]evolution. Both come from the Greenpeace / European Renewable Energy Council report (GPI/ EREC 2008) Their Reference case is the International Energy Agency 2007 projection (IEA 2007), and the [R]evolution case is the GPI/ EREC low carbon projection.
- ***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 derived from OECD data, and are adjusted using regional multipliers to allow for the fact that economic activities in poorer regions are generally more labour intensive. 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. These 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:*** where equipment, coal or gas is imported, 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.
- ***Energy efficiency employment:*** is calculated from the reduction in electricity generation in the [R]evolution compared to the Reference scenario, multiplied by a derived factor for jobs per unit of energy, with adjusted for regions by the regional job multiplier, reduced by a decline factor in 2020 and 2030. See section 3.9 for details.

The calculation of energy supply jobs in each region is summarised in the four equations below:

E1 Jobs in region = manufacturing + construction + operations and maintenance (O&M) + fuel, where:

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		
O&M	=	Cumulative capacity	**x**	O&M 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
Fuel supply (nuclear, oil, diesel, biomass)	=	Electricity generation	**x**	Fuel employment factor	**x**	regional job multiplier		

E2 Jobs in region at 2010 = jobs (as above)

E3 Jobs in region at 2020 = jobs (as above) x technology decline factor^{10}

E4 Jobs in region at 2030 = jobs (as above) x technology decline factor^{20}

3.2 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 extremely difficult to obtain, even in established industries such as coal and gas generation, so it is not possible to calibrate the methodology against time series data, or even against the current situation. As projections go further into the future, they rest on exogenous assumptions, for example, economic growth and learning rates, which may introduce considerable systematic error into the analysis. In addition, the adjustments from region to region may vary considerably from reality, for example because practices within the energy industries may not follow the whole of economy patterns. However, within the limits of data availability, the figures presented are indicative of employment levels under the two scenarios.

Some variations in methodology are used for the case studies, as results need to be at a more detailed level. These are described in Section 3.9.

3.3 Employment factors overview

Table 5 Employment factors for use in global analysis

	Capacity factors	Year for factors	CMI JOBS: Total CMI (person years/ MW)	CMI JOBS: Construction/ installation (person years/ MW)	CMI JOBS: Manufacturing (person years/ MW)	O&M AND FUEL: Total O&M and fuel (Jobs/MW)	O&M AND FUEL: O&M (Jobs/MW)	O&M AND FUEL: FUEL (jobs/GWh)	MAIN REFERENCE
Coal	66%	2009	**14.4**	14.4	0.003	**0.25-3.2**	0.10	Regional factors	JEDI model
Gas	39%	2009	**3.4**	3.4	0.001	**0.47**	0.05	0.12	JEDI model
Nuclear	87%	2009	**16**			**0.33**	0.32	0.0009	Derived from US and Au industry data
Biomass	69%	2004	**4.3**	3.9	0.4	**4.40**	3.1	0.22	EPRI 2001, DTI 2004
Hydro	39%	2008	**11.3**	10.8	0.5	**0.22**	0.22		Pembina 2004
Wind (onshore)	25%	2007	**15.4**	2.5	12.5	**0.40**	0.40		EWEA 2009
Wind (offshore)		2010	**28.8**	4.8	24	**0.77**	0.77		EWEA 2009
PV	15%	2010	**38.4**	31.9	9.1	**0.40**	0.40		EPIA 2008A, BMU 2008a
Geothermal	77%	2005	**6.4**	3.1	3.3	**0.74**	0.74		GEA 2005
Solar thermal	26%	2008	**10.0**	6.0	4.0	**0.30**	0.3		EREC 2008
Ocean	26%	2007	10	9.0	1.0	**0.32**	0.32		SERG 2007/ SPOK ApS 2008
Energy efficiency	0.29 jobs /GWh (adjusted to 0.23 jobs/ GWh for 2010)								ACEEE 2008

Note 1 Factors are all for OECD countries, and need to be adjusted for use in other regions

Note 2 The capacity factors listed used to convert fuel factors to the totals given in tables for O&M and fuel, and are from GPI/ EREC 2008.

Note 3 Regional factors are used for coal fuel supply – see section 3.4.

Note 4 Additional factors are used for case studies – see section 3.9.

The factors used in the global analysis are presented in Table 5. The method used to derive factors and the explanation for their choice is given in the next two sections, along with factors from other studies for comparison. Where possible, factors from industry sources are used.

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.

The factors presented in Table 1 are all for OECD countries or regions. These are adjusted to:

- Take account of differing stages of economic development by using regional job multipliers (see Section 3.7).
- Take account of the proportion of manufacturing which occurs locally by using local manufacturing percentages (see section 3.8).
- Take account of the reduction in technology costs and the corresponding fall in employment per MW by using decline factors (see section 3.6).

3.4 Employment factors for coal and lignite

Table 6 Employment factors for coal power construction and O&M (also used for lignite)

COAL	YEAR	CMI JOBS: TOTAL CMI	Installation	Manufacturing	O&M	Region	Source and Notes
		Person years/ MW					
Factors used in this study							
Coal – new	2009	14.4	14.4	0.003	0.10	California	**NRELJEDI model, downloaded 30/4/09** The model calculates employment effects of a new coal power station.
Factors for comparison							
Coal – new	2001	8.5			0.18		**REPP 2001, Appendix B** Economic analysis of capital and operating costs of hypothetical coal plant.
Coal – existing	2007				0.14	NSW	**CoFFEE 2008, Table 15 page 47** Derived from industry data for employment and capacity

Despite the fact that coal generation is the most established form of electricity generation, it is difficult to find robust data on current employment.

The factors for construction, manufacturing, and operations and maintenance used in this study are derived from the USA National Renewable Energy Laboratory publicly available JEDI model, which was developed to allow calculation of local benefits from different electricity supply options. Default values from the model were used for all variables.

The factors for coal are also used for lignite.

The construction employment factor from the model is much higher than the values most commonly used in the literature, as may be seen in Table 5. This will tend to increase jobs in the Reference compared to the [R]evolution scenario, as the Reference case is heavily dependent on coal generation. Factors other than construction are very close to values in the literature.

Coal for fuel is treated in more detail than other employment factors because it accounts for such a significant proportion of current energy sector jobs, and because employment per ton (and therefore per GWh) in coal mining varies so extremely around the world.

Employment and production data has been collected for as many of the major coal producing countries as possible. This is shown in Table 7, with employment data available for 68% of world coal production. As can be seen, employment per GWh varies by almost a factor of twenty between the USA and China. Data for individual countries has been used to arrive at regional factors. The individual country data used is given in Appendix 2.

The reference case shows very strong growth in generation from coal. Employment from generation in each modelled year (2010, 2020, and 2030) up to the 2005 generation level is calculated using the factor headed “Employment factor (existing)” in Table 7. The factor headed “Employment factor (new)” is used for generation above the 2005 level.

The employment factor for existing generation is calculated from current employment and production data. This is modified for new generation, assuming that new generation will come from hard coal rather than lignite, and will use generation equipment which is more efficient than existing.

Employment per GWh is calculated from the employment per ton, and the tons per GWh, as shown in the equation below.

Employment per GWh = Employment per ton coal **x** tons per GWh

At present 20% of electricity generation comes from lignite, which requires more tons per GWh than generation from hard coal because of the higher water content of lignite. However, the growth in electricity generation in the Reference scenario is almost entirely from hard coal. At 2030, while generation from hard coal increases by 8000 TWh from 2010 levels, generation from lignite increases by only 400 TWh.

Therefore we estimate the tons of hard coal per GWh which will be used in new generation capacity. For this estimate we use the weighted average of the five OECD countries which use less than 5% lignite, which is 322 tons per GWh, as shown in **Table 8**. This is used to calculate the employment per GWh for new generation in each region except China, using the regional employment per ton from present (2006) data multiplied by 322.

Employment data for three regions was not available, Developing Asia (which includes Indonesia, a major coal producer), the Middle East, and Latin America. The analysis uses the average world factor these three regions, namely 0.39 jobs per GWh for existing generation and 0.24 for new generation.

Table 7 Regional and country factors for coal production and employment

	Production	Domestic production	Coal for electricity	% of lignite in electricity production	Employment	Productivity	Employment factor (existing)	Employment factor (new)
	million tons	%	Tons/ GWh		'000s	Tons / person /year	Jobs per GWh	
YEAR	**2006**	**2006**	**2006**	**2006**	**2006**	**2006**	**2010**	**2010**
World	6,669 m	99%	520	19%	n/a			
OECD North America	1,238 m	104%	403	9%	88	14,116	**0.03**	**0.02**
OECD Europe (see Note 1)	550 m	84%	678	66%	298	1,843	**0.34**	**0.18**
OECD Pacific (data for Australia only)	371 m	257%	659	51%	27	13,800	**0.04**	**0.02**
India	466 m	92%	745	6%	464	1,004	**0.59**	**0.25**
China	2,525 m	97%	516	-	3,600	701	**0.55**	**0.02**
Africa (data for South Africa only)	247 m	138%	492	-	60	4,110	**0.11**	**0.08**
Transition economies (see Note 2)	347 m		772	56%	237		**0.43**	**0.20**
Developing Asia (data for Asia exc China)	801 m	108%	648	9%	n/a			
Latin America	90 m	198%	425	20%	n/a			
Middle east	3 m	20%	365	3%	n/a			

Note 1 OECD Europe results are the weighted average of data from the Czech Republic, France, Finland, Germany, Greece, Poland, the Slovak Republic and the UK.
Note 2 Transition economies results are the weighted average of data from Russia, Bulgaria, and Slovenia.
Note 3 All data for coal production and electricity from International Energy Agency statistics, downloaded 18th June 2009. www.iea.org
Note 4 Employment data sources:
USA: Energy Information Administration (2008) Report No. DOE/EIA 0584 (2007) Table 18. Average Number of Employees by State and Mine Type, 2007, 2006
Canada: Natural Resources Canada. 2007. Table 22. Canada, employment in the mineral industry, stage 1 – mineral extraction and concentrating (total activity), (1) 1961-2006
Australia: Australian Bureau of Statistics. Cat. No. 2068.0 - 2006 Census Tables 2006
India: Data for coal mining employment from *Government of India Ministry of Coal. 2008. Annual report 2007 - 08*. Table 8.2.3. Employment has been scaled up from the reported figure of 429,500 employees because the reported production is 431 million tons rather than the IEA figure of 466 million tons.
China: China Yearbook 2008, cited in personal communication, Sven Teske, 21/6/09.
South Africa personal communication, Sven Teske, 21st June 2009
Europe Glückauf (German Coal statistics), cited in personal communication, Sven Teske, 21/6/09.
Russia personal communication, Sven Teske, 21st June 2009
Note 5 The calculated employment factors shown have been modified using the annual percentage growth in labour productivity for each region to arrive at the 2010 factor. 2006 factors are shown in the Appendix 2.

Table 8 OECD countries with less than 5% lignite in electricity production

	Tons coal per GWh
Finland	264
France	328
Italy	316
Japan	299
UK	377
Weighted average	**322**

The employment factor for new generation in China has been taken as the current level for the US. China has the lowest average productivity in the world at present, with only 700 tons produced per employee. 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 tons per person per year (IEA 2007, page 337).

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 tons per person per year, double the highest average productivity for any OECD country.

The Reference case sees coal production in China doubling by 2030. This is not going to be from small mines; Chinese government policy is to close at least half of the 20,000 small village mines by 2010. There are 16 mines planned with average annual output of more than 70 million tonnes each, and new approvals will only be considered for mines with an output of 30,000 tons per year or more (IEA 2007).

The factor for coal employment for new generation in China in 2010 is therefore taken as identical to the US figure. Even this may overestimate the employment for coal supply in China in the future, if the projected doubling of output is primarily from 'super mines' such as are being developed at the present.

Coal trade

Jobs in coal supply have been allocated after taking international trade into account. The projected volumes of international trade and world coal production in the Reference scenario are taken from the IEA 2008, and shown in Table 9 and Table 10.

The proportion of coal imports in the Reference and [R]evolution scenarios are shown in Table 11. These are calculated for the Reference scenario from the tons imported divided by the total consumed.

Table 9 Net Inter-regional hard coal trade, 2006 – 2030, IEA reference scenario
Negative values = imports, positive values = exports. Million tons of coal equivalent.

	2006	2010	2015	2020	2030
OECD N America	15	38	67	75	90
OECD Europe	**-202**	**-221**	**-245**	**-233**	**-209**
OECD Pacific	**-16**	**-2**	**16**	**44**	**101**
Asia	-232	-243	-256	-253	-246
Oceania	216	240	271	296	347
E. Europe/Eurasia	**52**	**68**	**88**	**91**	**96**
Russia	53	71	94	103	120
Asia	**73**	**20**	**-47**	**-98**	**-199**
China	34	-10	-65	-73	-88
India	-42	-67	-98	-139	-220
Middle East	-12	-15	-18	-23	-34
Africa	56	68	83	87	95
Latin America	42	48	56	57	60
World	**613**	**698**	**804**	**862**	**979**
European Union	*-191*	*-208*	*-229*	*-216*	*-191*

From IEA 2008, Table 5.3, with values for 2010 and 2020 calculated assuming linear change.

Table 10 Regional production of coal, 2006 – 2030, IEA reference scenario (million tons of coal equivalent)

	2006	2010	2015	2020	2030
OECD N America	878	915	962	991	1048
OECD Europe	273	261	246	233	208
OECD Pacific	294	322	358	381	427
Non OECD	2950	3497	4180	4562	5327
E. Europe/Eurasia	**357**	**395**	**443**	**456**	**481**
Russia	205	245	295	315	354
Asia	**2316**	**2783**	**3367**	**3723**	**4435**
China	1763	2155.889	2647	2898	3399
India	283	314	352	437	607
Middle East	203	227	257	261.6667	271
Africa	73	89	110	119	137
Latin America	4396	4996	5746	6168	7011
World	**613**	**698**	**804**	**862**	**979**
European Union	*273*	255	*232*	215	*180*

From IEA 2008, Table 5.2, with values for 2010 and 2020 calculated assuming linear change.

Table 11 Proportion of coal imports in the Reference and [R]evolution scenario

IMPORT	REFERENCE			[R]EVOLUTION		
	2010	2020	2030	2010	2020	2030
OECD North America	-	-	-	-	-	-
OECD Europe	46%	50%	50%	38%	14%	0%
OECD Pacific	1%	-	-	-	-	-
Transition economies	-	-	-	-	-	-
Developing Asia	-	-	-	-	-	-
China	0%	2%	3%	0%	0%	0%
India	18%	24%	27%	6%	0%	0%
Middle East	91%	91%	92%	90%	84%	64%
Africa	-	-	-	-	-	-
Latin America	-	-	-	-	-	-

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. The regional coal production for the relevant year is subtracted to see if there is net import. Potential coal production is assumed to be constant between the two scenarios, so coal is only imported if the adjusted consumption is more than production. The revised figure for imports is divided by the coal production to determine the percentage import.

The proportion of domestic coal 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 9.

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. The regional coal production for the relevant year is subtracted to see if there is net import. Potential coal production is assumed to be constant between the two scenarios, so coal is only imported if the adjusted consumption is more than production. The revised figure for imports is divided by the coal production to determine the percentage import.

The proportion of domestic coal 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 9.

3.5 Employment factors by technology

Gas, oil, and diesel

The proposed factors are derived from the USA National Renewable Energy Laboratory's publicly available JEDI model, which was developed to allow calculation of local benefits from different electricity supply options. This has been used in preference to the factors given in CALPRG 2002 (shown in Table 12) as it is more recent and may include a more complete assessment of manufacturing employment. Default values from the JEDI model are used for all variables except fuel. In order to obtain a factor for fuel supply, the default value for 'local percentage' was changed from zero to 100%.

The JEDI figures are uniformly higher than the CALPRG figures, so the use of the JEDI factors will tend to increase jobs in the Reference scenario compared to the [R]evolution scenario.

As no factors are available for diesel or oil generation, the factor for gas has been used for both of these technologies. The small penetration of the technology means this has little effect on the overall employment calculation.

Table 12 Employment factors for gas (also used for oil and diesel)

GAS	YEAR	CMI JOBS			O&M AND FUEL			Region	Source and notes
		TOTAL CMI	Installation	Manufacturing	TOTAL O&M and fuel	O&M	Fuel		
		Person years/ MW			Jobs/ MW		Jobs/ GWh		
Factors used in this study									
Natural gas, new	2009	**3.4**	3.4	0.001	**0.46**	0.05	0.12	California	**NREL JEDI model, downloaded 30/4/09.** The model calculates employment effects of natural gas power station.
Factors for comparison									
Natural gas, new	2002		0.49		**0.35**	0.04	0.09	California	**CALPRG, 2002** Direct construction jobs include work on the gas pipelines. Installation and O&M from Table 9, page 15. Factors derived from review of applications for 19 gas power plants built or approved from 2001, total 12 GW.
Natural gas, existing	2002				**0.38**	0.07	0.09	California	**CALPRG, 2002** Table 8, page 14. Employees at 16 GW of existing gas generation.

Note: Fuel supply jobs per GWh are converted to jobs per MW using a capacity factor of 39%

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 2008, and shown in Table 13 and Table 14.

The proportion of gas imports in the Reference and [R]evolution scenarios are shown in Table 11. These are calculated for the Reference scenario from the billion cubic metres imported divided by the total consumed.

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 9, with the assumption that export regions will increase production in response to demand.

Table 13 Net Inter-regional gas trade, 2006 – 2030, IEA reference scenario
Negative values = imports, positive values = exports. Billion cubic metres.

	2006	2010	2015	2020	2030
OECD N America	-15	-32	-53	-83	-143
OECD Europe	-241	-282	-333	-381	-477
OECD Pacific	**-97**	**-103**	**-111**	**-114**	**-121**
Asia	-115	-127	-143	-155	-179
Oceania	18	24	32	41	58
E. Europe/Eurasia	**137**	**158**	**185**	**198**	**224**
Russia	198	201	205	227	270
Asia	**46**	**42**	**36**	**-18**	**-126**
China	-1	-8	-17	-47	-106
India	-8	-12	-16	-34	-71
Middle East	55	77	105	178	323
Africa	50	53	57	59	63
Latin America	16	12	8	17	35
World	**441**	**504**	**582**	**729**	**1022**
European Union	*-305*	*-363*	*-435*	*-484*	*-582*

From IEA 2008, Table 4.3, with values for 2010 and 2020 calculated assuming linear change.

Table 14 Regional production of gas, 2006 – 2030, IEA reference scenario (billion cubic metres)

	2006	2010	2015	2020	2030
OECD N America	1117	1131	1149	1128	1086
OECD Europe	761	776	795	785	765
OECD Pacific	524	529	535	528	515
Non OECD	1842	2074	2363	2691	3348
E. Europe/Eurasia	846	898	963	998	1069
Russia	651	678	712	739	794
Asia	335	386	449	479	540
China	59	79	104	108	115
India	28	34	41	42	45
Middle East	324	395	483	655	999
Africa	197	236	286	341	452
Latin America	139	158	182	217	287
Brazil	11	14	17	24	38
World	2959	3205	3512	3819	4434
European Union	228	202	170	146	99

From IEA 2008, Table 4.2, with values for 2010 and 2020 calculated assuming linear change.

Table 15 Proportion of gas imports in the Reference and [R]evolution scenario

IMPORT	REFERENCE			[R]EVOLUTION		
	2010	2020	2030	2010	2020	2030
OECD North America	4%	10%	16%	13%	20%	9%
OECD Europe	49%	59%	69%	46%	53%	53%
OECD Pacific	63%	58%	54%	65%	62%	55%
Transition economies	-	-	-	-	-	-
Developing Asia	-	-	-	-	-	-
China	9%	30%	48%	8%	36%	47%
India	25%	45%	61%	26%	58%	77%
Middle East	-	-	-	-	-	-
Africa	-	-	-	-	-	-
Latin America	-	-	-	-	-	-

Nuclear

Although the nuclear industry is well established, global employment data is surprisingly difficult to find. The factors for operations and maintenance and fuel supply have been derived from industry and national sources for employment and production as described below.

The construction, manufacturing and installation factor is derived from a Nuclear Energy Institute (NEI) 2009 fact sheet, which states that building a new [1000 MW] nuclear plant would result in the creation of 1,400 to 1,800 jobs, assuming a 10 year construction period.

The O&M factor is derived for this study from 2002 US Census data on the number of paid employees in census category 221113 “nuclear electric power generation” (2007 census data was not available at the time of writing). In 2002 this was 31,698. The jobs/MW factor is calculated using Energy Information Administration (EIA) data on US nuclear capacity for 2002, which was 99,209 MW. This is used in preference to the NEI figure, as it derives from a large existing industry.

The fuel factor has been derived for this study from data on Australian uranium mining and uranium requirements for the US industry.

Uranium (as U) required per GWh of power generation has been derived. World Nuclear Association (WNA) data states 18,867 tonnes of U was required for nuclear generation in the US in 2009 (which was the same as 2007). 2007 US nuclear generation was 806,425 GWh, giving a requirement of 0.023396 tonnes per GWh. This has been converted to $U_3O_{8\ \mathrm{requirement}}$ using a standard conversion of 1.179.

Employment per tonne of U_3O_8 has been derived for this study using industry data for Australia (Deloitte 2008).

Table 16 Employment factors for nuclear power

NUCLEAR	Year	Total CMI jobs	O&M	Fuel	Region	Source and Notes
		Person years/ MW	Jobs/ MW	Jobs/ GWh		
Factors used in this study						
Nuclear (CMI)	2009	16				**NEI 2009** Factor derived from fact sheet assuming a 10 year construction time
Nuclear (O&M)	2002		0.32		US	**US Census 2002 Table 1 and EIA 2009a** Factors derived for this study from industry employment and capacity data
Nuclear (fuel)	2007			0.009	Australia/ US	**Deloitte 2008 and WNA 2009** Uranium requirement from WNA 2009 Australian production and employees from Deloitte 2008, page 25, Table 3.1
Factors for comparison						
Nuclear (O&M)	2009		0.4-0.7		US	**NEI 2009**

Biomass

Table 17 Employment factors for biomass

BIOMASS POWER	YEAR	CMI JOBS: TOTAL CMI	CMI JOBS: Installation	CMI JOBS: Manufacturing	O&M AND FUEL: TOTAL O&M and fuel	O&M AND FUEL: O&M	O&M AND FUEL: fuel	Region	Notes	Source
		Person years/ MW			Jobs/ MW	Jobs/ GWh				
Factors used in this study										
From energy crops	2004				**4.4**	(3.4)	(0.22)	UK	Detailed economic analysis	**DTI 2004**
Fuel source not stated	2001	**4.29**	4.29	0.001				US	Table C-3, page C-6. No details given of derivation. Manufacturing factor taken from gas (NREL JEDI)	**EPRI 2001**
Factors for comparison										
Fuel source not stated	2001				**1.53**			US	No details given	**EPRI 2001**
From energy crops	2004	**21**						UK	Detailed economic analysis	**DTI 2004**
From waste	2004	**21**			**6.8**			UK	Detailed economic analysis	**DTI 2004**
Fuel source not stated	2007				**14.2**	5.4	1.46	Germany	Derived for this study from industry data	**BMU 2008a and 2008b**
Fuel source not stated	2004	**8.5**			**0.08-0.66**	0.04-0.44	0.04-0.22	US	Derived from REPP 2001	**Kammen 2004, Pg 10**
Fuel source not stated	2004		2		**0.95**			Canada	Derived from REPP 2001	**Pembina 2004, Table 2**
	2003	**14-17**						Europe	**Includes O&M**	**MITRE 2003**

Note 1: Fuel supply jobs/GWh are converted to jobs/MW using a capacity factor of 69%

Note 2: The value from DTI 2004 is for O&M and fuel combined. This has been split using the higher end of the Kammen factor for biomass fuel jobs, and a capacity factor of 15%.

Only biomass for power generation is considered in this analysis. There is very little available data for biomass power generation, although biofuels for transport is a large and well established industry. A detailed UK DTI analysis provides O&M fuel factor by fuel source, and the factor for energy crops is used in this study. The DTI O&M factors are higher than factors from other studies, but lower than factors derived from German industry data.

The DTI only gives a factor for O&M and fuel combined. This has been split using the higher end of the Kammen range of factors for biomass fuel jobs, and a capacity factor of 69%.

The construction factor used in this study is taken from the EPRI report. Unfortunately it does not include manufacturing jobs. These are assumed to be similar to gas, namely in the region of 0.001 jobs per MW, as biomass plant equipment is likely to be similar to gas plant equipment.

The construction factors provided by the DTI report have not been used in this analysis because they are much higher than other factors in the literature, and this analysis has generally chosen a cautious approach. Factors derived by Kammen and Pembina from REPP data are provided for comparison, although the factors derived differ slightly from each other. MITRE factors are also shown for comparison.

Hydro

Operations and maintenance employment factors for hydro from Pembina (2004) have been used in this study. These are lower than the UK study (DTI 2004), but have the advantage of being split into manufacturing and installation. The factor for operations and maintenance is in between the figures derived from the US and German industry data.

The figure for operations and maintenance for Germany has been derived from data on employment and capacity published by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU 2008a and 2008b). There were 4,400 people employed in operations and maintenance for hydro, and 4,720 MW installed capacity. This is much higher than the industry figure for the US, which may reflect the higher proportion of small hydro in the German electricity supply.

The factor derived from the MITRE 2003 data is higher than all the others.

Table 18 Employment factors for hydro

HYDRO	YEAR	CMI JOBS			Operations & Maintenance	Region	Notes	Source
		TOTAL CMI	Installation	Manufacturing				
		Person years/ MW			Jobs/ MW			
Factors used in this study								
Small hydro (run of river)	2004	**11.3**	10.8	0.5	0.22	Canada	From industry interviews and literature survey.	Pembina 2004
Factors for comparison								
Hydro	2007				0.93	Germany	Industry data for employment and capacity.	Derived from BMU 2008a and 2008b
Hydro	2007				0.10	US	Industry data for employment and capacity.	Derived from Bedzek, 2007 and EIA 2009b.
Small hydro (less than 30 MW)	2001		5.7		1.14	California		EPRI 2001
Hydro	2004	**25**				UK	New developments; detailed economic analysis for UK	DTI 2004
Small hydro	2010	**41 - 50**				Europe	Includes O&M	MITRE 2003

Geothermal

Factors used in this study have been derived from US geothermal industry data projections for jobs and installed capacity. Data in the GEA report has been collated from an industry survey and other sources such as environmental impact assessments. The derived construction factor is similar to EPRI and the derived operations and maintenance factor is slightly lower than EPRI. The factor derived from the MITRE 2003 data is considerably higher, as is the case for many of the MITRE technology employment factors.

Table 19 Employment factors for geothermal power

GEO-THERMAL	YEAR	CMI JOBS TOTAL CMI	 Installation	 Manufacturing	Operations & Maintenance	Region	Notes	Source
		Person years/ MW			Jobs/ MW			
Factors used in this study								
Geothermal power	2005	**6.41**	3.11	3.30	0.74	US	Factors derived for this study from geothermal industry projection.	GEA 2005, page 20 Table 7
Factors for comparison								
Geothermal power	2001		4.00		1.67	California	No details of derivation.	EPRI 2001, page C-6, Table C-3
Geothermal power	2010	**18**				Europe	**Includes operations and maintenance**	MITRE 2003

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. A study of a particular wave power technology, Wave Dragon, provided jobs creation potential for that technology. The O&M factor used here is based on that report. However, the construction factor used in this study is lower and therefore more conservative than the factor provided by the Wave Dragon study.

Table 20 Employment factors for ocean power

OCEAN	YEAR	CMI JOBS: TOTAL CMI	CMI JOBS: Installation	CMI JOBS: Manufacturing	Operations & Maintenance	Region	Notes	Source
		Person years/ MW			Jobs/ MW			
Factors used in this study								
Ocean/ocean-wave	2007/ 2008	10			0.32	UK	SPOK report references Wave Dragon study	SERG 2007, Section 6/ SPOK ApS 2008, p17
Factors for comparison								
Ocean – wave	2004		1.18	3.04	0.1	US	Calculated using data from REPP 2001 & EPRI 2001	Pembina 2004, Table 2
Ocean - wave	2008	15.3				UK	References Wave Dragon study	SPOK ApS 2008, p17

PV

The construction factors used in this study 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). As can be seen from the comparison factors, the construction factor is in the mid range of available factors and more conservative than those proposed by the UK Department of Trade and industry study (DTI 2004). The O&M factor used in this study has been derived from 2007 German industry data for employment and capacity, which is deemed to be the most robust of the available data for O&M.

Table 21 Employment factors for PV

PV	CMI JOBS						
YEAR	TOTAL CMI (Person years/ MW)	Installation (Person years/ MW)	Manufacturing (Person years/ MW)	Operations & Maintenance (Jobs/ MW)	Region	Notes	Source
Factors used in this study							
2010	42.2	31.9	10.2		Europe	Industry projections.	EPIA 2008b
2007				0.48	Germany	Derived for this study from industry data for capacity and employment.	EPIA 2008A and BMU 2008a
Factors for comparison							
2007		n/a	34.5		Germany	Derived for this study from industry data for capacity and employment	Sawin 2008 and BMU 2008
2007		n/a	22.1	n/a	US	Derived for this study from industry data for capacity and employment	EIA 2008 (PV), Tables 3.1 & 3.16.
2004	84			0.45	UK	Detailed economic analysis for the UK	DTI 2004
2001		7.1		0.12	California	No details of derivation given. From Table C-3, Page C-6	EPRI 2001
2004	25.9	“	18.8		Canada	Data from industry interviews and literature survey; however, installation and O&M figures come from EPRI, so are not reproduced here.	Pembina 2004, Table 2
2001	32.3			0.25	US	Analytical study from industry survey. The study reports 5,000 person hours per MW for O&M, and assumes 10 years servicing, and a working year of 40 hours x 49 weeks. . Reported here as 0.25 FTE jobs per MW.	REPP 2001
2010	68-79				Europe	Includes O&M jobs	MITRE 2003

Solar thermal

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. The European Renewable Energy Council (EREC) estimate that every 100 MW of solar thermal-electric power plant installed will provide 400 full-time equivalent manufacturing jobs, 600 contracting and installation jobs, and 30 annual jobs in O&M (EREC 2008). Note that a more recent report from the European Solar Thermal Electricity Association quotes the same figures for construction, installation, and manufacturing, but a figure three times higher for operations and maintenance. We have taken a conservative approach and used the lower figure (GPE/ESTELA 2009).

These projected figures are higher than the US National Renewable Energy Laboratories (NREL) projections. Black & Veatch used the Regional Input-Output Modelling System (RIMS II) developed and maintained by the US Bureau of Economic Analysis. In their analysis, it has been assumed that all construction and operations labour jobs created are in southern California, but that there is a high proportion of importing, so not all manufacturing jobs are included in their estimates.

The installation factor is similar to EPRI and operations and maintenance slightly higher. However the total installation and manufacturing jobs is lower than the Shwer and Riddel factor, which was derived from data generated using the REMI model.

Table 22 Employment factors for solar thermal

SOLAR THERMAL	CMI JOBS						
YEAR	TOTAL CMI	Installation	Manufacturing	Operations & Maintenance	Region	Notes	Source
	Person years/ MW			Jobs/ MW			
Factors used in this study							
2008	**10**	6	4	0.3		Industry projection	GPI/ ESTELA 2009 page 62, EREC 2008 Page 16
Factors for comparison							
2009	**10**			1	World	Industry projection	GPI & ESTELA 2009, page 62
2006		4.55		0.38	California	Black & Veatch used the Regional Input-Output Modelling System (RIMS II)	NREL 2006, Table 5-7
2001		5.7		0.22	California	No details given of derivation.	EPRI 2001, page C-6, Table C-3
2004	**15.65**			0.46	Nevada	Factors derived from data generated using the REMI model.	Schwer & Riddel 2004. Table 4, page12

Wind energy

The factors for wind energy used in this analysis all come from the most recent industry data, contained in the European Wind Energy Association (EWEA 2009) report on wind energy employment. This is the most robust data source for wind energy employment.

Table 23 Employment factors for wind energy

WIND ENERGY	YEAR	CMI JOBS TOTAL CMI	Installation	Manufacturing	Operations & Maintenance	Region	Notes	Source
		Person years/ MW			Jobs/ MW			
Factors used in this study								
Onshore	2007	**15**	2.5	12.5	0.4	Europe	Table 07 Page 21	EWEA 2009
Onshore	2030	**11**	1.9	9.1	0.29	Europe	Footnote 5 page 22 for total annual jobs decline, with the same ratios of installation to O&M maintained.	EWEA 2009
Offshore	2010	**28.8**	4.8	24.0	0.8	Europe	The ratio of employment in offshore: onshore wind is assumed to be the same as the cost ratios, which are given in footnote 5 page 22	Derived from EWEA 2009
Factors for comparison								
Onshore	2007				0.8	Germany	Industry data for employment and production.	Derived from BMU 2008a and 2008b
Onshore	2004	**16**			0.12	UK	Detailed economic analysis for the UK.	DTI 2004
Onshore	2001	**2.6**	2.57		0.29	California	No details of derivation given	EPRI 2001
Onshore	2004	**3.9**	0.9	3.04	0.1	Canada	Data from industry interviews and literature survey.	Pembina 2004
offshore	2004	**21**			0.17	UK	Detailed economic analysis for the UK.	DTI 2004
offshore	2004	**4.2**	1.18	3.04	0.1	Canada	Data from industry interviews and literature survey.	Pembina 2004
Onshore	2010	**32**				Europe	**Includes O&M jobs**	MITRE 2003

3.6 Adjustment for learning rates – decline factors

Employment factors are adjusted to take account of 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.

Industry projections for employment decline values are only available in a small number of technologies, namely wind, solar, and ocean.

For other technologies, the annual decline in cost for each technology is taken as a proxy value for the decline in employment. Cost declines will correspond to a reduction in employment, whether they result from greater efficiency in production processes, scaling up of technology, or as a direct result of more efficient working practices.

The decline factors derived from the GPI/EREC data are presented in Table 24, along with decline factors from industry sources. The decline factors from cost data for wind, PV, solar thermal, and ocean energy are shown for comparison but are not used in the analysis.

Table 24 Decline rates

	Annual decline in job factors Reference scenario		Annual decline in job factors [R]evolution scenario		Source
	2010-20	2020-30	2010-20	2020-30	
Coal	0.9%	0.3%	1.0%	0.3%	GPI & EREC 2008 (cost data)
Gas	0.4%	0.5%	0.4%	0.6%	GPI & EREC 2008 (cost data)
Oil	0.4%	0.4%	0.4%	0.4%	GPI & EREC 2008 (cost data)
Diesel	0.0%	0.0%	0.0%	0.0%	GPI & EREC 2008 (cost data)
Nuclear	0.0%	0.0%	0.0%	n/a	GPI & EREC 2008 (cost data)
Biomass power plant	1.0%	0.5%	1.0%	0.5%	GPI & EREC 2008 (cost data)
Hydro	-0.6%	-0.5%	-0.6%	-0.5%	GPI & EREC 2008 (cost data)
Wind – on shore	1.40%	1.40%	1.40%	1.40%	Derived from EWEA 200, footnotes 5 & 6 page 22.
Wind – off shore	3.90%	1.50%	3.90%	1.50%	Derived from EWEA 200, footnotes 5 & 6 page 22.
Wind turbine *	1.1%	0.8%	1.2%	0.7%	GPI & EREC 2008 (cost data)
PV	6.88%	1.41%	7.72%	2.42%	EPIA 2008b
PV *	6.5%	5.7%	6.9%	5.2%	GPI & EREC 2008 (cost data)
Geothermal	2.3%	2.0%	2.5%	1.7%	GPI & EREC 2008 (cost data)
Solar thermal (electricity)	0%	2.2%	1.6%	0.5%	GPI/ ESTELA 2009, page 62
Solar thermal (electricity) *	2.0%	1.7%	2.0%	1.7%	GPI & EREC 2008 (cost data)
Ocean	7.80%	7.80%	7.80%	7.80%	SERG 2007
Ocean energy *	8.4%	3.8%	8.4%	3.8%	GPI & EREC 2008 (cost data)

** Factors not used in analysis, provided for comparison only.*

3.7 Regional adjustments

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, we would derive employment factors for both developed and developing countries. In practice, data for developing countries is extremely limited. Instead we multiply the derived OECD employment factors using 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 have therefore used the projected change in GDP per capita to adjust the regional job multipliers over time.

Derivation of regional adjustment factors

We calculate a regional labour productivity value for each of the ten Energy [R]evolution scenario regions using data from International Labour Organisation Key Indicators of the Labour Market database (ILO 2007 KILM).

The KILM database holds data for economy wide average labour productivity, and for productivity in agriculture, forestry, and fishing, and manufacturing. Productivity is calculated as average GDP per worker.

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

Table 25 Numbers of countries included in energy scenarios and numbers 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	23
OECD Pacific	4	3
Africa	55	25
China	2	2
Developing Asia	29	12
India	1	1
Latin America	38	18
Middle East	13	12
Transition economies	25	25

Where available, GDP per worker for the year 2006 was used. Of a total of 178 countries included in the energy projections, reasonably complete data was available in the KLIM database for 125. However, the regional distribution was uneven. The numbers of countries per region with productivity data are shown Table 25. While some regions have relatively few countries represented, those with data tend to be the larger ones.

Two sets of indicators from the KILM database were used in order to obtain total workforce numbers for every country included. The indicators were employment by industry, and educational levels by industry. Where workforce numbers were available from both data sets the average value was used.

Annual average growth in productivity over the period 1980 to 2005 can be derived from the KILM data. However, this cannot be used to forecast growth up to 2030. Instead, we used a proxy, namely growth in GDP per capita. We applied this to the 2006 regional labour productivity data to calculate labour productivity in 2020 and 2030.

We derived GDP per capita growth for each of the 10 regions using projected GDP and population growth from IEA 2007 (these economic assumptions are key inputs to the IEA scenario and the [R]evolution scenario). The derived average growth in GDP per capita over the period 1980 to 2005 was compared to the derived average growth in productivity from the KILM data. As the two rates of growth are broadly similar, we conclude that GDP per capita growth is a reasonable proxy for labour productivity growth. The comparison is shown in Table 26.

Table 26 Growth in GDP per capita compared to growth in labour productivity, historic values

Reference **Indicator**	WEO 2007 Average annual growth in GDP per capita	ILO 2007 Average annual growth in labour productivity, whole economy
Region	1980 - 2005	1980 - 2005
World	1.7%	3.1%
OECD	1.5%	1.6%
OECD North America	1.5%	1.7%
OECD Europe	1.4%	1.6%
OECD Pacific	1.5%	1.8%
Africa	0.9%	0.2%
China	5.8%	6.1%
Developing Asia	3.9%	2.8%
India	3.0%	3.7%
Latin America	1.3%	-0.04%
Middle East	1.6%	-1.5%
Transition economies	0.4%	0.2%

We calculated three sets of productivity data – one set for whole of economy, a second for agricultural, forestry and fisheries workers only, and a third set which is 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, as shown in Table 27. However, agricultural productivity is not relevant to the majority of energy technologies.

Table 27 Regional labour productivity compared to OECD labour productivity

	Ratio to OECD 2010			Ratio to OECD 2020			Ratio to OECD 2030		
	Whole economy	**Agriculture**	**Whole economy excluding Agriculture**	**Whole economy**	**Agriculture**	**Whole economy excluding agriculture**	**Whole economy**	**Agriculture**	**Whole economy excluding agriculture**
World	**0.38**	0.10	0.54	**0.43**	0.11	0.60	**0.44**	0.12	0.63
OECD	**1.0**	1.0	1.0	**1.0**	1.0	1.0	**1.0**	1.0	1.0
OECD North America	**1.2**	3.1	1.2	**1.2**	3.0	1.2	**1.2**	3.0	1.2
OECD Europe	**0.85**	0.70	0.87	**0.86**	0.71	0.88	**0.85**	0.70	0.87
OECD Pacific	**0.92**	0.66	0.92	**0.93**	0.66	0.93	**0.94**	0.67	0.94
Africa	**0.11**	0.07	0.16	**0.11**	0.07	0.16	**0.11**	0.07	0.16
China	**0.30**	0.07	0.49	**0.49**	0.12	0.80	**0.59**	0.14	0.97
Developing Asia	**0.25**	0.08	0.40	**0.36**	0.12	0.57	**0.42**	0.14	0.67
India	**0.16**	0.05	0.36	**0.23**	0.08	0.52	**0.30**	0.10	0.68
Latin America	**0.36**	0.31	0.40	**0.38**	0.33	0.42	**0.38**	0.34	0.42
Middle East	**0.37**	0.34	0.41	**0.40**	0.37	0.44	**0.39**	0.36	0.44
Transition economies	**0.34**	0.22	0.38	**0.45**	0.29	0.50	**0.49**	0.31	0.54

Note 1 Labour productivity (defined as average GDP per worker) from ILO KILM 2007 edition 5.

Note 2 Growth rates in labour productivity taken as growth rate in GDP per capita, derived from World Energy Outlook 2007

Note 3 The multiplier listed as 'agriculture' is in fact for forestry, fisheries and agriculture.

The multiplier for agriculture is used for bioenergy fuel production, while the multipliers for the economy excluding agriculture is used for all other fuels and for construction, manufacturing, and operations and maintenance. It was not possible to calculate separate productivity ratios for manufacturing, construction or O&M due to insufficient data sets, so the same multiplier is used for all three.

Productivity data for each region and time period is compared to the OECD region, where OECD is presented as 1.0 and all other regions as a ratio to OECD. The ratios are presented in Table 27 below.

Regional job multipliers are obtained from the ratios in Table 27, 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 presented in Table 27.

Table 28 Multipliers to be applied to employment factors

JOB MULTIPLIERS	2010		2020		2030	
	Construction, manufacturing, O&M	Biomass fuel supply	Construction, manufacturing, O&M	Biomass fuel supply	Construction, manufacturing, O&M	Biomass fuel supply
OECD	1.0	1.0	1.0	1.0	1.0	1.0
Africa	6.3	13.7	6.2	13.4	6.3	13.7
China	2.0	13.5	1.2	8.3	1.0	6.9
Developing Asia	2.5	12.0	1.7	8.4	1.5	7.2
India	2.7	18.2	1.9	12.7	1.5	9.7
Latin America	2.5	3.2	2.4	3.0	2.4	3.0
Middle East	2.4	3.0	2.2	2.7	2.3	2.8
Transition economies	2.6	4.5	2.0	3.4	1.9	3.2

The calculated values may in fact underestimate the additional employment in non-OECD countries. Regional data was collected for PV employment, and jobs per MW production in China is approximately 3 times greater than employment in the US and Germany. The regional multiplier used for China is 1.9 in 2010.

Table 29 Employment per MW in wafer production

PV company	Country	Production capacity 2008 MW	Employees per MW 2008	Source
Suntech	China	1,000	9.1	Suntech Power Holdings Co Ltd Annual Report for 2008, Pages 12 & 84
Q-Cells	Germany	760	3.4	Q.Cells 2008 Annual Report, page 2
First Solar	US/Germany/ Malaysia	1,145	3.1	First Solar 2008 Annual Report, pages 4 & 9

3.8 Adjustment for manufacturing in the renewable sector

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 30.

Table 30 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%	50%	-	25%	25%
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%	25%	25%	-
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.

Local manufacturing percentages vary from 100% manufacturing within Europe for each period, to only 30% of manufacturing occurring within Africa in 2010, rising to only 70% by 2030. Local percentages are applied to all 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 30. Import and export percentages, and current export regions, are set according to current practice. Local manufacturing is generally increased over time.

3.9 Energy efficiency

It is difficult to assess employment creation in energy efficiency, as the sector is diverse and activities are frequently bundled into other actions. For example, energy efficiency improvements may occur as part of normal replacement cycles, so the associated employment must be differentiated into that which results from the 'energy efficiency premium'[1] rather than the total investment (or work) associated with the retrofit.

[1] The energy efficiency premium is the additional expenditure incurred, over and above the expenditure for the normal replacement or retrofit, in order to reduce energy consumption.

The most common way to derive or describe employment creation from energy efficiency is via annual investment (for example, Dupressoir et al, 2007, Wade et al, ACEEE 2005, CEC 2009). Energy efficiency investment data is not available for the Energy [R]evolution scenarios.

In order to make an assessment of the efficiency employment, an employment factor of job creation per GWh saved is derived for this study.

The most comprehensive assessment of the energy efficiency industry is given in a 2008 study of the USA, *The Size of the U.S. Energy Efficiency Market: Generating a More Complete Picture,* by Ehrhardt-Martinez and Laitner (ACEEE 2008). This identifies the energy efficiency premium spending by sector in the US in 2004, and gives both the energy savings and the job creation. This information has been used to derive sectoral figures for energy efficiency jobs per GWh, shown in Table 31.

The multiplier is adjusted with regional multipliers in the same way as all other technology multipliers.

While there are jobs in energy efficiency in the Reference Scenario, this calculation takes the Reference as a base line, and only considers ***additional*** energy efficiency employment over and above what would occur in the Reference scenario.

A weighted average of 0.29 jobs per GWh for energy efficiency jobs in the residential, commercial, industrial and utilities sectors is calculated using the approximate distribution of electricity savings in the Energy [R]evolution Scenario (based on the Ecofys study). This is reduced for 2010 by the average decline factor for renewable technologies (wind, PV, and geothermal), to a value of 0.23 jobs per GWh.

This figure is used to estimate jobs in energy efficiency which result from the [R]evolution Scenario. The employment factor is adjusted in 2020 and 2030 using the renewable decline for wind and PV, giving 0.15 in 2020 and 0.13 in 2030.

Table 31 Employment from energy efficiency investment in the US, 2004

	Residential	Commercial	Industrial	Appliances and electronics	Transport	Utilities	Entire economy
Efficiency premium employment	47,400	45,200	52,700	44,700	22,700	20,800	**233,500**
Jobs per million US$ investment	8.1	5.9	4.6	4.2	4.7	8.8	**5.4**
Investment billion US$	5.9 bn	7.7 bn	11 bn	10.6 bn			**n/a**
Energy savings GWh	96,713	73,268	193,427	43,961	407,369	718,024	**1,532,762**
Employment per GWh	**0.49**	**0.62**	**0.27**	**1.02**	**0.06**	**0.03**	**0.35**

From ACEEE 2008, Table 8 (employment and jobs per million), Figures 5 – 8 and page 24 (investment and energy savings).

Table 32 Energy efficiency comparative employment factors derived from various studies

Sector	Country	Total energy savings GWh	Jobs per GWh	Source
Factor used in this analysis for 2010	**US**		**0.23**	2004 sectoral factors from ACEEE 2008, weighted according to the mix of energy savings in the [R]evolution scenario, declined to 2010.
Residential	Australia	13,922	0.16	Access Economics 2009
Commercial		4,781	0.36	
Industrial		3,708	0.07	
Weighted average		**22,410**	**0.19**	
All sectors	Germany	75,000	**0.60**	Dupressoir et al, 2007
Residential	US	96,713	0.49	ACEEE 2008
Commercial		73,268	0.62	
Industrial		193,427	0.27	
Utilities		718,024	0.03	
Weighted average		**363,408**	**0.19**	

Other studies were examined to obtain employment factors per GWh, but many did not have appropriate data to enable the calculation. Table 32 shows factors from different studies for comparison.

The factors for Germany derive from projections for the Energy Saving Fund Project, which includes 12 programmes between 2006 and 2030, covering manufacturing, tertiary, public administration, and housing (Dupressoir et al, 2007, page 152). The German factor covers only electricity. The Australian data comes from a 2009 CEC Economics report, and derives from programs and actions that are planned in Australia between 2009 and 2020.

For this study, the US data is used as it is both the most comprehensive study, and has the largest coverage. The sectoral results for jobs per GWh for residential, commercial, industrial and utilities from the ACEEE 2008 report are used to derive a factor for the sectoral mix in the Energy [R]evolution, which projects sectoral electricity savings as shown in Table 33. The [R]evolution mix includes relatively more of residential and commercial sector savings, and relatively less of the utilities sector (here described as ‘services’) than the US data shown in Table 32. This is why the factor used here is higher than the weighted average from the US study (0.23 and 0.19 respectively), as the relatively high proportion of utilities energy efficiency in the US data led to an overall low figure.

Table 33 Proportion of electricity savings by sector, Energy [R]evolution

Sector	Proportion of electricity savings
Industry	32%
Residential & commercial	26%
Other	7%
Services	24%
Agriculture	11%

3.10 Methodology variations for case studies

The analysis includes case studies for the G8 countries and for the European Union. Some methodological changes are made in the case studies, in order that the results are more meaningful on the country level. These are:

- Importing and exporting is treated in more detail. Manufacturing of globally traded components in renewable energy is allocated by technology and country, rather than an overall figure being used for all renewable technologies, as there are significant differences between countries within the G8.
- Country specific employment multipliers are used for Germany, as detailed data is available on their renewable energy sector.
- Job multipliers are used for countries in the same way as they were used for regions in the global analysis, to adjust for different productivity levels in the OECD. The job multiplier is derived using exactly the same methodology as used in the regional analysis. This means, for example, that the US, which has higher labour productivity, is assigned lower job creation per unit of generation.

International trade - coal

To derive the percentage of imported coal used in each scenario at 2010, 2020, and 2030 we use country data for the proportion of coal domestic production in 2006 from the International Energy Agency statistics, combined with the growth in coal use in the Reference and revolution scenarios, and the projected consumption in IEA 2008. The import percentages are shown in Table 34.

Table 34 Percentage of coal imported, G8 countries and EU-27

	Reference scenario			[R]evolution scenario		
	2010	2020	2030	2010	2020	2030
Canada	-	-	-	-	-	-
France	87%	92%	96%	85%	86%	85%
Germany	23%	16%	-12%	23%	-	-
Italy	83%	75%	88%	82%	74%	67%
Japan	82%	82%	82%	72%	69%	66%
Russia	-	-	-	-	-	-
UK	69%	67%	65%	65%	-	-
USA	-	-	-	-	-	-
EU27	45%	50%	51%	32%	0%	0%

The need to import coal is reduced in the [R]evolution scenario compared to the Reference scenario because coal consumption is reduced.

Only Russia, the USA, and Canada are net coal exporting countries in the G8 and EU-27. Coal exports are calculated in the regional analysis, as exports are not just for countries included in the case studies. Coal exports assigned to ‘Developing Asia’ from the regional analysis are assigned to Russia. 90% of the OECD North America coal exports are allocated to the USA, and 10% of OECD North America coal exports are allocated to Canada.

International trade - gas

To derive the percentage of imported gas used in each scenario at 2010, 2020, and 2030 we use country data for the proportion of domestic gas production in 2006 from the International Energy Agency statistics, combined with the growth in gas use in the Reference and [R]evolution scenarios, and the projected production. The import percentages are shown in Table 35.

The need to import gas increases in some cases in the [R]evolution scenario compared to the Reference scenario because gas consumption goes up, and it is assumed that production levels in importing countries remain the same.

Table 35 Percentage of gas imported, G8 countries and EU-27

	Reference scenario			[R]evolution scenario		
	2010	2020	2030	2010	2020	2030
Canada	-	-	-	-	-	-
France	99%	100%	100%	100%	100%	100%
Germany	98%	98%	99%	98%	99%	99%
Italy	91%	95%	97%	90%	93%	92%
Japan	96%	96%	97%	97%	97%	97%
Russia	-	-	-	-	-	-
UK	13%	65%	76%	22%	35%	11%
USA	15%	17%	17%	36%	48%	51%
EU27	64%	77%	85%	67%	77%	83%

Only Russia and Canada are net gas exporting countries in the G8 and EU-27. Gas exports are assigned to Russia from the total gas exports calculated in the regional analysis, as exports are not just for countries included in the case studies. Exports are assigned to Russia according to the proportion of net inter-regionally traded gas in the relevant year. Canada is assumed to export a constant amount in the reference scenario, with this going up in the [R]evolution scenario as domestic consumption goes down.

International trade – renewables

Global inter-regional trade in renewables is allocated within the G8 and EU27 countries according to the percentages in Table 36. Trade within regions is not accounted for. This is likely to result in an underestimate of jobs in countries which are high exporters, and an overestimate of jobs in countries which do not manufacture renewable components. For example, jobs in Germany will be underestimated, as Germany has a very high share of renewable manufacturing, while jobs in Italy may be overestimated.

The country proportions of globally traded wind and solar components have been taken from the European Commission EmployRes study (Solar PV from Table 9, and Table 10, wind from Figure 72, EmployRes 2009), as has the figure for the EU27 overall share of renewable components. The EU27 figure is from the moderate scenario for European exports (EmployRes 2009, page 124). Proportions are assumed to stay constant over the study period.

Table 36 Proportions of globally traded renewable energy components

	Biomass	Hydro	Wind	PV	Geothermal	Solar thermal	Ocean
Canada	-	-	-	-	-	-	-
France	-	-	4%	1%	-	-	-
Germany	-	-	12%	13%		100%	
Italy	-	-	-	-	-	-	-
Japan	-	-	0%	16%	-	-	-
Russia	-	-	-	-	-	-	-
UK	-	-	3%	1%	-	-	-
USA	-	-	-	-	-	-	-
EU27	43%	43%	34%	23%	43%	100%	43%

Note: percentages derived from EmployRes 2009, Tables 9 and 10, Figure 72, and page 124.

Country specific factors

Job multipliers have been used in the same way as for the regional analysis (see Section 3.7), as the inverse ratio of labour productivity in the relevant country to the OECD average. The whole of economy values have been used. The projections are obtained from the IEA projections for growth in GDP per capita (IEA 2007). The job multipliers are shown in Table 37.

Factors for employment in coal fuel supply are also calculated for each country, and are shown in Table 38. The methodology to derive these factors is described in Section 3.4.

The employment factors for operations and maintenance in biomass, wind, and hydro were modified for Germany, as specific data is available for current jobs in those fields in Germany (BMU 2008). While this would not make a significant difference on a regional analysis, at the country level it is enough to make a noticeable difference. Unfortunately the same level of data is not available in any other study country. The modified factors are presented in Table 39, with the ones that they replace.

Table 37 Multipliers to be applied to employment factors in case study countries (whole of economy)

JOB MULTIPLIERS	2010	2020	2030
OECD	1	1	1
Canada	1.1	1.1	1.0
France	0.9	0.9	0.9
Germany	1.2	1.2	1.2
Italy	1.1	1.1	1.1
Japan	1.2	1.2	1.1
Russia	2.9	2.3	3.3
UK	1.0	1.0	1.0
USA	0.8	0.8	0.8
EU27	1.2	1.2	1.3

Table 38 Employment factors for coal supply, G8 and EU27

Employment per GWh	Coal fuel factor (existing consumption)	Coal fuel employment (new consumption)
Canada	0.0	0.0
France	0.2	0.2
Germany	0.1	0.1
Italy	0.37	0.17
Japan	0.37	0.17
Russia	0.37	0.17
UK	0.52	0.45
USA	0.02	0.02
EU27	0.37	0.17

Table 39 Employment factors for Germany in country analysis

Employment per GWh	Unit	Factor for Germany	Factor used in regional analysis
Biomass operations and maintenance	person years/ MW	5.2	3.1
Biomass fuel supply	person years/ GWh	1.4	0.2
Hydro operations and maintenance	person years/ MW	0.9	0.2
Wind operations and maintenance	person years/ MW	0.7	0.4

Note German factors from 2007 data (BMU 2008a and 2008b), reduced by three years of decline factors for the relevant technology.

4 Employment in the energy sector – world results

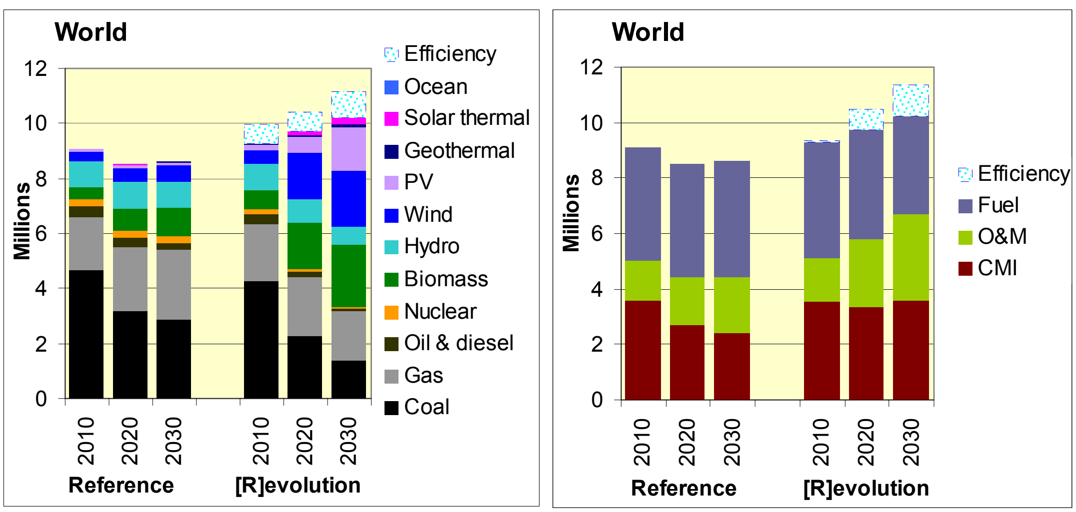
Highlights

- By 2010 global energy sector jobs in the [R]evolution scenario are estimated at about 9.3 million, 200,000 more than the Reference scenario.
- By 2020, the [R]evolution scenario is estimated to have about 10.5 million jobs, 2 million more than the Reference scenario. More than half a million jobs are lost in the Reference scenario between 2010 and 2020, while 1 million are added in the [R]evolution scenario.
- By 2030 the [R]evolution scenario has about 11.3 million, 2.7 million more than the Reference scenario. Approximately 800,000 new jobs are created between 2020 and 2030 in the [R]evolution, ten times the number created in the Reference scenario.

Detailed results

Figure 2 shows the number of jobs under both the [R]evolution scenario and the Reference scenario by technology and by type: construction, manufacturing and installation (CMI), operations and maintenance (O&M), fuel supply, and energy efficiency in 2010, 2020 and 2030. Combined heat and power generation is included under the fuel type, for example gas or biomass.

Figure 2 World jobs by technology and type in 2010, 2020, and 2030



Jobs in the [R]evolution scenario jobs increase significantly from 9.3 million in 2010 to 10.5 million by 2020, and then reach 11.3 million in 2030. In the Reference scenario energy sector jobs fall between 2010 and 2020, from 9.1 million to 8.5 million, before climbing back to 8.6 million in 2030.

Figure 3 shows the change in job numbers under both scenarios for each technology between 2010 and 2020, and 2010 and 2030.

There is a decrease in coal power jobs in both scenarios between 2010 and 2020, but strong growth in renewable energy jobs in the [R]evolution scenario leads to a net gain in employment. Growth in gas generation jobs in the Reference scenario is not sufficient to compensate for the losses in coal jobs.

Employment numbers are indicative only, as a large number of assumptions are required to make calculations, particularly for energy efficiency. However, within the limits of data availability, the figures presented are indicative of employment levels under the two scenarios.

Table 40 presents worldwide electricity generation, jobs in energy supply by energy source and energy efficiency under the Reference and [R]evolution Scenarios from 2010 to 2030.

Figure 3 World employment change in 2020 and 2030, compared to 2010

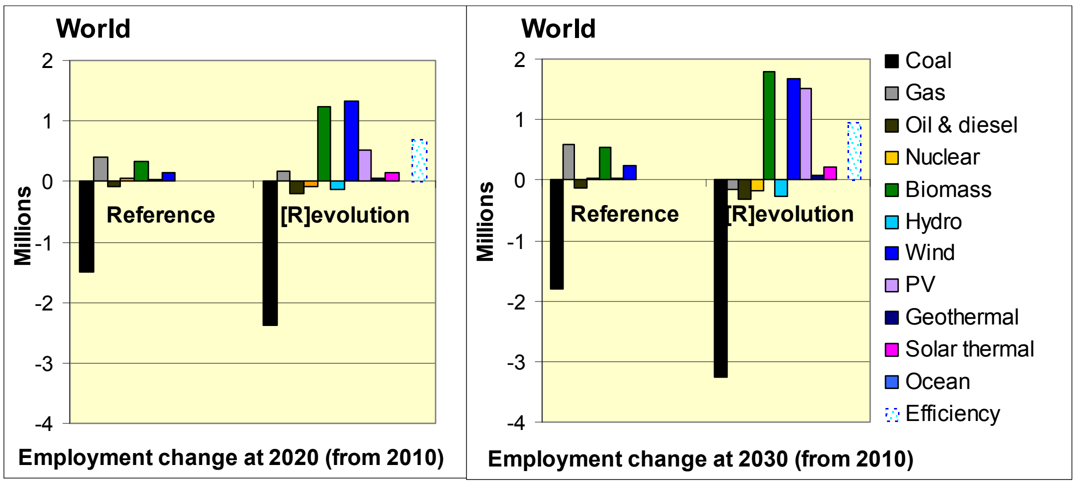


Table 40 World employment and electricity generation at 2010, 2020, and 2030

WORLD	REFERENCE SCENARIO 2010	2020	2030	[R]EVOLUTION SCENARIO 2010	2020	2030
Electricity generation (TWh)						
Coal	9,283	12,546	16,030	8,751	8,953	7,784
Gas	4,447	6,256	7,974	4,704	6,126	6,335
Nuclear, oil & diesel	4,004	4,133	4,079	3,814	2,309	1,003
Renewable	4,047	5,871	7,286	4,254	8,355	14,002
TOTAL electricity generation	**21,780 TWh**	**28,807 TWh**	**35,369 TWh**	**21,523 TWh**	**25,743 TWh**	**29,124 TWh**
JOBS (millions)						
Energy supply	**9.1 m**	**8.5 m**	**8.6 m**	**9.3 m**	**9.7 m**	**10.2 m**
Energy efficiency	-	-	-	0.06 m	0.72 m	1.13 m
TOTAL JOBS	**9.1 m**	**8.5 m**	**8.6 m**	**9.3 m**	**10.5 m**	**11.3 m**

Note: Energy efficiency jobs are only those over and above efficiency jobs in the reference scenario.

Discussion

As shown in Figure 2 above, total energy sector jobs in the Reference scenario fall by 600,000 between 2010 and 2020. This fall is dominated by a reduction in coal generation jobs. The decrease in coal jobs occurs despite an **increase** of 37% in electricity generation from coal in the Reference scenario, as shown in Table 40.

The biggest influence on coal generation jobs in the **Reference** scenario is the reduction in jobs per MW as prosperity and labour productivity increases, which is reflected in the regional job multipliers. Regional job multipliers are applied to OECD employment factors in non-OECD regions. These regional multipliers are higher in earlier years, and fall over the study period as the difference between labour productivity in the OECD and other regions falls (see section 3.7 for more details). If regional multipliers are not used, coal employment by 2020 falls by only 5% relative to 2010, rather than by 32%.

As shown in **Decline factors** are used to reflect the reduced labour intensity of generation as costs fall over time. Decline factors are applied to every technology and are taken as the average annual cost reduction between 2010 and 2020, or 2020 and 2030.

Decline factors affect every type of generation, although coal is less affected than most, as it is already a mature technology. The decline factor accounts for only 17% of the reduction in coal sector employment, or 250,000 jobs.

However, decline factors significantly reduce the total number of jobs. If decline factors were not used, it would increase employment projections in both scenarios, but would affect the [R]evolution scenario considerably more. Without decline factors, at 2020 [R]evolution energy supply jobs (not including energy efficiency) would be 1.7 million higher than presented above, while the Reference scenario energy supply jobs would be 0.7 million higher. In 2030, [R]evolution jobs would be 4 million higher, while the Reference scenario jobs would be 1.2 million higher. The [R]evolution scenario is more affected because it has much stronger growth in new technologies, which have steeper cost declines.

As there is uncertainty about what decline factors are appropriate for energy efficiency, this analysis has taken a cautious approach in using the average decline of renewable technologies. However, it may be, for example, that job creation per GWh **increases** in later years as the easier options to save energy disappear. Certainly, the actual projected numbers are low in this analysis compared to other studies. For example, applying the multipliers to energy savings in the US, additional energy efficiency jobs are calculated as 70,000 in 2020 and 11,000 in 2030 (see section 6.8). A recent analysis of grid management jobs associated with ‘Intelligent Grid’ operation estimated 280,000 new jobs created in the US during the implementation phase, with 140,000 permanent jobs, more than double the total jobs projected here (KEMA 2008). If no decline factor is applied, energy efficiency jobs would be projected at 1.4 million in 2020 and 2.6 million in 2030.

More explanation of decline factors can be found in Section 3.6.

Figure 4 , China accounts for one third of worldwide energy sector jobs in 2010 under the Reference scenario, with more than three quarters of those in coal power. The change in the regional factor for China accounts for a significant proportion of the coal job losses projected in the Reference scenario, a reduction of 700,000 jobs.[2]

[2] Compared to the situation of maintaining the multiplier at 1.9 in 2020. If no multiplier was used at all, 2010 and 2020 totals would both be reduced significantly.

More explanation of the decline in Reference scenario jobs may be found in the discussion of coal employment (Section 7.1), and of China (Section 5.4).

The decline factors applied to each technology also reduce the employment per MW, although his does not affect coal sector employment substantially, as it is a mature technology.

Lastly, annual world wide growth in coal generation falls from 71 GW per year in 2010 to 58 GW per year in 2020. This means construction and manufacturing jobs fall, reflecting the slower annual growth in 2020.

Although there is job growth in gas generation and renewable energy in the Reference scenario, it is insufficient to counteract the job losses. By 2030 there has been some recovery in total job numbers, with strong growth in the gas generation employment resulting from the 50% expansion in gas capacity. However, jobs in the Reference scenario do not regain the 2010 levels.

In the [R]evolution scenario, the reduction in coal sector jobs occurs mainly because growth in coal capacity is almost zero, and by 2030 there is a slight **reduction** in coal capacity. This means that construction, installation and manufacturing jobs in the coal sector fall to almost zero. The reduction in coal jobs is compounded by the same influences that operate in the Reference scenario, as the change in regional employment multipliers and decline factors exaggerate the effect of zero growth.

Job growth in renewable energy and energy efficiency in the [R]evolution scenario is so strong that there is a net gain of 2 million jobs by 2030, relative to the 2010 Reference case.

Decline factors are used to reflect the reduced labour intensity of generation as costs fall over time. Decline factors are applied to every technology and are taken as the average annual cost reduction between 2010 and 2020, or 2020 and 2030.

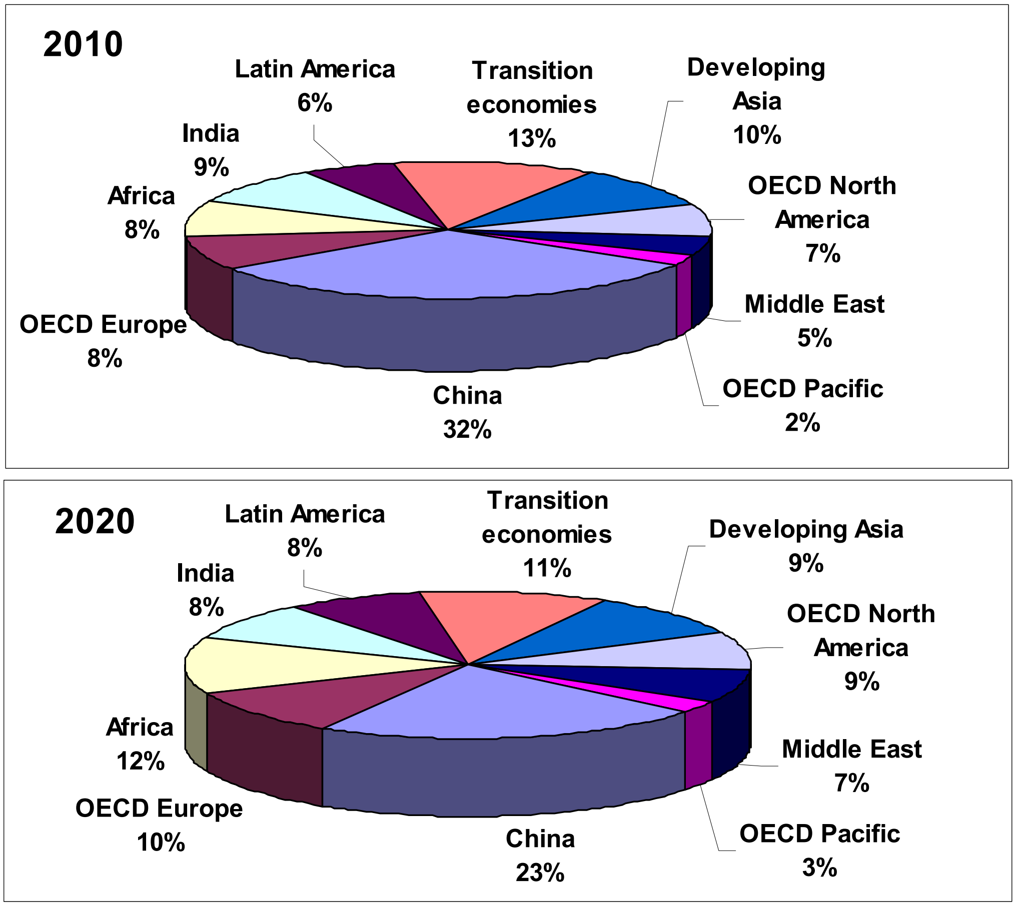
Decline factors affect every type of generation, although coal is less affected than most, as it is already a mature technology. The decline factor accounts for only 17% of the reduction in coal sector employment, or 250,000 jobs.

However, decline factors significantly reduce the total number of jobs. If decline factors were not used, it would increase employment projections in both scenarios, but would affect the [R]evolution scenario considerably more. Without decline factors, at 2020 [R]evolution energy supply jobs (not including energy efficiency) would be 1.7 million higher than presented above, while the Reference scenario energy supply jobs would be 0.7 million higher. In 2030, [R]evolution jobs would be 4 million higher, while the Reference scenario jobs would be 1.2 million higher. The [R]evolution scenario is more affected because it has much stronger growth in new technologies, which have steeper cost declines.

As there is uncertainty about what decline factors are appropriate for energy efficiency, this analysis has taken a cautious approach in using the average decline of renewable technologies. However, it may be, for example, that job creation per GWh **increases** in later years as the easier options to save energy disappear. Certainly, the actual projected numbers are low in this analysis compared to other studies. For example, applying the multipliers to energy savings in the US, additional energy efficiency jobs are calculated as 70,000 in 2020 and 11,000 in 2030 (see section 6.8). A recent analysis of grid management jobs associated with 'Intelligent Grid' operation estimated 280,000 new jobs created in the US during the implementation phase, with 140,000 permanent jobs, more than double the total jobs projected here (KEMA 2008). If no decline factor is applied, energy efficiency jobs would be projected at 1.4 million in 2020 and 2.6 million in 2030.

More explanation of decline factors can be found in Section 3.6.

Figure 4 World energy sector employment by region, Reference scenario



5 Employment in the energy sector – regional results

5.1 OECD North America

Highlights

- There are 694,000 energy sector jobs in the [R]evolution scenario in OECD North America in 2010, compared to 665,000 in the Reference scenario.
- In 2020, job numbers reach over 1.3 million in the [R]evolution scenario, 600,000 more than in the Reference scenario.
- Job numbers climb slightly in the [R]evolution scenario by 2030, to nearly 1.4 million, and reach nearly 0.8 million in the Reference scenario.

Discussion

Figure 22 shows the number of jobs under both the [R]evolution scenario and the Reference scenario by technology and by type. There are more energy sector jobs in OECD North America in the [R]evolution scenario at every stage.

Figure 5 OECD North America: jobs by technology and type in 2010, 2020, and 2030

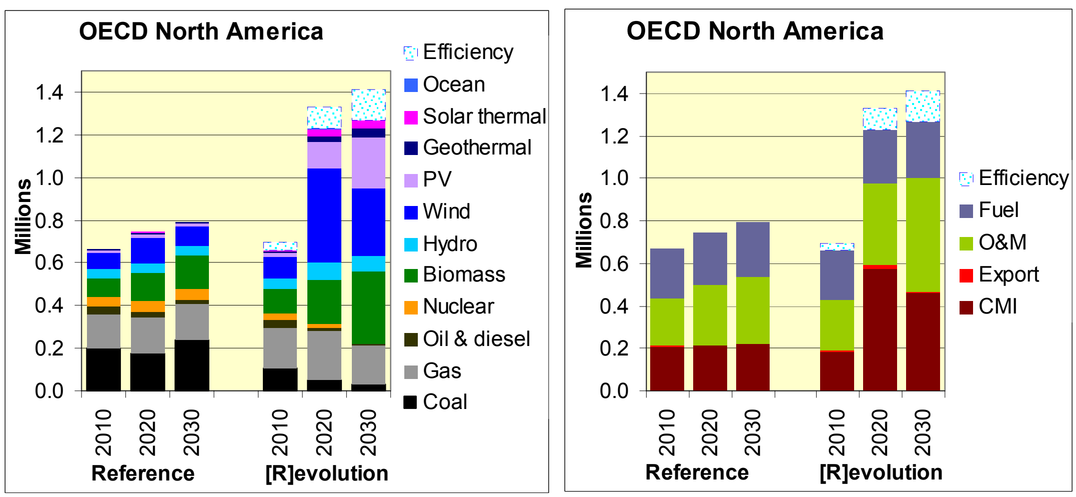


Figure 6 shows the change in job numbers under both scenarios for each technology between 2010 and 2020, and 2010 and 2030. Both scenarios show losses in coal generation, but these are outweighed by employment growth in renewable technologies and gas.

Wind shows particularly strong growth in the [R]evolution scenario at 2020, but by 2030 there is significant employment in a portfolio of renewable technologies.

Figure 6 OECD North America: employment change 2020 and 2030, compared to 2010

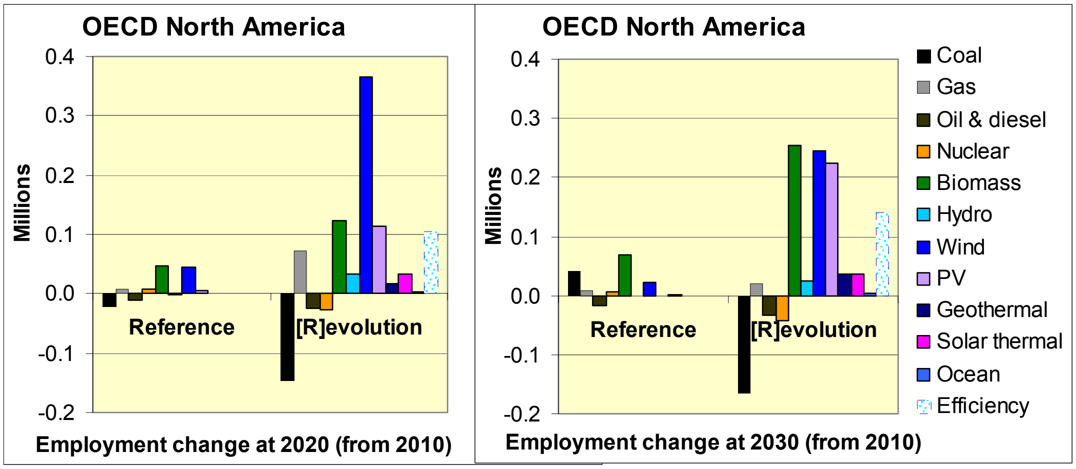


Table 35 presents OECD North America electricity generation, jobs in energy supply by energy source and energy efficiency under the Reference and [R]evolution Scenarios from 2010 to 2030.It is assumed that all manufacturing occurs within OECD North America, and that the region exports just under 10% of globally traded renewable energy components. In the [R]evolution scenario export jobs reach 5% of the total energy sector jobs in 2020, and stay at that level. In the Reference scenario export jobs do not even reach 1%.

Table 41 OECD North America: employment and electricity generation at 2010, 2020, and 2030

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	2020	2030	2010	2020	2030
JOBS (thousands)						
Coal	198	175	239	104	52	33
Gas	160	169	169	193	234	181
Nuclear, oil, Diesel	81	79	70	67	29	7
Renewable	226	323	316	295	927	1,048
Energy supply jobs	**665**	**745**	**793**	**659**	**1,241**	**1,269**
Energy efficiency jobs	-	-	-	35	105	141
TOTAL JOBS	**665**	**745**	**793**	**694**	**1,346**	**1,410**
ELECTRICITY GENERATION TWh						
Coal	2,534	2,918	3,446	2,303	1,583	1,052
Gas	1,000	1,211	1,358	1,113	1,560	1,426
Nuclear, oil, diesel	1,153	1,173	1,179	1,046	478	83
Renewable	879	1,179	1,367	948	2,172	3,673
Total electricity generation (TWh)	**5,565 TWh**	**6,481 TWh**	**7,350 TWh**	**5,411 TWh**	**5,793 TWh**	**6,234 TWh**

Note: Base case energy efficiency jobs are not calculated, so the energy efficiency jobs shown are only those ***additional*** *to the reference scenario.*

5.2 Latin America

Highlights

- There are 581,000 energy sector jobs in the [R]evolution scenario in Latin America in 2010, compared to 541,000 in the Reference scenario.
- In 2020, job numbers grow in both scenarios. The [R]evolution scenario reaches 814,000 and the Reference scenario 651,000.
- Job numbers in the [R]evolution scenario continue to grow strongly, reaching just over a million jobs by 2030, nearly 300,000 more than in the Reference scenario.

Discussion

There are more energy sector jobs in Latin America in the [R]evolution scenario at every stage. In 2010, the [R]evolution has about 50,000 additional jobs compared to the Reference scenario, with 160,000 more in 2020, and 300,000 more by 2030.

Figure 7 shows total projected jobs in the energy sector, broken down by technology. While there is strong growth in both sectors, employment under the [R]evolution scenario increases much more strongly.

It is assumed that only 30% of renewable energy manufacturing occurs within the region at 2010, increasing to 70% by 2030. However, Latin America exports a high percentage of the inter-regionally traded gas, which results in high employment numbers in the Reference scenario, and significant numbers in the [R]evolution.

Figure 7 Latin America: jobs by technology and type in 2010, 2020, and 2030

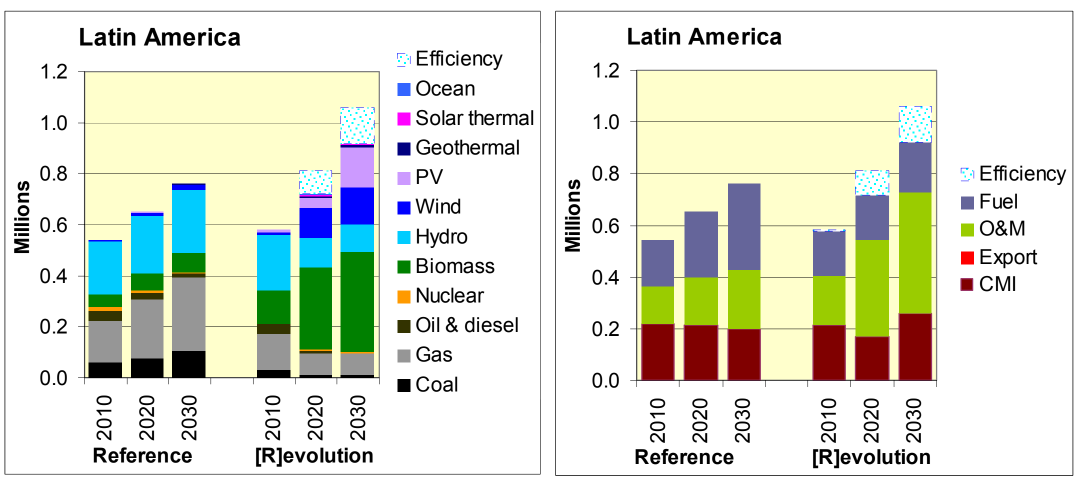


Figure 8 shows the change in job numbers under both scenarios for each technology between 2010 and 2020, and 2010 and 2030. Employment associated with gas generation grows most strongly in the Reference scenario, but this is dwarfed by the exceptional growth in renewable energy employment, especially biomass, in the [R]evolution scenario.

Figure 8 Latin America: employment change 2020 and 2030, compared to 2010

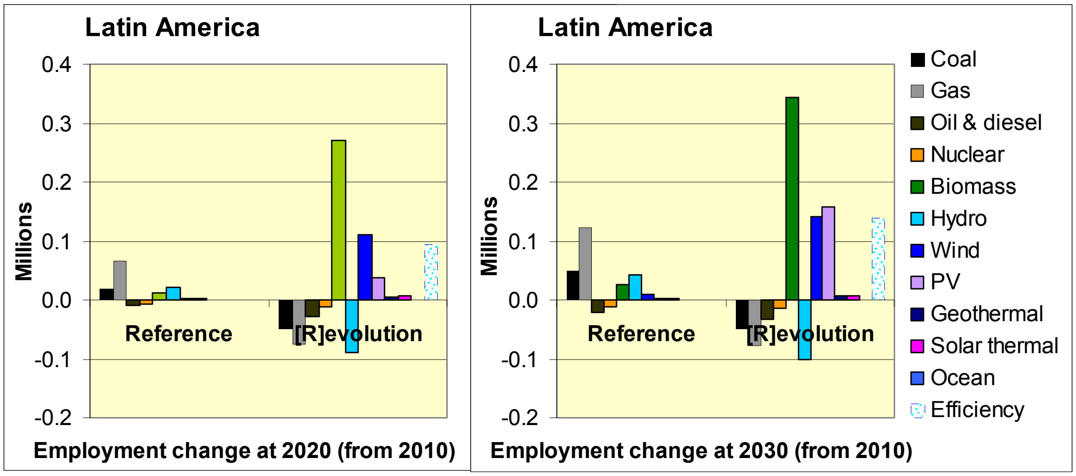


Table 42 Latin America: employment and electricity generation at 2010, 2020, and 2030

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	2020	2030	2010	2020	2030
JOBS (thousands)						
Coal	58	77	107	32	8	9
Gas	165	232	286	138	90	86
Nuclear, oil, Diesel	52	36	19	43	12	4
Renewable	266	306	349	367	609	821
Energy supply jobs	**541**	**651**	**762**	**579**	**719**	**920**
Energy efficiency jobs	-	-	-	2	95	138
TOTAL JOBS	**541**	**651**	**762**	**581**	**814**	**1,058**
ELECTRICITY GENERATION TWh						
Coal	35	58	92	24	5	12
Gas	241	464	696	209	194	168
Nuclear, oil, diesel	108	100	77	103	40	7
Renewable	754	974	1,186	796	1,095	1,392
Total electricity generation (TWh)	**1,137 TWh**	**1,596 TWh**	**2,051 TWh**	**1,130 TWh**	**1,333 TWh**	**1,579 TWh**

Note: Base case energy efficiency jobs are not calculated, so the energy efficiency jobs shown are only those ***additional*** *to the reference scenario.*

5.3 OECD Europe

Highlights

- There are 888,000 energy sector jobs in the [R]evolution scenario in OECD Europe in 2010, and 749,000 in the Reference scenario.
- In 2020, job numbers reach 1.2 million in the [R]evolution scenario and 854,000 in the Reference scenario.
- Job numbers reach nearly 1.3 million in 2030 in the [R]evolution scenario, compared to 940,000 in the Reference scenario.

Detailed results

There are more energy sector jobs in OECD Europe in the [R]evolution scenario at every stage. In 2010, the [R]evolution has about 140,000 additional jobs compared to the Reference scenario. By 2020, the [R]evolution scenario has 350,000 additional jobs. The gap between the two scenarios remains similar in 2030.

Figure 10 shows the change in job numbers under both scenarios for each technology between 2010 and 2020, and 2010 and 2030. New jobs in the [R]evolution scenario are dominated by wind, and there are significant losses in the coal sector in both scenarios.

It is assumed that by 2020 all manufacturing occurs within Europe, and that OECD Europe is a major exporter to other regions. In the [R]evolution scenario export jobs reach 5% of the energy supply jobs in 2020, and 7% by 2030. In the Reference scenario export jobs fall to 1% by 2020.

Figure 9 OECD Europe: jobs by technology and type in 2010, 2020, and 2030

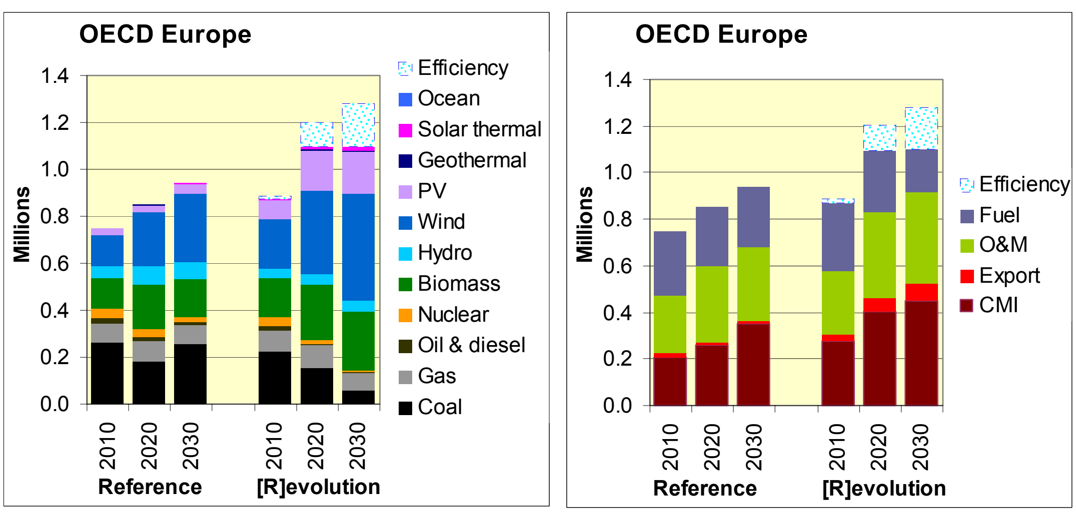


Figure 10 OECD Europe: employment change 2020 & 2030, compared to 2010

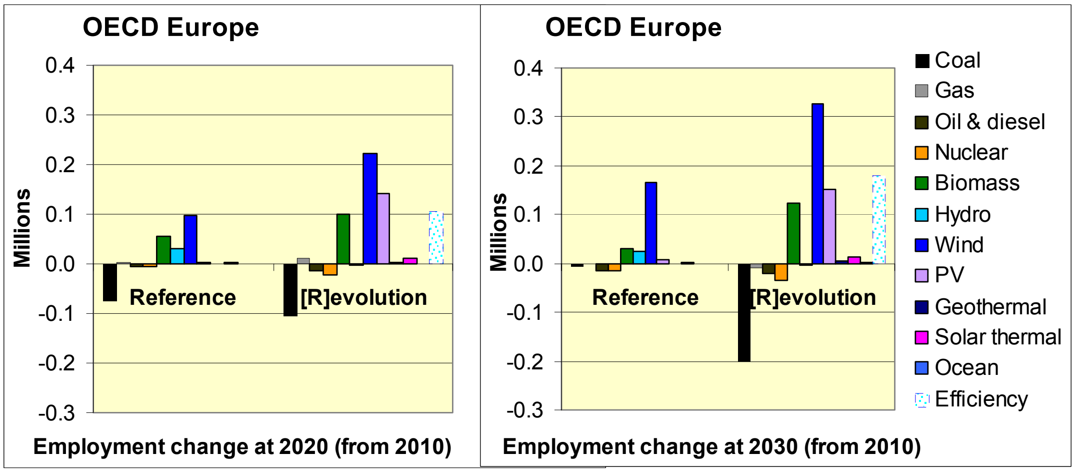


Table 43 OECD Europe: employment and electricity generation at 2010, 2020, and 2030

OECD Europe	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	2020	2030	2010	2020	2030
JOBS (thousands)						
Coal	260	184	255	221	154	58
Gas	83	86	82	92	95	73
Nuclear, oil, Diesel	64	51	34	61	27	10
Renewable	342	533	571	498	821	958
Energy supply jobs	**749**	**854**	**942**	**872**	**1,097**	**1,099**
Energy efficiency jobs	-	-	-	16	105	179
TOTAL JOBS	**749**	**854**	**942**	**888**	**1,202**	**1,278**
ELECTRICITY GENERATION TWh						
Coal	1,001	995	1,260	890	542	184
Gas	859	1,106	1,394	877	1,090	1,040
Nuclear, oil, diesel	1,071	893	631	1,044	471	175
Renewable	812	1,293	1,521	861	1,496	1,991
Total electricity generation (TWh)	**3,742 TWh**	**4,288 TWh**	**4,805 TWh**	**3,672 TWh**	**3,599 TWh**	**3,391 TWh**

Note: Base case energy efficiency jobs are not calculated, so the energy efficiency jobs shown are only those ***additional*** *to the reference scenario.*

5.4 Africa

Highlights

- There are 783,000 energy sector jobs in the [R]evolution scenario in Africa in 2010, compared to 767,000 in the reference scenario.
- Job growth is strong to 2020, and there are close to 1 million jobs in both scenarios by 2020. The [R]evolution has slightly higher growth, with 40,000 more jobs by 2020.
- Strong job growth is maintained in both scenarios to 2030, with projected jobs in the [R]evolution 1.5 million, compared to 1.4 million in the Reference scenario.

Detailed results

Figure 11 shows total jobs by technology in both scenarios at 2010, 2020, and 2030. Gas jobs grow very strongly in the Reference scenario, and while they also grow in the [R]evolution, it is less significant, particularly after 2020. Job numbers are almost the same in both scenarios, although the Revolution scenario always has slightly higher results.

Under the [R]evolution scenario electricity use is reduced by 9% in 2020 compared to the reference case, and by 16% by 2030. The Reference case has slightly higher employment in energy supply jobs in both 2020 and 2030, as may be expected with the generation so much greater, but this is outweighed by the increase in energy efficiency jobs.

Africa is an important gas exporter, with exports accounting for 40% of fuel supply jobs in 2010. This falls to 22% in the Reference scenario by 2030, reflecting the steep increase in domestic use of fuel. The proportion of exports remains higher in the [R]evolution scenario (33% at 2030).

Africa is assumed to largely remain a technology importer in these projections, importing 30% of renewable technology in 2020 and 50% in 2030. If 100% of manufacturing occurred locally in 2030 there would be an additional 86,000 jobs in the [R]evolution scenario by 2030, while the same change would only create an additional 16,000 jobs in the Reference scenario.

Figure 11 Africa: jobs by technology and type in 2010, 2020, and 2030

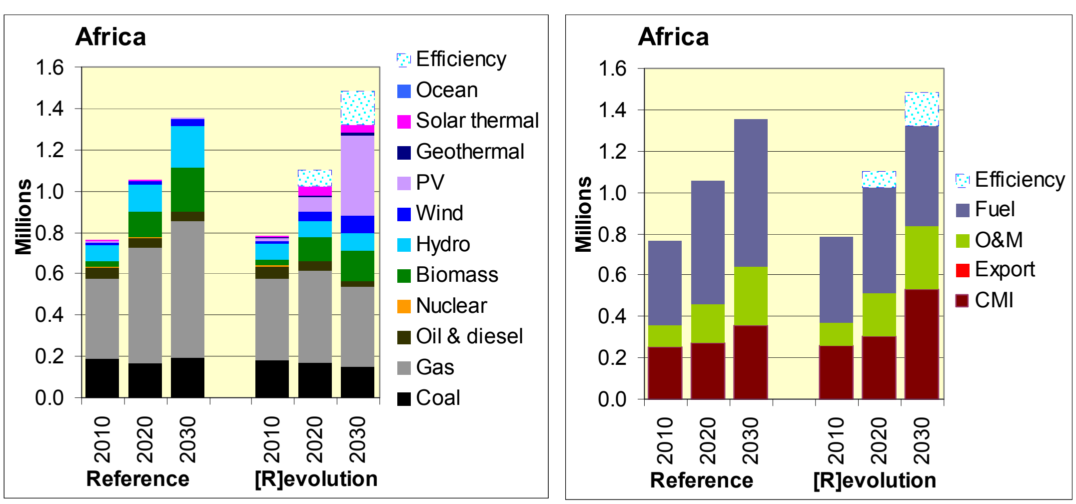


Figure 12 shows the change in job numbers under both scenarios for each technology between 2010 and 2020, and 2010 and 2030. Jobs in solar PV are very significant in the [R]evolution scenario by 2030.

Figure 12 Africa: employment change 2020 and 2030, compared to 2010

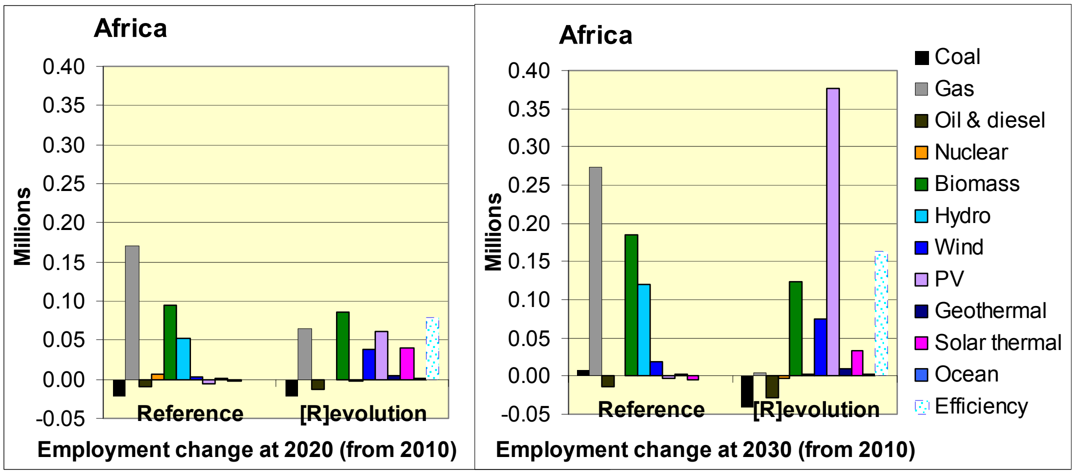


Table 44 Africa: employment and electricity generation at 2010, 2020, and 2030

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	**2020**	**2030**	**2010**	**2020**	**2030**
JOBS (thousands)						
Coal	189	167	196	184	167	148
Gas	386	556	660	396	451	391
Nuclear, oil, Diesel	59	56	47	59	44	27
Renewable	133	277	453	145	363	755
Energy supply jobs	**767**	**1,056**	**1,357**	**783**	**1,025**	**1,321**
Energy efficiency jobs	-	-	-		79	164
TOTAL JOBS	**767**	**1,056**	**1,357**	**783**	**1,104**	**1,485**

ELECTRICITY GENERATION TWh						
Coal	281	325	396	281	331	360
Gas	220	414	599	220	303	313
Nuclear, oil, diesel	65	61	56	65	49	22
Renewable	118	202	311	118	231	451
Total electricity generation (TWh)	**683 TWh**	**1,001 TWh**	**1,362 TWh**	**684 TWh**	**914 TWh**	**1,146 TWh**

Note: Base case energy efficiency jobs are not calculated, so the energy efficiency jobs shown are only those additional to the reference scenario.

5.5 *Middle East*

Highlights

- There are 422,000 electricity sector jobs in the [R]evolution scenario in the Middle East in 2010, and 427,000 in the Reference scenario.
- In 2020, jobs in the [R]evolution scenario are slightly higher, with 655,000 compared to 615,000 in the Reference case.
- Jobs in both scenarios grow strongly to 2030. The [R]evolution has 790,000 compared to 753,000 in the Reference scenario.

Figure 13 shows total jobs by technology in both scenarios at 2010, 2020, and 2030. Gas jobs grow very strongly in the Reference scenario, and while they also grow in the [R]evolution, it is less significant, particularly after 2020.

Growth in renewable jobs make up for the reduced growth in the gas sector in the [R]evolution scenario. Energy efficiency jobs are also important, resulting from the 19% reduction in electricity use compared to the Reference case in 2020.

The Middle East is a very important gas exporting region, with exports accounting for 30% of fuel jobs in both sectors in 2010. This increases to 40% of fuel supply jobs in the Reference scenario by 2030, and reaches 60% in the [R]evolution scenario.

Only 30% of renewable technology is assumed to be manufactured locally by 2030; securing these manufacturing jobs within the region would add another 85,000 jobs.

Figure 13 Middle East: jobs by technology and type in 2010, 2020, and 2030

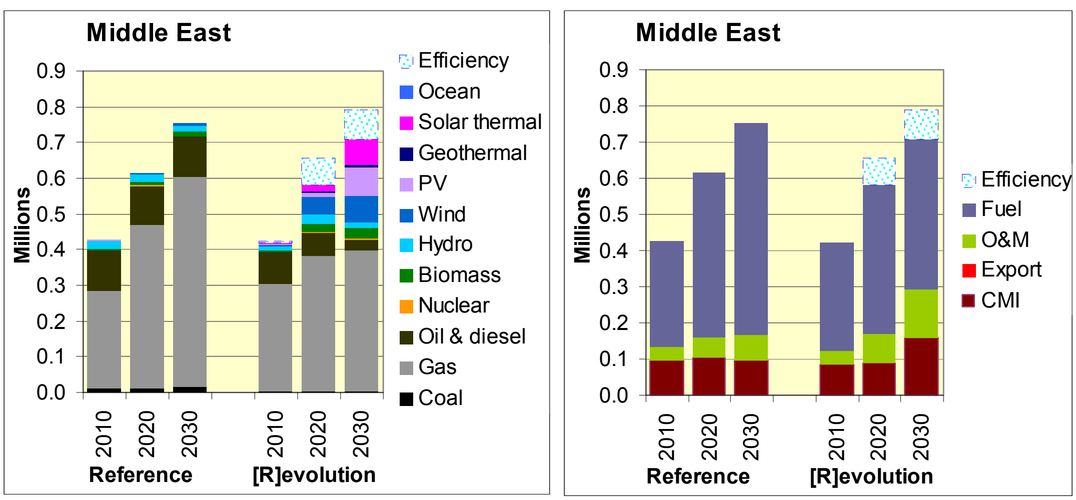


Figure 14 shows the change in job numbers under both scenarios for each technology between 2010 and 2020, and 2010 and 2030. The big difference between the scenarios is the jobs associated with gas generation, which grow very strongly in the Reference scenario, and fall in the [R]evolution. This is primarily because of the reduction in domestic gas generation as a result of improved energy efficiency in the [R]evolution scenario.

Figure 14 Middle East: employment change 2020 and 2030, compared to 2010

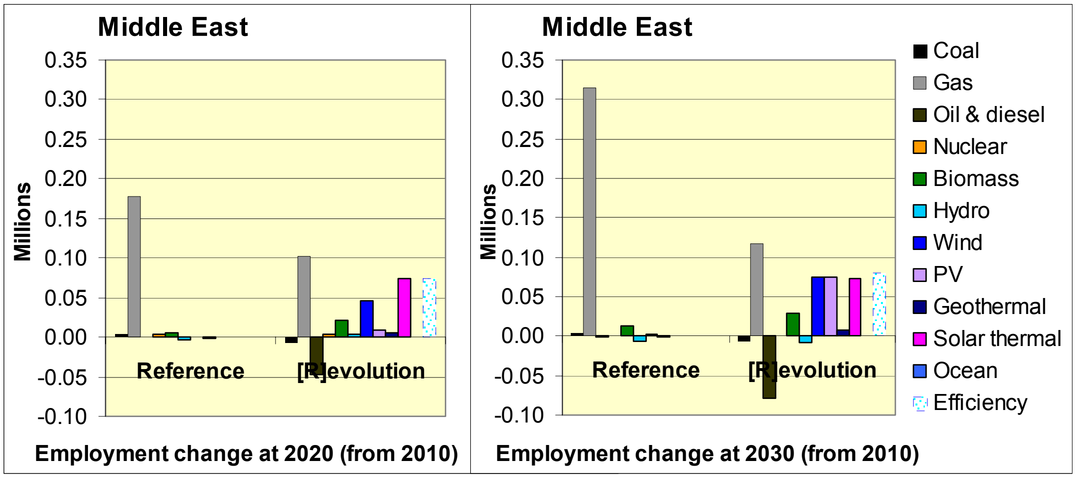


Table 45 Middle East: employment and electricity generation at 2010, 2020, and 2030

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	**2020**	**2030**	**2010**	**2020**	**2030**
JOBS (thousands)						
Coal	10	13	13	5	2	2
Gas	277	455	592	299	380	394
Nuclear, oil, Diesel	111	114	110	89	66	33
Renewable	30	32	37	27	132	279
Energy supply jobs	**427**	**615**	**753**	**421**	**581**	**709**
Energy efficiency jobs	-	-	-	2	74	81
TOTAL JOBS	**427**	**615**	**753**	**422**	**655**	**790**

ELECTRICITY GENERATION TWh						
Coal	42	63	82	38	26	16
Gas	448	726	1,033	470	535	503
Nuclear, oil, diesel	268	313	336	243	208	108
Renewable	32	51	71	31	164	598
Total electricity generation (TWh)	**789 TWh**	**1,154 TWh**	**1,522 TWh**	**781 TWh**	**933 TWh**	**1,225 TWh**

Note: Base case energy efficiency jobs are not calculated, so the energy efficiency jobs shown are only those additional to the reference scenario.

5.6 Transition Economies

Included in the Transition Economies are Albania, Armenia, Azerbaijan, Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, Estonia, Serbia and Montenegro, the former Republic of Macedonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Romania, Russia, Slovenia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan, Cyprus, and Malta.

Highlights

- There are 1 million energy sector jobs in the [R]evolution scenario in the Transition Economies in 2010, and 1.1 million in the Reference scenario.
- Jobs fall sharply in the Reference case after 2010, while growing in the [R]evolution scenario. By 2020, there are 1.1 million jobs in the [R]evolution scenario, 200,000 more than in the Reference scenario.
- Job numbers continue to fall in the Reference scenario between 2020 and 2030, and strong growth continues in the [R]evolution technologies. By 2030 there are 1.2 million jobs in the [R]evolution compared to 0.9 million in the Reference scenario.

Discussion

Figure 15 shows the overall job numbers by technology for 2010, 2020, and 2030. Strong growth in the [R]evolution scenario contrasts with continuing job losses in the Reference scenario.

It is assumed that only 30% of renewable energy manufacturing occurs within the region at 2010, increasing to 70% by 2030. However, the Transition economies (mainly Russia) export a high percentage of the inter-regionally traded gas, which results in high employment numbers in the Reference scenario, and significant numbers in the [R]evolution.

Figure 16 shows the change in job numbers under both scenarios for each technology between 2010 and 2020, and 2010 and 2030. The biggest changes are in coal employment, which drops sharply in both scenarios. In the [R]evolution scenario coal employment almost disappears, to be replaced by biomass as the largest employment sector.

Figure 15 Transition Economies: jobs by technology and type in 2010, 2020, and 2030

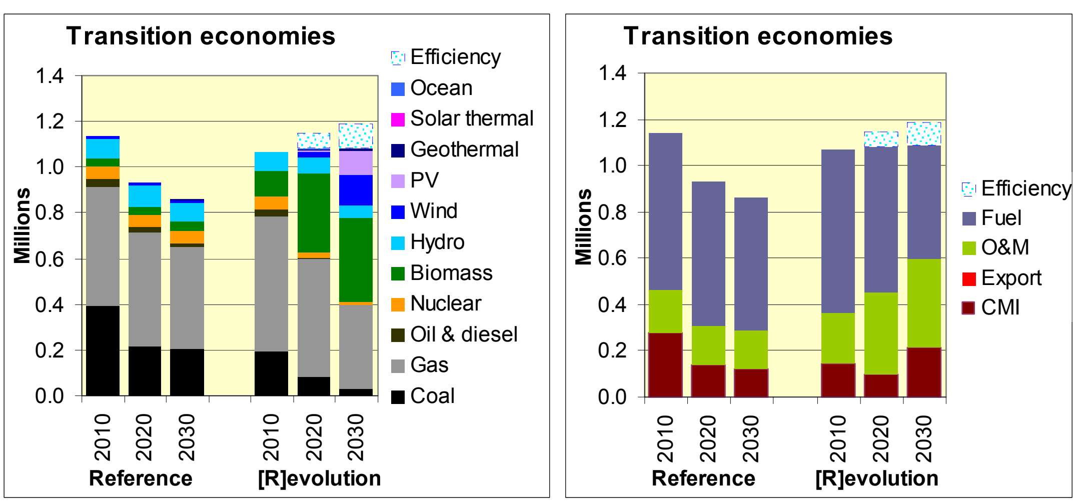


Figure 16 Transition Economies: employment change 2020 and 2030, compared to 2010

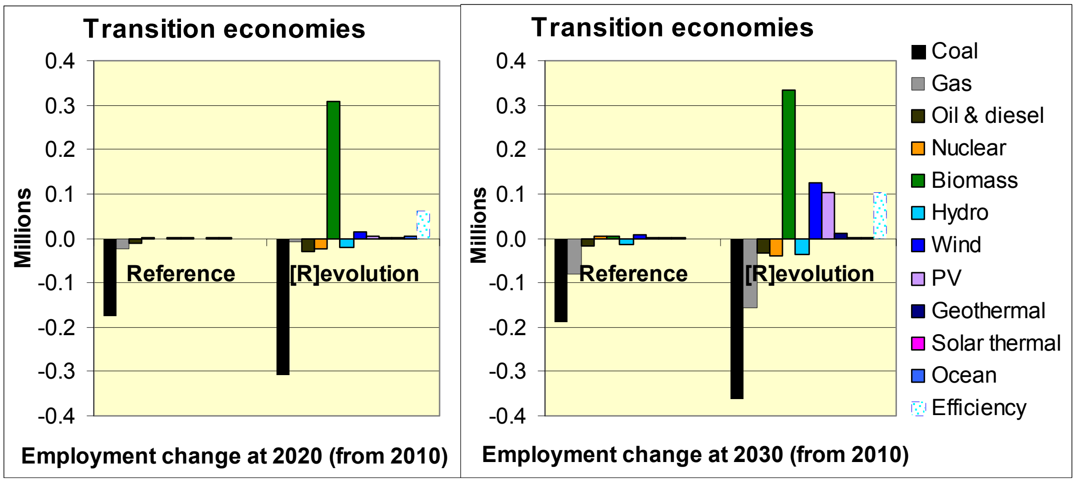


Table 46 Transition Economies: employment and electricity generation at 2010, 2020, and 2030

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	2020	2030	2010	2020	2030
JOBS (thousands)						
Coal	394	220	207	194	84	32
Gas	520	498	441	594	512	364
Nuclear, oil, Diesel	86	74	74	87	33	13
Renewable	138	142	137	193	455	676
Energy supply jobs	**1,138**	**934**	**860**	**1,068**	**1,083**	**1,086**
Energy efficiency jobs	-	-	-	0	63	102
TOTAL JOBS	**1,138**	**934**	**860**	**1,068**	**1,146**	**1,188**
ELECTRICITY GENERATION TWh						
Coal	439	488	532	324	210	100
Gas	662	834	946	758	852	761
Nuclear, oil, diesel	342	377	428	353	305	154
Renewable	346	425	491	354	556	933
Total electricity generation (TWh)	**1,789 TWh**	**2,123 TWh**	**2,397 TWh**	**1,788 TWh**	**1,923 TWh**	**1,948 TWh**

Note: Base case energy efficiency jobs are not calculated, so the energy efficiency jobs shown are only those ***additional*** *to the reference scenario.*

5.7 *India*

Highlights

- There are 862,000 energy sector jobs in the [R]evolution scenario in India in 2010, and 817,000 in the Reference scenario.
- In 2020, job numbers fall in the Reference scenario, but the [R]evolution scenario reaches 949,000.
- Job numbers in the [R]evolution scenario continue to grow, reaching 1 million by 2030, compared to 706,000 in the Reference scenario.

Discussion

Figure 17 shows the overall job numbers by technology for 2010, 2020, and 2030. Strong growth in the [R]evolution scenario contrasts with continuing job losses in the Reference scenario.

Under the [R]evolution scenario electricity use in India is reduced by 8% in 2020 compared to the reference case, and by 12% in 2030. This will require a program of retrofitting buildings, potentially creating large numbers of energy efficiency jobs.

It is assumed that all manufacturing occurs within the region by 2030, and that India exports nearly 25% of inter-regionally traded renewable energy components. Technology exports account for 5% of energy supply jobs by 2020.

The Reference scenario shows falling employment, mainly in coal associated jobs.

Figure 17 India: jobs by technology and type in 2010, 2020, and 2030

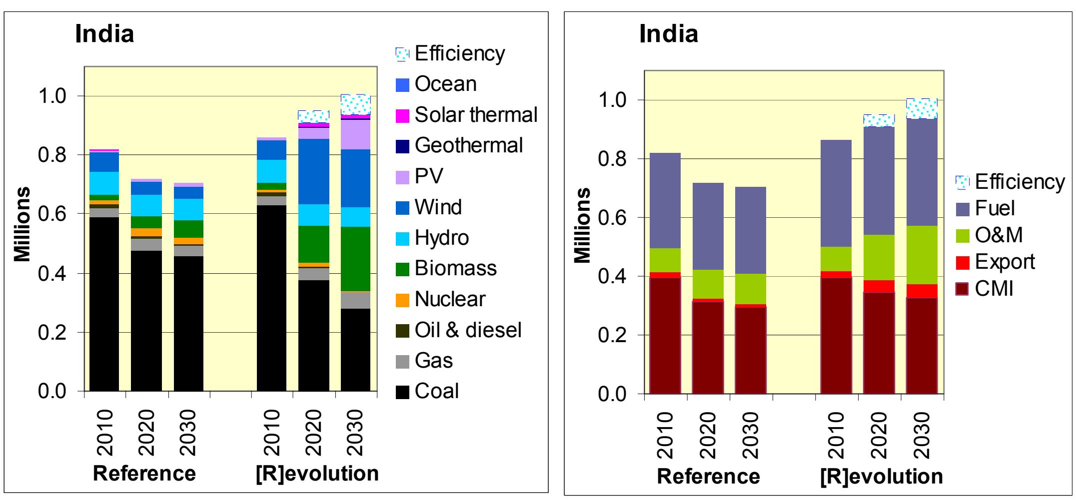


Figure 18 shows the change in job numbers under both scenarios for each technology between 2010 and 2020, and 2010 and 2030. There are losses in employment associated with coal generation in both scenarios, but in the [R]evolution scenario these are more than compensated for by gains in the renewable sector. Biomass and wind show particularly strong growth.

Figure 18 India: employment change 2020 and 2030, compared to 2010

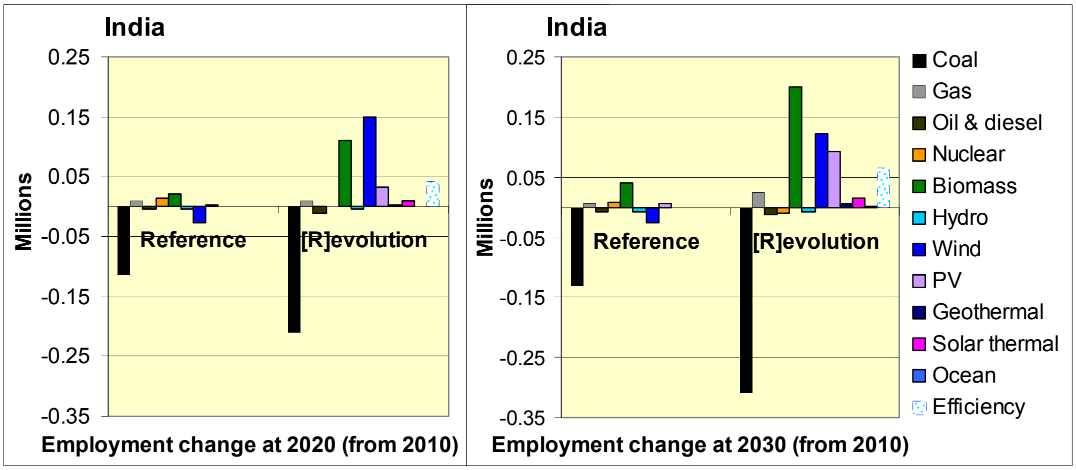


Table 47 India: employment and electricity generation at 2010, 2020, and 2030

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	2020	2030	2010	2020	2030
JOBS (thousands)						
Coal	588	474	457	628	377	280
Gas	31	42	37	31	40	55
Nuclear, oil, Diesel	27	36	27	27	16	3
Renewable	172	167	185	176	475	600
Energy supply jobs	**817**	**719**	**706**	**862**	**908**	**938**
Energy efficiency jobs	-	-	-		42	65
TOTAL JOBS	**817**	**719**	**706**	**862**	**949**	**1,003**
ELECTRICITY GENERATION TWh						
Coal	699	1,248	1,958	699	965	1,080
Gas	85	186	292	85	198	446
Nuclear, oil, diesel	57	116	159	57	65	46
Renewable	156	257	365	156	434	831
Total electricity generation (TWh)	**997 TWh**	**1,807 TWh**	**2,774 TWh**	**997 TWh**	**1,661 TWh**	**2,403 TWh**

*Note: Base case energy efficiency jobs are not calculated, so the energy efficiency jobs shown are only those **additional** to the reference scenario.*

5.8 Developing Asia

Highlights

- There are 861,000 jobs projected in the [R]evolution scenario in 2010, compared to 881,000 in the Reference scenario.
- In 2020, job numbers in both scenarios fall. There is somewhat better retention of jobs in the Reference scenario, with 799,000 compared to 741,000 in the [R]evolution scenario.
- By 2030 the job numbers in the [R]evolution scenario are increasing, and there are 754,000. Jobs in the Reference scenario continue to fall, reaching 738,000

Detailed results

Figure 19 shows the overall job numbers by technology for 2010, 2020, and 2030.

The Reference scenario has 50,000 more jobs in 2020. However, electricity use in the [R]evolution scenario is reduced by 11% in 2020 compared to the Reference case, and 17% by 2030. This will require a major energy efficiency program, potentially creating large numbers of additional construction and energy management jobs. By 2030, the jobs in energy efficiency mean that there are more jobs in the [R]evolution than the Reference scenario.

Figure 20 shows the change in job numbers under both scenarios for each technology between 2010 and 2020, and 2010 and 2030. Both scenarios show significant losses in coal sector employment, with 100,000 coal jobs lost by 2020 in the Reference scenario. While losses in the coal sector are greater in the [R]evolution scenario, strong growth in the renewable sectors, particularly wind power means there are slightly higher job numbers in the [R]evolution scenario by 2030.

Figure 19 Developing Asia: jobs by technology in 2010, 2020, and 2030

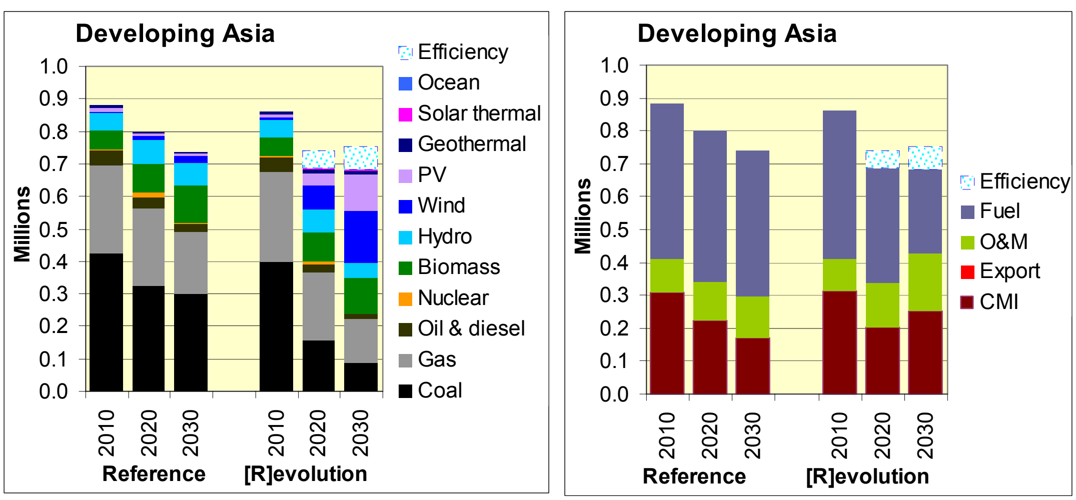


Figure 20 Developing Asia: employment change 2020 and 2030, compared to 2010

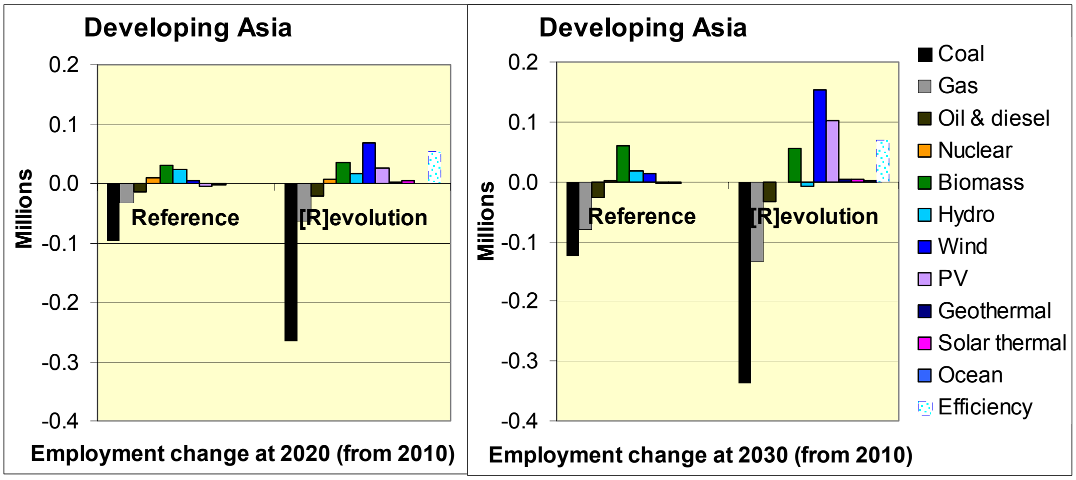


Table 48 Developing Asia: jobs and electricity generation 2010, 2020, and 2030

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	**2020**	**2030**	**2010**	**2020**	**2030**
JOBS (thousands)						
Coal	423	327	300	399	158	86
Gas	272	239	192	276	208	138
Nuclear, oil, Diesel	50	46	26	50	36	15
Renewable	135	188	220	135	286	445
Energy supply jobs	**881**	**799**	**738**	**861**	**688**	**684**
Energy efficiency jobs	-	-	-	0.2	53	70
TOTAL JOBS	**881**	**799**	**738**	**861**	**741**	**754**
ELECTRICITY GENERATION TWh						
Coal	390	595	820	389	425	342
Gas	456	644	786	456	545	570
Nuclear, oil, diesel	179	208	186	179	170	110
Renewable	184	311	442	184	420	823
Total electricity generation (TWh)	**1,210 TWh**	**1,758 TWh**	**2,234 TWh**	**1,209 TWh**	**1,560 TWh**	**1,845 TWh**

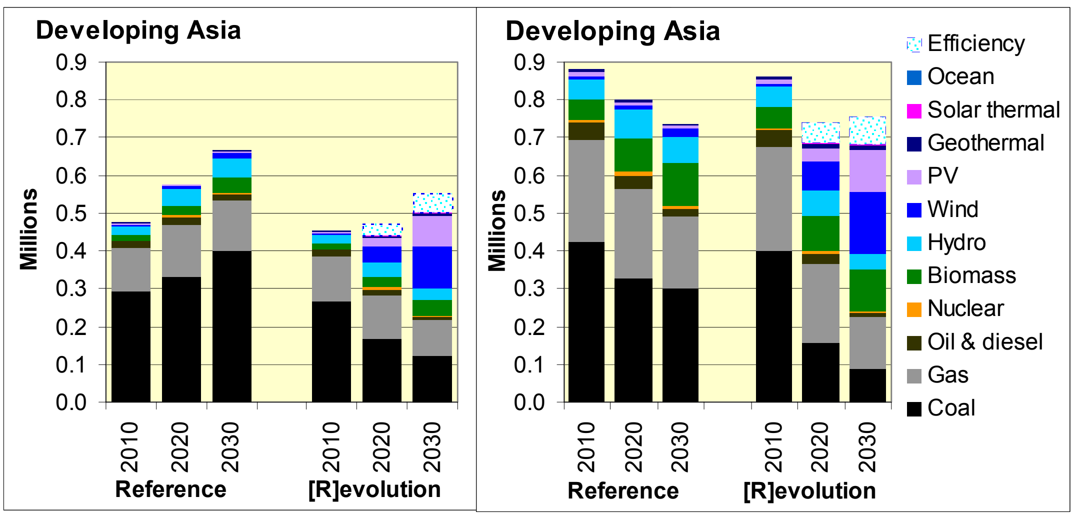
Note: Base case energy efficiency jobs are not calculated, so the energy efficiency jobs shown are only those additional to the reference scenario.

Developing Asia (mostly Indonesia) is a major coal exporter, and fuel exports account for nearly a quarter of the fuel supply jobs in 2020 (both scenarios). However, while coal exports jobs fall in the [R]evolution scenario, gas exports increase relative to the Reference scenario. Figure 20 shows the change in job numbers under both scenarios for each technology between 2010 and 2020, and 2010 and 2030.

Developing Asia is assumed to import 30% of renewable technology in 2030 (down from 70% in 2010). If domestic production reached 100% by 2030, jobs in the [R]evolution scenario reach 798,000 by 2030.

Energy sector job projections for Developing Asia are highest in 2010 in both scenarios, mainly because projections of economic growth are high in this region (IEA 2007). This has the effect that the job multiplier used to adjust employment projections from OECD factors gets much smaller over the study period. Figure 21 shows the effects if no job multiplier was used: in this case jobs would be projected to grow steadily over the study period in both scenarios; however job projections would be much lower overall.

Figure 21 Developing Asia: the effect of the job multiplier projections



5.9 China

Highlights

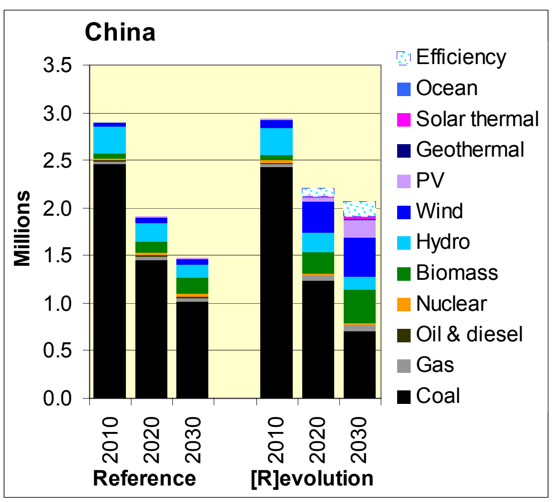
- There are close to 2.9 million energy jobs in China in both scenarios in 2010, with about 40,000 more in the [R]evolution scenario (note that these only include the electricity sector).[3]
- In 2020, job numbers in both scenarios fall relative to 2010, but the [R]evolution scenario keeps 2.2 million jobs compared to 1.9 million in the Reference scenario. The [R]evolution has 300,000 more jobs than the Reference scenario.
- In 2030 the [R]evolution retains just over 2 million jobs, while the Reference scenario job numbers fall to 1.5 million. The [R]evolution has 500,000 more jobs than the Reference scenario at 2030.

Detailed results

The most striking feature of the job projections for China is the decrease between 2010 and 2020. Job numbers fall from close to 2.9 million in both scenarios to just 1.9 million in the Reference scenario, and 2.1 million in the [R]evolution scenario.

There are more energy sector jobs in China in the [R]evolution scenario at every stage. In 2010, [R]evolution jobs are about 40,000 higher than the Reference scenario. By 2020, the [R]evolution scenario has 300,000 additional jobs, and by 2030 the [R]evolution scenario has about 570,000 more jobs than the Reference scenario.

Figure 22 China: jobs by technology and type in 2010, 2020, and 2030



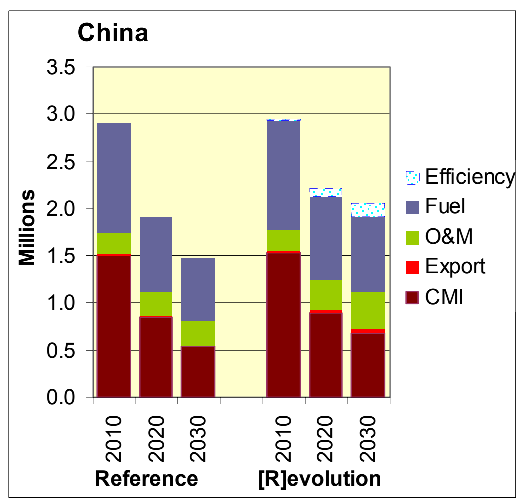
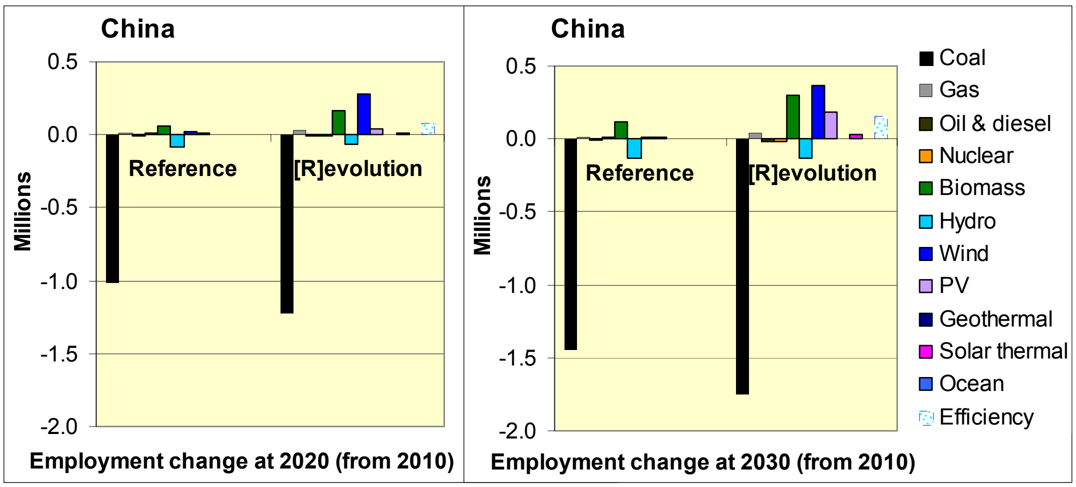


Figure 23 shows the change in job numbers under both scenarios for each technology between 2010 and 2020, and 2010 and 2030. While both scenarios show significant job losses, more jobs are retained in the [R]evolution scenario.

[3] Only coal for electricity generation and combined heat and power is included here, in order to use a consistent methodology. The China Year Book 2008 reports 3.6 million jobs in coal mining and 2.3 million in electricity generation; however, as a little more than half of Chinese coal production was used for non-electricity purposes, approximately 1.9 million of these are not included in this analysis.

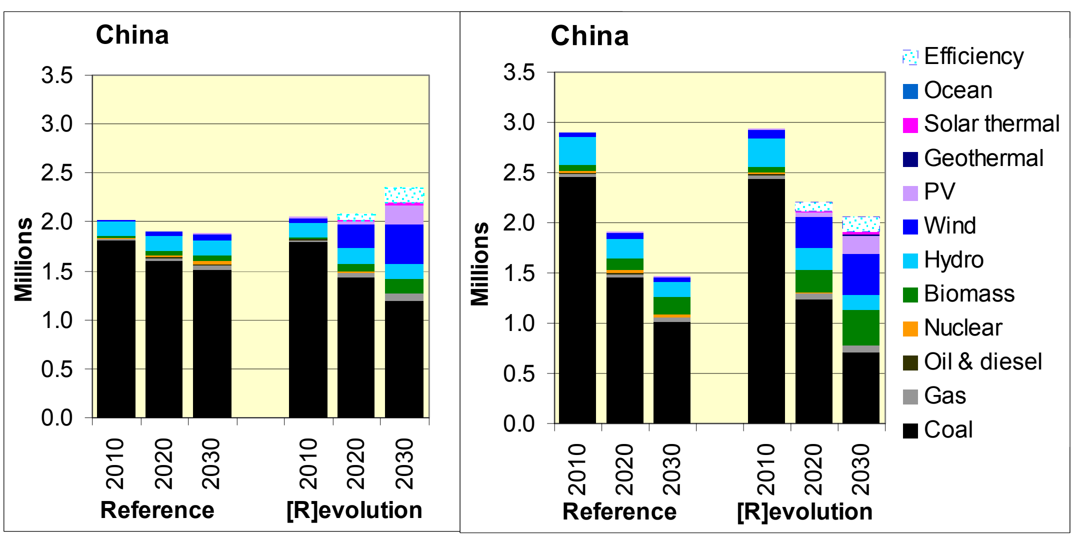
Coal sector jobs fall substantially between 2010 and 2020 in both scenarios. For example, in the Reference scenario jobs in the coal sector are 100,000 less at 2020 than 2010, continuing current trends world wide. In the [R]evolution scenario coal losses are greater, but only by about 20,000. In the [R]evolution, these losses are counteracted by strong growth in the renewable energy sectors, particularly wind energy, combined heat and power, and solar PV, with the effect that more jobs are retained in the [R]evolution scenario. In the Reference case, job growth in renewable energy is weak, so the job losses in the coal sector dominate.

Figure 23 China: employment change in 2020 and 2030, compared to 2010



The job losses projected between 2010 and 2020 are largely a result of the increased prosperity in China. This can be seen in Figure 24, which shows the projected employment for China, and what it would be if no job multiplier were used. Thus the modelled fall in employment results is a direct result of the projected growth in prosperity and labour productivity.

Figure 24 China: the effect of the job multiplier on employment projections



Specific data for China has been used in the coal sector, and it is possible that the change in productivity in coal production has been underestimated. This would lead to an even greater loss of jobs in the coal sector. However, both the increase in productivity and the scale of job losses is very much a matter of policy. As discussed in Section 3.4, it is Chinese government policy to close the small, employment intensive, village coal mines, which is likely to see a sharp reduction in coal sector jobs. It may also be government policy to transfer these jobs into, for example, energy efficiency, cogeneration, or renewable energy, so that the losses would be compensated for by jobs in these other sectors.

The job multiplier is the ratio of jobs creation per MW to job creation per MW in the OECD. The multiplier for China is 1.9 in 2010, and reduces to only 1.2 by 2020, and to 1 by 2030. This fall is a result of the projected 7% annual growth in GDP per capita, derived from IEA 2007[4]. It projected that China will have the same GDP per capita as the OECD average by 2030, with the effect that generating capacity which supported 1.8 jobs in 2010 will only support 1 by 2030.

Coal mining has been treated separately, as described in *Section 3.4 Employment factors for coal*.

Table 49 China: employment and electricity generation at 2010, 2020, and 2030

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	**2020**	**2030**	**2010**	**2020**	**2030**
JOBS (thousands)						
Coal	2,461	1,449	1,017	2,438	1,232	709
Gas	27	42	42	28	59	66
Nuclear, oil, Diesel	34	43	33	31	20	5
Renewable	378	379	382	442	811	1,128
Energy supply jobs	**2,899**	**1,912**	**1,474**	**2,940**	**2,123**	**1,909**
Energy efficiency jobs	-	-	-	2	80	151
TOTAL JOBS	**2,899**	**1,912**	**1,474**	**2,942**	**2,204**	**2,059**
ELECTRICITY GENERATION TWh						
Coal	3,179	5,050	6,586	3,150	4,238	4,105
Gas	62	170	313	62	220	420
Nuclear, oil, diesel	130	222	305	126	148	88
Renewable	587	946	1,268	611	1,378	2,645
Total electricity generation (TWh)	**3,957 TWh**	**6,388 TWh**	**8,472 TWh**	**3,948 TWh**	**5,983 TWh**	**7,258 TWh**

*Note: Base case energy efficiency jobs are not calculated, so the energy efficiency jobs shown are only those **additional** to the reference scenario.*

[4] The job multiplier is calculated from labour productivity across the non-agricultural economy, and the change in labour productivity is assumed to mirror the change in GDP per capita.

5.10 OECD Pacific

Highlights

- There are 240,000 energy sector jobs in the [R]evolution scenario in the OECD Pacific region in 2010, and 214,000 in the Reference scenario.
- In 2020, job numbers reach 310,000 in the [R]evolution scenario, 80,000 more than in the Reference scenario.
- Energy supply job numbers fall slightly in the [R]evolution scenario at 2030, but growth in energy efficiency means that are there are 324,000 jobs in the [R]evolution scenario by 2030, nearly 90,000 more than in the Reference scenario.

Discussion

There are more energy sector jobs projected for the OECD Pacific region in the [R]evolution scenario at every stage. Figure 25 shows the job totals by technology for both scenarios at each year.

Under the [R]evolution scenario electricity use in OECD Pacific region is reduced by 12% in 2020 compared to the Reference case. This will require a major program of retrofitting buildings, improving industrial and service efficiency. Jobs in energy efficiency maintain the growth in jobs when energy supply jobs remain level.

Figure 26 shows the change in job numbers under both scenarios for each technology between 2010 and 2020, and 2010 and 2030. The greatest losses occur in jobs associated with coal generation in the [R]evolution scenario, but extremely strong growth in all renewable sectors lead to a substantial net gain in job numbers.

It is assumed that by 30% of renewable energy manufacturing occurs within the region at 2020, and this increases to 50% by 2030

Figure 25 OECD Pacific: jobs by technology and type in 2010, 2020, and 2030

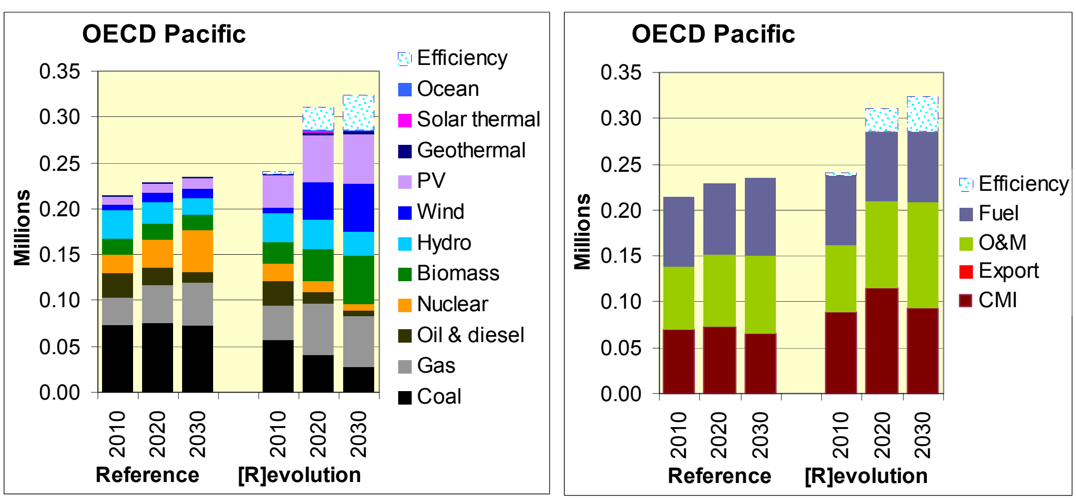


Figure 26 OECD Pacific: employment change 2020 and 2030, compared to 2010

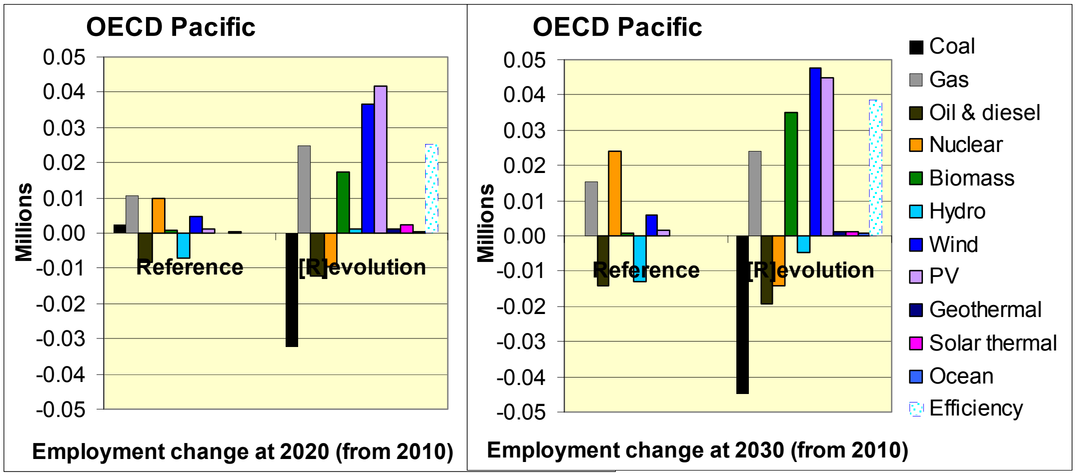


Table 50 OECD Pacific: employment and electricity generation at 2010, 2020, and 2030

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	2020	2030	2010	2020	2030
JOBS (thousands)						
Coal	73	76	73	56	41	28
Gas	30	41	46	39	55	54
Nuclear, oil, Diesel	47	49	57	45	26	14
Renewable	63	64	58	98	164	189
Energy supply jobs	**214**	**229**	**235**	**238**	**285**	**286**
Energy efficiency jobs	-	-	-	2	25	39
TOTAL JOBS	**214**	**229**	**235**	**240**	**310**	**324**
ELECTRICITY GENERATION TWh						
Coal	684	808	857	652	629	533
Gas	415	501	557	454	631	687
Nuclear, oil, diesel	632	669	723	600	375	210
Renewable	180	233	265	196	411	665
Total electricity generation (TWh)	**1,911 TWh**	**2,210 TWh**	**2,402 TWh**	**1,902 TWh**	**2,045 TWh**	**2,096 TWh**

*Note: Base case energy efficiency jobs are not calculated, so the energy efficiency jobs shown are only those **additional** to the reference scenario.*

6 Case studies – the G8 countries and the EU27

6.1 The G8 summary

Highlights

- There are 1.5 million energy sector jobs in the G8 countries in the [R]evolution scenario in 2010, compared to 1.4 million in the Reference scenarios.
- In 2020, job numbers grow in the [R]evolution scenario, while job growth in the Reference scenario is flat. The [R]evolution scenario reaches 2 million and the Reference scenario remains near 1.4 million.
- Job numbers in the [R]evolution scenario continue to grow strongly, reaching 2.4 million jobs by 2030, nearly 900,000 more than in the Reference scenario.

Discussion

There are more energy sector jobs in the G8 as a whole in the [R]evolution scenario at every stage. In 2010, the [R]evolution has about 130,000 additional jobs compared to the Reference scenario, 600,000 more in 2020, and 900,000 more by 2030.

Figure 27 shows total projected jobs in the energy sector, broken down by technology and type. Employment under the [R]evolution scenario grows very strongly to 2030, while employment in the Reference scenario is almost stagnant.

Figure 28 shows the change in job numbers under both scenarios for each technology between 2010 and 2020, and 2010 and 2030. The greatest losses occur in jobs associated with coal generation in the [R]evolution scenario, but extremely strong growth in all renewable sectors lead to a substantial net gain in job numbers.

Figure 27 G8 countries: jobs by technology and type in 2010, 2020, and 2030

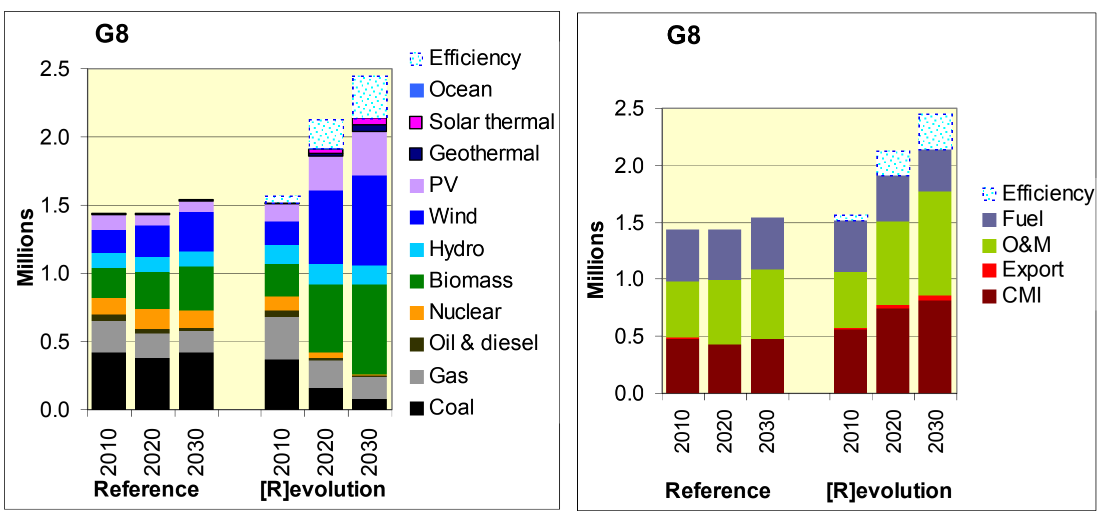


Figure 28 The G8 countries: employment change 2020 and 2030, compared to 2010

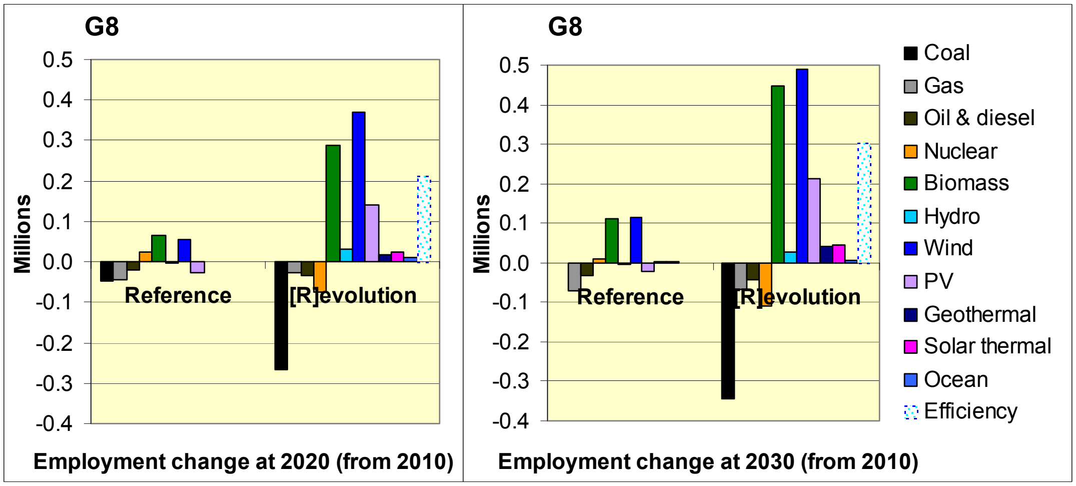


Table 51 The G8 countries: employment and electricity generation at 2010, 2020, and 2030

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	2020	2030	2010	2020	2030
JOBS (millions)						
Coal	0.42 m	0.38 m	0.42 m	0.37 m	0.16 m	0.08 m
Gas	0.23 m	0.18 m	0.16 m	0.31 m	0.20 m	0.16 m
Nuclear, oil and diesel	0.17 m	0.18 m	0.15 m	0.15 m	0.07 m	0.02 m
Renewable	0.61 m	0.70 m	0.82 m	0.70 m	1.49 m	1.88 m
Energy supply jobs	**1.44 m**	**1.44 m**	**1.54 m**	**1.52 m**	**1.92 m**	**2.14 m**
Energy efficiency jobs	0.00 m	0.00 m	0.00 m	0.05 m	0.21 m	0.30 m
TOTAL JOBS	**1.44 m**	**1.44 m**	**1.54 m**	**1.57 m**	**2.13 m**	**2.45 m**

ELECTRICITY GENERATION TWh						
Coal	3,439	3,810	4,316	3,209	2,160	1,296
Gas	2,170	2,471	2,674	2,505	3,027	3,062
Nuclear, oil, diesel	2,431	2,442	2,415	2,026	1,161	330
Renewable	1,446	1,954	2,372	1,533	3,111	4,944
Total electricity generation (TWh)	**9,486 TWh**	**10,677 TWh**	**11,777 TWh**	**9,274 TWh**	**9,459 TWh**	**9,632 TWh**

*Note: Base case energy efficiency jobs are not calculated, so the energy efficiency jobs shown are only those **additional** to the reference scenario.*

6.2 Canada

Highlights

- There are 72,000 energy sector jobs in the Canada in the [R]evolution scenario in 2010, compared to 62,500 in the Reference scenarios.
- In 2020, job numbers grow in both scenarios, although much more strongly in the [R]evolution scenario. The [R]evolution reaches 89,200 and the Reference scenario 68,300.
- Job numbers fall slightly to 88,800 jobs in the [R]evolution scenario by 2030, and fall sharply in to 60,000 jobs in the Reference scenario.

Discussion

There are more energy sector jobs in the Canada in the [R]evolution scenario at every stage. In 2010, the [R]evolution has about 10,000 additional jobs compared to the Reference scenario, with 21,000 more in 2020, and 29,000 more by 2030.

Figure 29 shows total projected jobs in the energy sector, broken down by technology. Employment under the [R]evolution scenario grows very strongly to 2030, while employment in the Reference scenario rises at 2020, but then drops sharply to only 60,000 in 2030.

Figure 28 shows the change in job numbers under both scenarios for each technology between 2010 and 2020, and 2010 and 2030. The greatest loss is a reduction of 8,000 gas associated jobs in both scenarios by 2020.

Strong growth in all renewable sectors and energy efficiency in the [R]evolution scenario leads to a substantial net gain in job numbers despite the losses in gas jobs, while the Reference scenario sees overall net losses of about 250,000 jobs.

Figure 29 Canada: jobs by technology and type in 2010, 2020, and 2030

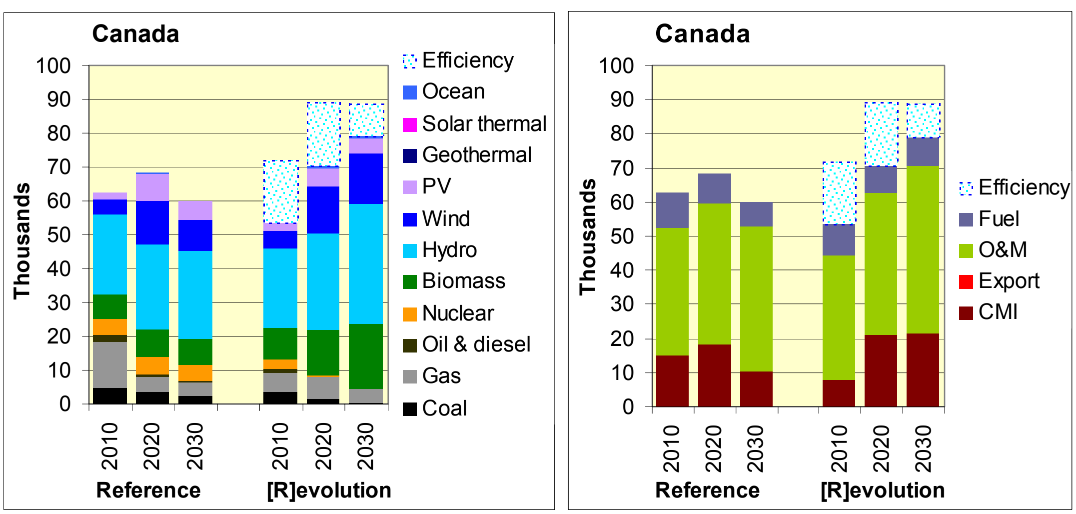


Figure 30 Canada: employment change 2020 and 2030, compared to 2010

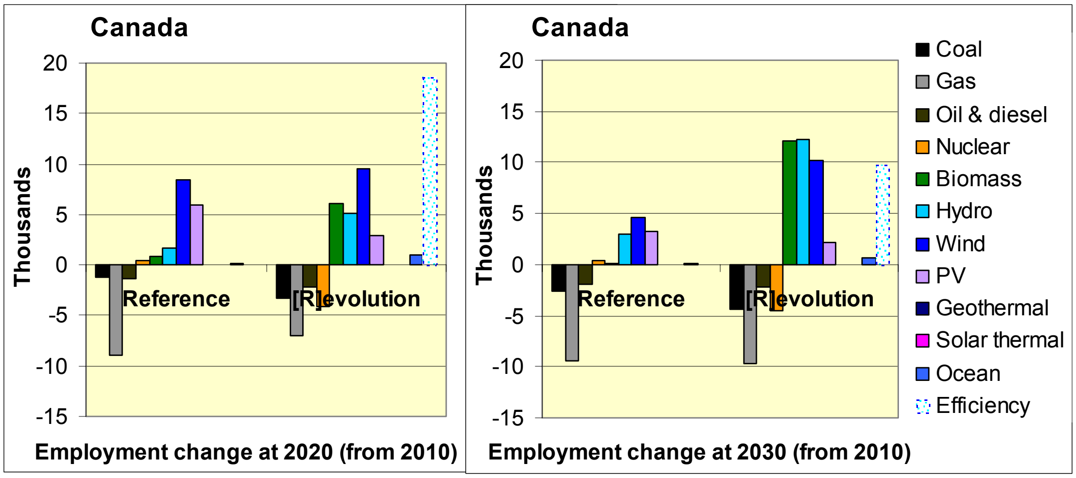


Table 52 Canada: employment and electricity generation at 2010, 2020, and 2030

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	**2020**	**2030**	**2010**	**2020**	**2030**
JOBS (thousands)						
Coal	4.8	3.6	2.3	3.5	1.5	0.5
Gas	13.5	4.5	4.0	5.7	6.5	3.8
Nuclear, oil & diesel	6.8	5.8	5.3	4.1	0.5	0.0
Renewable	37.4	54.4	48.3	40.4	62.1	74.7
Energy supply jobs	**62.5**	**68.3**	**60.0**	**53.6**	**70.5**	**79.1**
Energy efficiency jobs	-	-	-	18.3	18.7	9.7
TOTAL JOBS	**62.5**	**68.3**	**60.0**	**72.0**	**89.2**	**88.8**

ELECTRICITY GENERATION TWh						
Coal	105	72	32	75	34	13
Gas	63	47	43	41	48	34
Nuclear, oil, diesel	114	108	104	83	12	0
Renewable	381	406	416	383	427	478
Total electricity generation (TWh)	**662 TWh**	**634 TWh**	**595 TWh**	**581 TWh**	**521 TWh**	**525 TWh**

6.3 France

Highlights

- There are 62,000 energy sector jobs in France in the [R]evolution scenario in 2010, compared to 48,000 in the Reference scenarios.
- In 2020, job numbers grow in both scenarios, although more strongly in the [R]evolution scenario. The [R]evolution reaches 92,000 and the Reference scenario 62,000.
- Job numbers fall slightly in the Reference scenario by 2030, to 57,000. In the [R]evolution scenario, jobs grow slightly to reach 92,500.

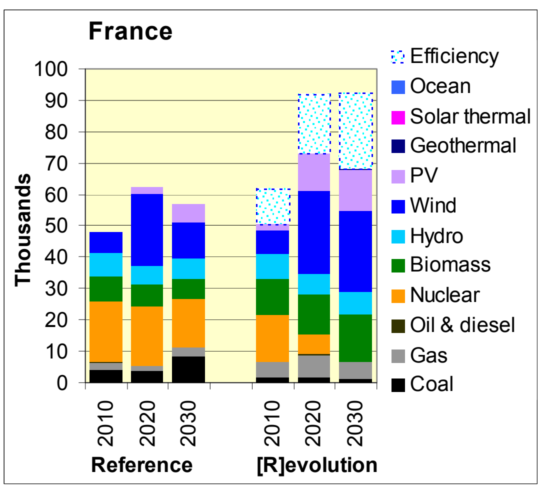
Discussion

There are more energy sector jobs in France in the [R]evolution scenario at every stage. In 2010, the [R]evolution has about 14,000 additional jobs compared to the Reference scenario, with 30,000 more in 2020, and 36,000 more by 2030.

Figure 31 shows total projected jobs in the energy sector, broken down by technology. Employment under the [R]evolution scenario grows very strongly to 2020, while employment in the Reference scenario rises at 2020, but then drops to only 57,000 in 2030.

Energy efficiency plays a large part in creating jobs, as can be seen. France's electricity consumption is reduced by 19% in 2020, and 29% by 2030, relative to the energy generated in the Reference scenario.

Figure 31 France: jobs by technology and type in 2010, 2020, and 2030



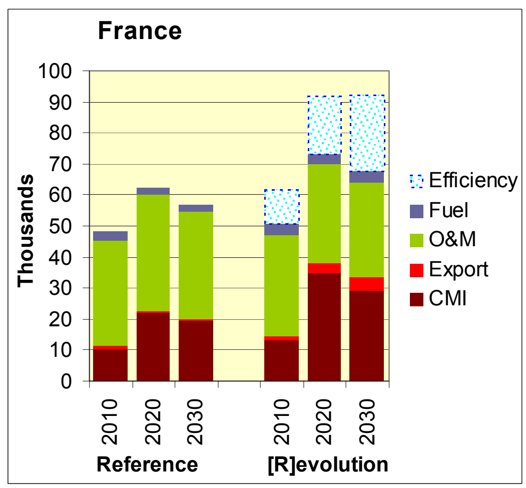


Figure 32 shows the change in job numbers under both scenarios for each technology between 2010 and 2020, and 2010 and 2030. The greatest losses occur in jobs associated with nuclear energy, with significant losses in both scenarios. These jobs are reduced by 12,000 in the Reference and by 18,000 in the [R]evolution scenario.

Strong growth in all renewable sectors and energy efficiency lead to a substantial net gain in jobs in the [R]evolution scenario, of about 30,000. The Reference scenario has a net job gain of about 8,000.

Figure 32 France: employment change 2020 and 2030, compared to 2010

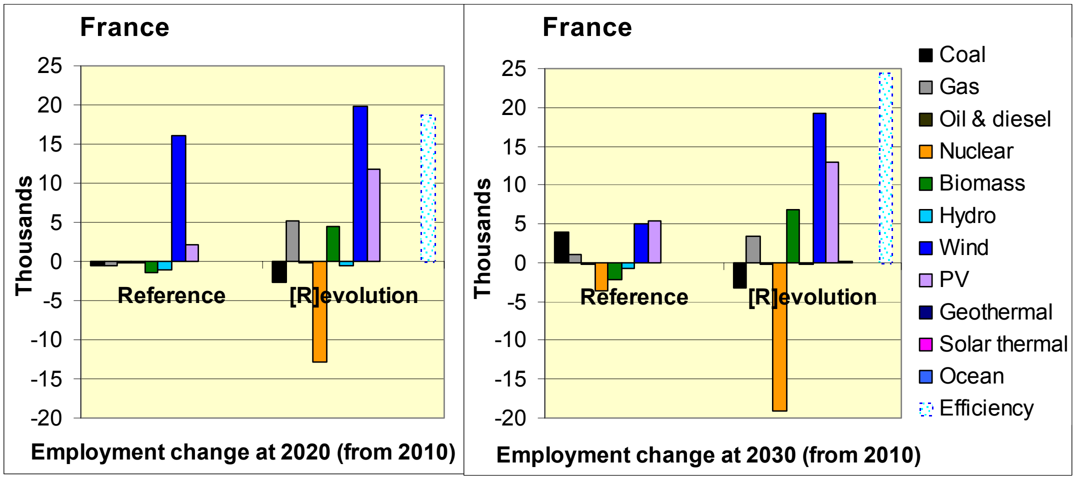


Table 53 France: employment and electricity generation at 2010, 2020, and 2030

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	2020	2030	2010	2020	2030
JOBS (thousands)						
Coal	4.3	3.9	8.3	1.7	1.6	1.1
Gas	2.1	1.5	3.1	4.8	7.3	5.4
Nuclear, oil & diesel	19.5	19.0	15.5	15.0	6.4	0.0
Renewable	22.4	38.1	29.9	29.2	57.9	61.4
Energy supply jobs	**48.3**	**62.4**	**56.8**	**50.8**	**73.3**	**68.0**
Energy efficiency jobs	-	-	-	11.1	18.8	24.5
TOTAL JOBS	**48.3**	**62.4**	**56.8**	**61.9**	**92.1**	**92.5**
ELECTRICITY GENERATION TWh						
Coal	30	38	61	25	23	18
Gas	53	72	120	107	234	309
Nuclear, oil, diesel	454	453	409	350	153	0
Renewable	90	125	135	98	145	189
Total electricity generation (TWh)	**628 TWh**	**688 TWh**	**724 TWh**	**578 TWh**	**555 TWh**	**517 TWh**

*Note: Base case energy efficiency jobs are not calculated, so the energy efficiency jobs shown are only those **additional** to the reference scenario.*

6.4 Germany

Highlights

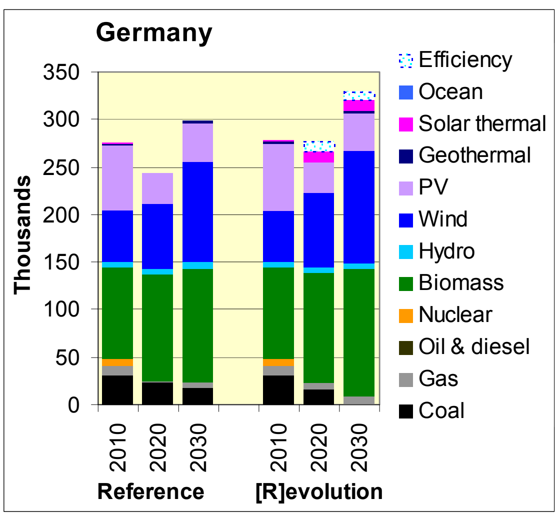
- There are 278,000 energy sector jobs in Germany in the [R]evolution scenario in 2010, compared to 275,000 in the Reference scenarios.
- In 2020, job numbers fall in both scenarios, although more jobs are preserved in the [R]evolution scenario. The [R]evolution jobs fall to 277,000 and the Reference scenario to 244,000.
- Job numbers reach 330,000 in the [R]evolution by 2030, and 299,000 in the Reference scenario.

Discussion

Figure 33 shows total projected jobs in the energy sector, broken down by technology. Employment under the both scenarios drops between 2010 and 2020, but then grows again to 2030.

The drop in employment at 2020 is mainly a result of the variation in the annual increment in capacity in 2020 relative to both 2010 and 2030. The combined annual increment in renewable capacity is 5.1 GW in 2010, drops to 4.3 GW in 2020, and then rises to 7.6 GW in 2030.

Figure 33 Germany: jobs by technology and type in 2010, 2020, and 2030



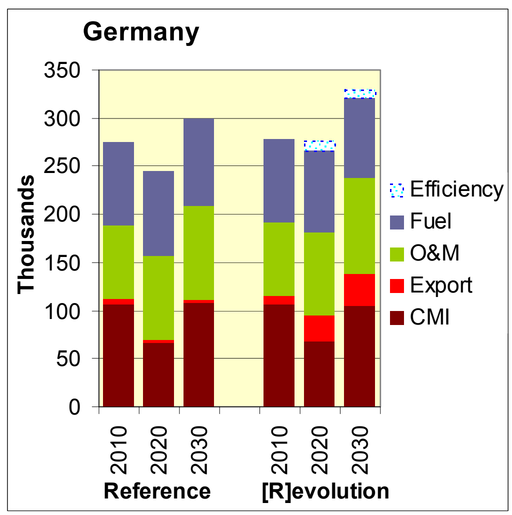


Figure 34 Germany: employment change 2020 and 2030, compared to 2010

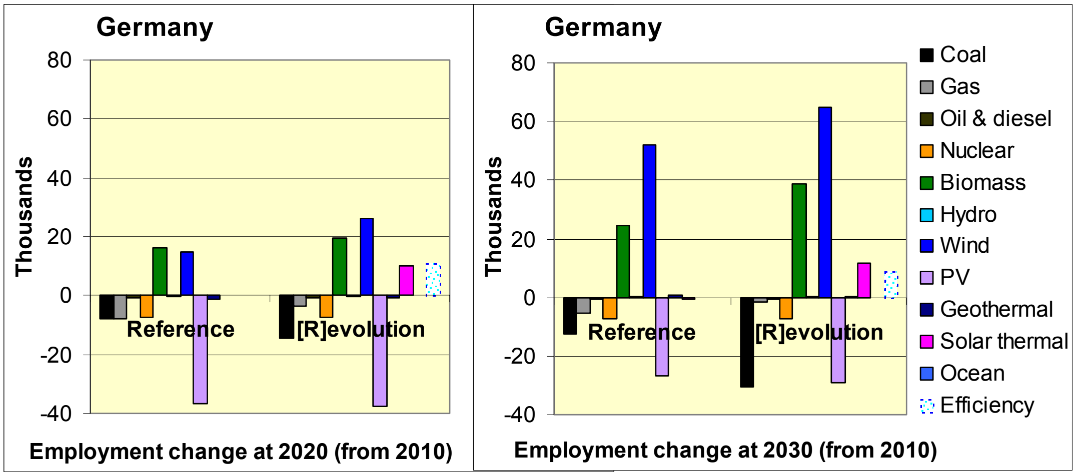


Table Germany: employment and electricity generation at 2010, 2020, and 2030

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	2020	2030	2010	2020	2030
JOBS (thousands)						
Coal	31	23	18	31	16	-
Gas	10	2	5	10	7	8
Nuclear, oil & diesel	8	0	-	8	-	-
Renewable	226	219	277	230	243	313
Energy supply jobs	**275**	**244**	**299**	**278**	**266**	**321**
Energy efficiency jobs	-	-	-	-	11	9
TOTAL JOBS	**275**	**244**	**299**	**278**	**277**	**330**

ELECTRICITY GENERATION TWh						
Coal	250	195	122	250	120	0
Gas	155	133	140	155	174	190
Nuclear, oil, diesel	110	30	0	110	0	0
Renewable	120	199	283	120	204	299
Total electricity generation (TWh)	**635 TWh**	**557 TWh**	**546 TWh**	**635 TWh**	**497 TWh**	**488 TWh**

Note: Base case energy efficiency jobs are not calculated, so the energy efficiency jobs shown are only those ***additional*** *to the reference scenario.*

6.5 Japan

Highlights

- There are 171,000 energy sector jobs in Japan in the [R]evolution scenario in 2010, compared to 140,000 in the Reference scenarios.
- In 2020, the [R]evolution scenario shows strong job growth, reaching 214,000. The Reference scenario jobs fall slightly, to 136,000.
- Job numbers reach 247,000 in the [R]evolution by 2030, compared to 145,000 in the Reference scenario.

Discussion

Figure 35 shows total projected jobs in the energy sector, broken down by technology.

Employment in the Reference scenario remains almost the same over the study period, varying only from 136,000 to 147,000.

Employment in the [R]evolution scenario show very strong growth, reaching 214,000 by 2020 and 247,000 by 2030, 100,000 more than in the Reference scenario.

Figure 35 Japan: jobs by technology and type in 2010, 2020, and 2030

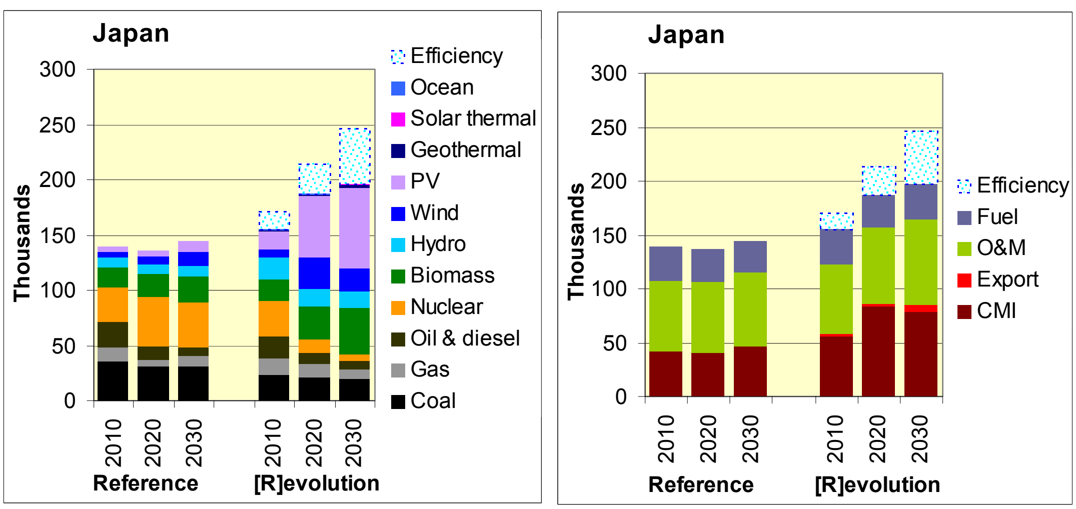


Figure 36 Japan: employment change 2020 and 2030, compared to 2010

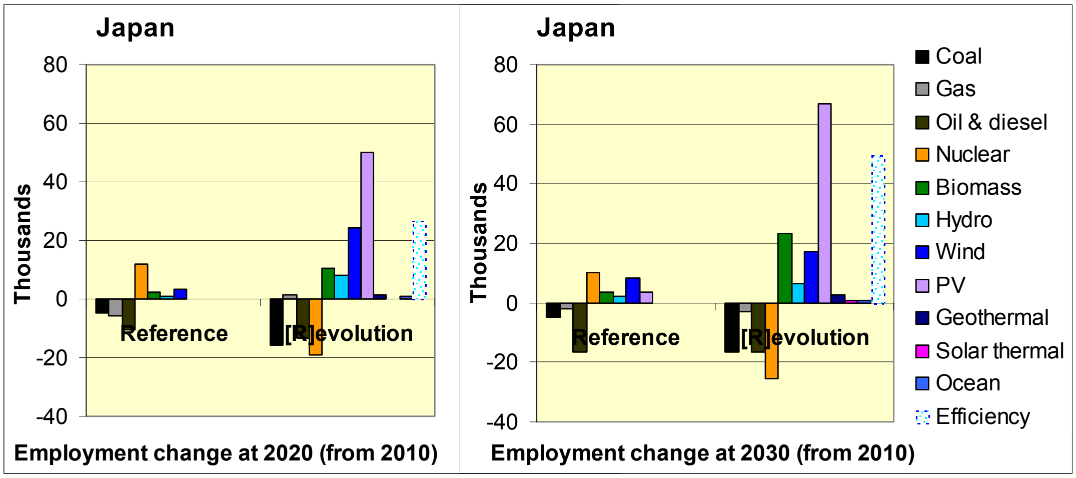


Table 54 Japan: employment and electricity generation at 2010, 2020, and 2030

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	2020	2030	2010	2020	2030
JOBS (thousands)						
Coal	36	31	31	23	20	20
Gas	12	6	9	15	13	9
Nuclear, oil & diesel	55	56	49	52	22	13
Renewable	37	43	55	65	132	155
Energy supply jobs	**140**	**136**	**145**	**155**	**188**	**197**
Energy efficiency jobs	-	-	-	16	26	50
TOTAL JOBS	**140**	**136**	**145**	**171**	**214**	**247**
ELECTRICITY GENERATION TWh						
Coal	288	312	349	187	167	151
Gas	308	323	375	321	398	413
Nuclear, oil, diesel	475	521	552	475	341	181
Renewable	113	132	155	131	233	347
Total electricity generation (TWh)	**1,185 TWh**	**1,288 TWh**	**1,430 TWh**	**1,114 TWh**	**1,138 TWh**	**1,092 TWh**

Note: Base case energy efficiency jobs are not calculated, so the energy efficiency jobs shown are only those ***additional*** *to the reference scenario.*

6.6 Italy

Highlights

- There are 61,000 energy sector jobs in Italy in the [R]evolution scenario in 2010, compared to 57,000 in the Reference scenarios.
- In 2020, the [R]evolution scenario shows strong job growth, reaching 88,000. The Reference scenario jobs reach 72,000.
- Job numbers reach 102,000 in the [R]evolution by 2030, and 56,000 in the Reference scenario.

Discussion

Figure 37 shows total projected jobs in the energy sector, broken down by technology. Employment in the Reference scenario grows to 2020, but then falls sharply to below the 2010 level between 2020 and 2030.

Employment in the [R]evolution scenario shows very strong growth, reaching 88,000 by 2020, and 102,000 by 2030. At 2030 there are 46,000 more jobs in the [R]evolution scenario compared to the Reference.

Figure 37 Italy: jobs by technology and type in 2010, 2020, and 2030

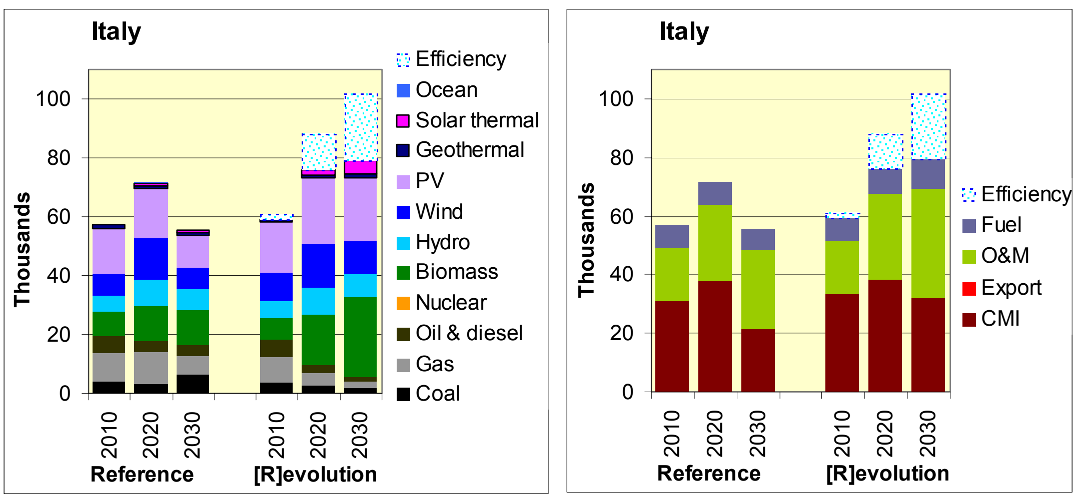


Figure 38 Italy: employment change 2020 and 2030, compared to 2010

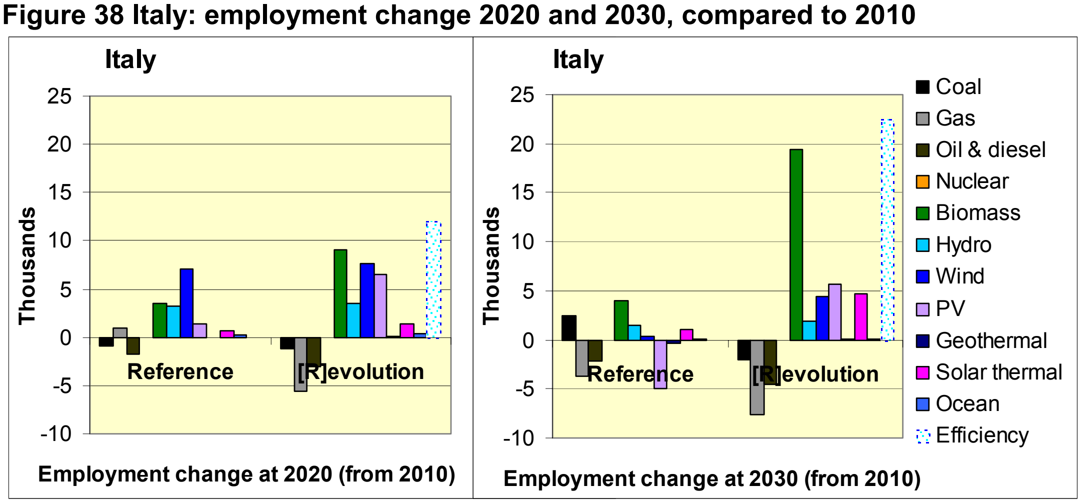


Table 55 Italy: employment and electricity generation at 2010, 2020, and 2030

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	2020	2030	2010	2020	2030
JOBS (thousands)						
Coal	3.9	3.0	6.4	3.8	2.7	1.8
Gas	9.8	10.8	6.1	8.5	4.3	2.2
Nuclear, oil & diesel	5.7	4.0	3.6	5.8	2.7	1.3
Renewable	38	54	40	41	66	74
Energy supply jobs	**57**	**72**	**56**	**59**	**76**	**79**
Energy efficiency jobs	-	-	-	1.7	12	22
TOTAL JOBS	**57**	**72**	**56**	**61**	**88**	**102**
ELECTRICITY GENERATION TWh						
Coal	47	27	46	44	25	15
Gas	185	262	290	179	186	131
Nuclear, oil, diesel	46	41	39	46	30	14
Renewable	61	105	121	62	121	175
Total electricity generation (TWh)	**339 TWh**	**435 TWh**	**496 TWh**	**331 TWh**	**363 TWh**	**336 TWh**

*Note: Base case energy efficiency jobs are not calculated, so the energy efficiency jobs shown are only those **additional** to the reference scenario.*

6.7 Russia

Highlights

- There are 406,000 energy sector jobs in Russia in the [R]evolution scenario in 2010, compared to 401,000 in the Reference scenarios.
- In 2020, the [R]evolution scenario shows strong job growth, reaching 465,000. The Reference scenario jobs fall by nearly 60,000, to 345,000.
- Job numbers continue to grow in the [R]evolution scenario, reaching 497,000 by 2030. Jobs continue to fall in the Reference case, dropping to 307,000 by 2030 in the Reference scenario.

Discussion

Figure 39 shows total projected jobs in the energy sector, broken down by technology.

Employment in the Reference scenario drops consistently between 2010 and 2030, from 401,000 down to 301,000.

Employment in the [R]evolution scenario shows strong and consistent growth, reaching 497,000 by 2030, 180,000 more than in the Reference scenario.

Figure 39 Russia: jobs by technology and type in 2010, 2020, and 2030

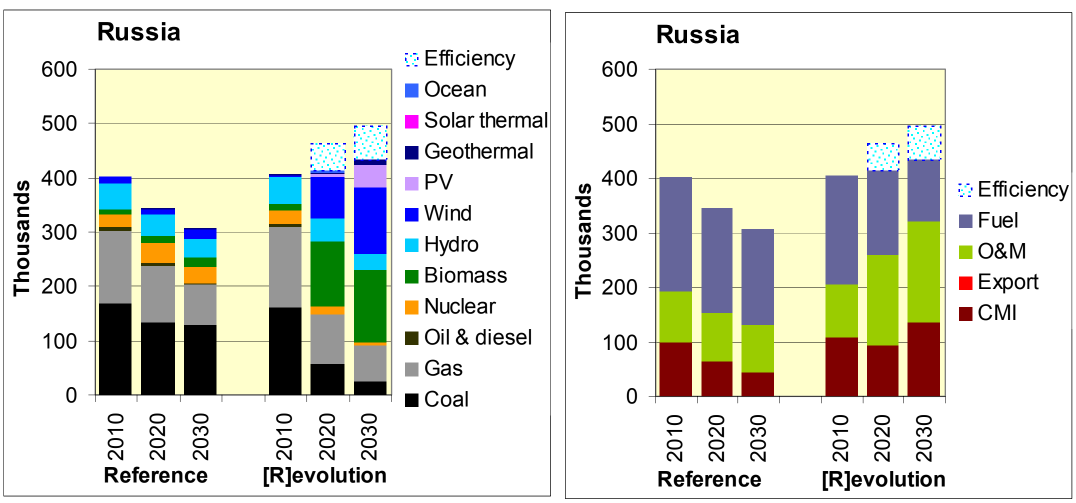


Figure 40 Russia: employment change 2020 and 2030, compared to 2010

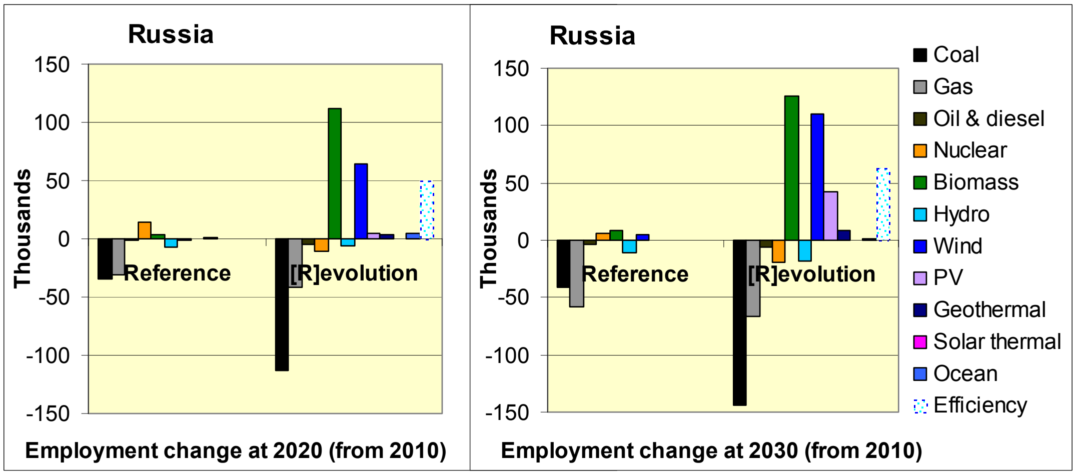


Figure 40 shows the shows the change in job numbers under both scenarios for each technology between 2010 and 2020, and 2010 and 2030. The greatest losses occur in jobs associated with coal and gas supply. These losses are more than outweighed in the [R]evolution scenario by strong growth in renewable energy technologies and energy efficiency. There are significant net losses in the Reference scenario. .

Table 56 Russia: employment and electricity generation at 2010, 2020, and 2030

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	2020	2030	2010	2020	2030
JOBS (thousands)						
Coal	169	134	128	161	56	25
Gas	134	103	76	147	92	68
Nuclear, oil & diesel	30	44	31	30	15	4
Renewable	69	64	71	67	252	337
Energy supply jobs	**401**	**345**	**307**	**406**	**415**	**434**
Energy efficiency jobs	-	-	-	0	50	63
TOTAL JOBS	**401**	**345**	**307**	**406**	**465**	**497**
ELECTRICITY GENERATION TWh						
Coal	239	275	307	237	170	95
Gas	460	527	543	461	450	420
Nuclear, oil, diesel	187	241	263	187	153	52
Renewable	193	225	264	194	352	550
Total electricity generation (TWh)	**1,078 TWh**	**1,268 TWh**	**1,377 TWh**	**1,078 TWh**	**1,125 TWh**	**1,117 TWh**

Note: Base case energy efficiency jobs are not calculated, so the energy efficiency jobs shown are only ***additional*** *to the reference scenario.*

6.8 United States

Highlights

- There are 449,000 energy sector jobs in the US in the [R]evolution scenario in 2010, compared to 382,000 in the Reference scenarios.
- Both scenarios have increased job numbers at 2020, with the [R]evolution showing exceptional growth. In 2020 there are 772,000 jobs projected for the [R]evolution, compared to 460,000 in the Reference.
- Job numbers continue to grow in both scenarios, reaching 938,000 in the [R]evolution and 547,000 in the Reference scenarios.

Discussion

Figure 41 shows total projected jobs in the energy sector, broken down by technology.

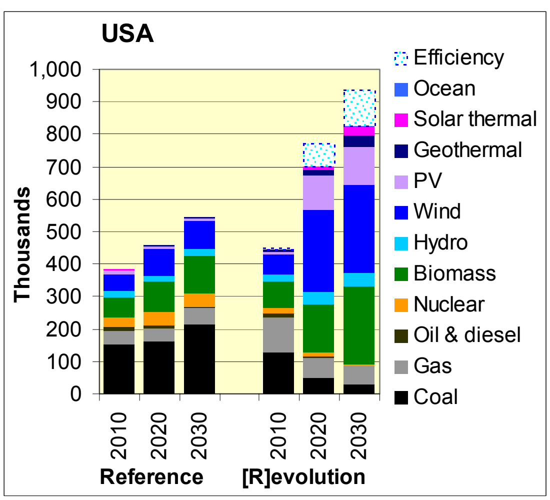
There are more energy sector jobs in the USA in the [R]evolution scenario at every stage. In 2010, the [R]evolution has about 70,000 additional jobs compared to the Reference scenario, with 300,000 more in 2020, and 400,000 more by 2030.

Employment in the [R]evolution scenario show very strong growth, reaching 772,000 by 2020 and 938,000 by 2030

Energy efficiency plays a significant role in employment creation, as electricity use is reduced by 10% and 16% relative to the Reference case in 2020 and 2030 respectively.

It is likely that the energy efficiency jobs have been underestimated. A recent report on the employment potential in 'smart grids' (KEMA 2009) estimated that approximately 280,000 jobs would be created during the implementation phase of rolling out meters, and in the long-term approximately 140,000 permanent staff. This is more than all the energy efficiency jobs projected in this study.

Figure 41 USA: jobs by technology and type in 2010, 2020, and 2030



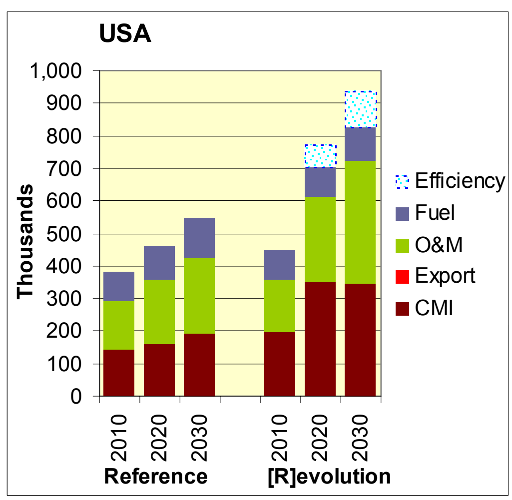


Figure 42 USA: employment change 2020 and 2030, compared to 2010

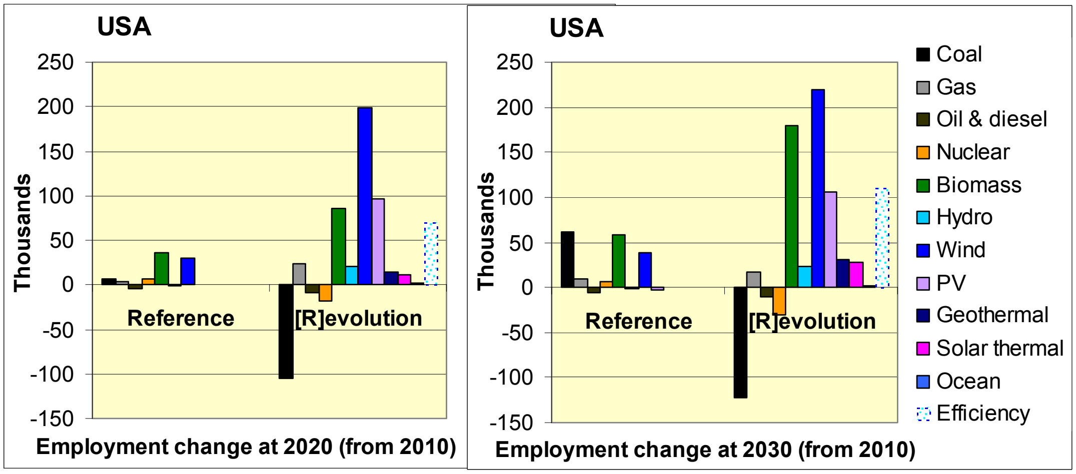


Table 57 USA: employment and electricity generation at 2010, 2020, and 2030

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	**2020**	**2030**	**2010**	**2020**	**2030**
JOBS (thousands)						
Coal	153	160	214	127	49	30
Gas	40	43	49	110	63	56
Nuclear, oil & diesel	45	47	45	28	17	4
Renewable	145	210	239	183	574	736
Energy supply jobs	**382**	**460**	**547**	**448**	**703**	**827**
Energy efficiency jobs	-	-	-	1	70	111
TOTAL JOBS	**382**	**460**	**547**	**449**	**772**	**938**
ELECTRICITY GENERATION TWh						
Coal	2,361	2,797	3,324	2,286	1,598	1,000
Gas	824	887	944	1,105	1,353	1,432
Nuclear, oil, diesel	969	1,021	1,037	702	451	78
Renewable	455	708	870	513	1,462	2,650
Total electricity generation (TWh)	**4,610 TWh**	**5,413 TWh**	**6,176 TWh**	**4,605 TWh**	**4,863 TWh**	**5,160 TWh**

Note: Base case energy efficiency jobs are not calculated, so the energy efficiency jobs shown are only those ***additional*** *to the reference scenario.*

6.9 United Kingdom

Highlights

- There are 73,000 energy sector jobs in the UK [R]evolution scenario in 2010, compared to 70,000 in the Reference scenarios.
- The Reference scenario loses jobs between 2010 and 2020, while the [R]evolution shows exceptional growth. In 2020 there are 150,000 jobs projected for the [R]evolution, double the amount in the Reference scenario.
- Between 2020 and 2030, job numbers grow in both scenarios, reaching 915,000 in the [R]evolution and 546,000 in the Reference scenarios.

Discussion

Figure 43 shows total projected jobs in the energy sector, broken down by technology.

There are more energy sector jobs in the UK in the [R]evolution scenario at every stage. In 2010, the [R]evolution has about 3,000 additional jobs compared to the Reference scenario, with 79,000 more in 2020, and 78,000 more by 2030.

Employment in the [R]evolution scenario show very strong growth, reaching 130,000 by 2020 and 152,000 by 2030.

Figure 44 shows the changes in shows the shows the change in job numbers under both scenarios for each technology between 2010 and 2020, and 2010 and 2030. The greatest losses in the Reference scenario are in wind energy. This is because the annual increment in wind power falls from 0.9 GW per year in 2010, to only 0.2 GW per year in 2020, at the same time as the decline factor is reducing the employment per MW.

The [R]evolution scenario shows steady capacity growth in renewable energy, with very strong growth in wind energy and biomass.

Figure 43 UK: jobs by technology and type in 2010, 2020, and 2030

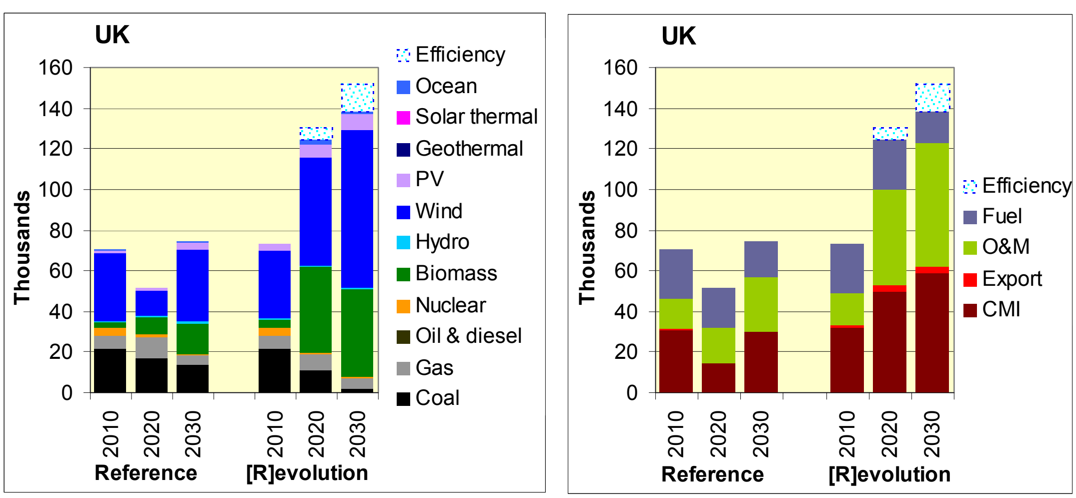


Figure 44 UK: employment change 2020 and 2030, compared to 2010

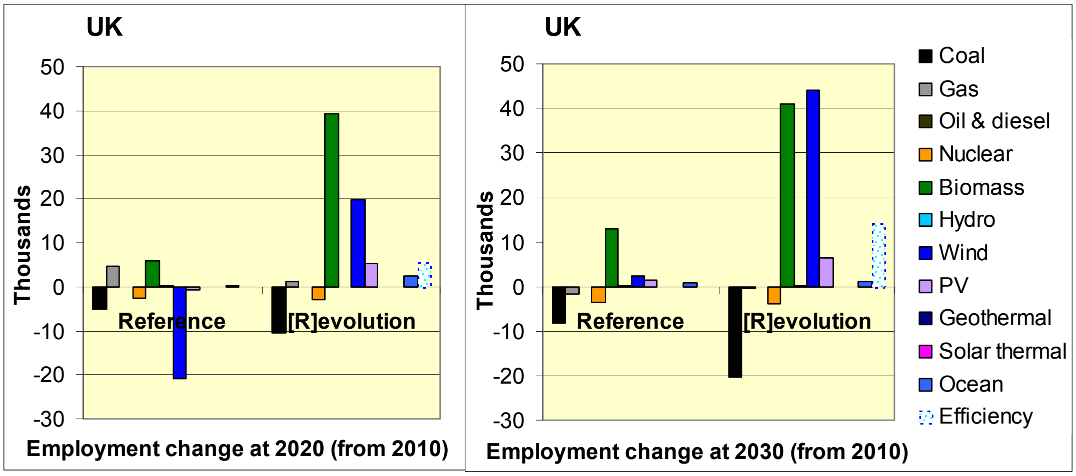


Table 58 UK: employment and electricity generation at 2010, 2020, and 2030

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	2020	2030	2010	2020	2030
JOBS (thousands)						
Coal	21.9	16.7	13.6	21.6	11.3	1.7
Gas	6.1	10.8	4.5	6.3	7.4	5.7
Nuclear, oil & diesel	4.3	1.6	0.6	4.3	1.2	0.3
Renewable	38	22	56	41	105	131
Energy supply jobs	**70**	**51**	**74**	**73**	**125**	**138**
Energy efficiency jobs	-	-	-		5.7	14.3
TOTAL JOBS	**70**	**51**	**74**	**73**	**130**	**152**
ELECTRICITY GENERATION TWh						
Coal	119	94	74	106	23	3
Gas	122	219	220	137	185	134
Nuclear, oil, diesel	76	28	11	75	21	4
Renewable	32	54	128	34	168	255
Total electricity generation (TWh)	**349 TWh**	**395 TWh**	**433 TWh**	**352 TWh**	**397 TWh**	**397 TWh**

*Note: Base case energy efficiency jobs are not calculated, so the energy efficiency jobs shown are only those **additional** to the reference scenario.*

6.10 The EU 27

Highlights

- There are approximately 1.1 million energy sector jobs in the EU-27 in the [R]evolution scenario in 2010, compared to 0.9 million in the Reference scenarios.
- The Reference scenario loses jobs at 2020, while the [R]evolution shows strong growth. In 2020 there are nearly 1.4 million jobs projected for the [R]evolution, 0.5 million more than the Reference scenario.
- Job numbers drop slightly in the [R]evolution scenario, falling to 1.3 million in 2030. Jobs keep falling in the Reference case, to 0.8 million by 2030. There are nearly 600,000 more jobs in the [R]evolution scenario in 2030.

Discussion

Figure 45 shows total projected jobs in the energy sector, broken down by technology. Employment in the [R]evolution scenario show very strong growth overall, reaching 1.4 million by 2020 and then falling slightly to 1.3 million by 2030.

There are more energy sector jobs in the EU-27 at every stage in the [R]evolution scenario. In 2010, the [R]evolution has about 150,000 additional jobs compared to the Reference scenario, 500,000 more in 2020, and 580,000 more by 2030.

Jobs in the coal industry drop in 2020 and 2030 in both scenarios. A combination of biomass, wind, PV, and energy efficiency jobs outweigh the losses in coal jobs in the [R]evolution scenario, contributing to net job growth. In the Reference scenario there are net losses 150,000 jobs by 2030, mostly in the coal industry.

Figure 45 EU-27: jobs by technology and type in 2010, 2020, and 2030

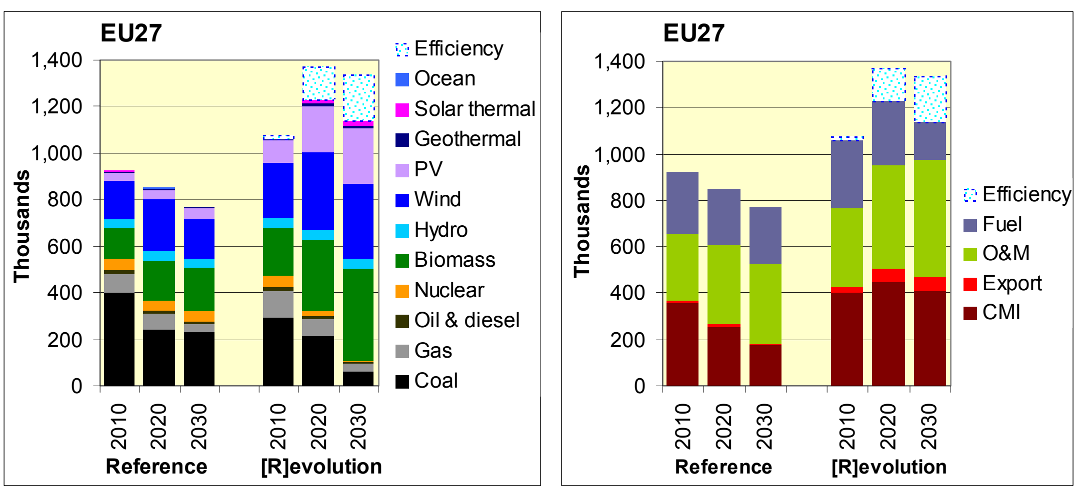


Figure 46 EU-27: employment change 2020 and 2030, compared to 2010

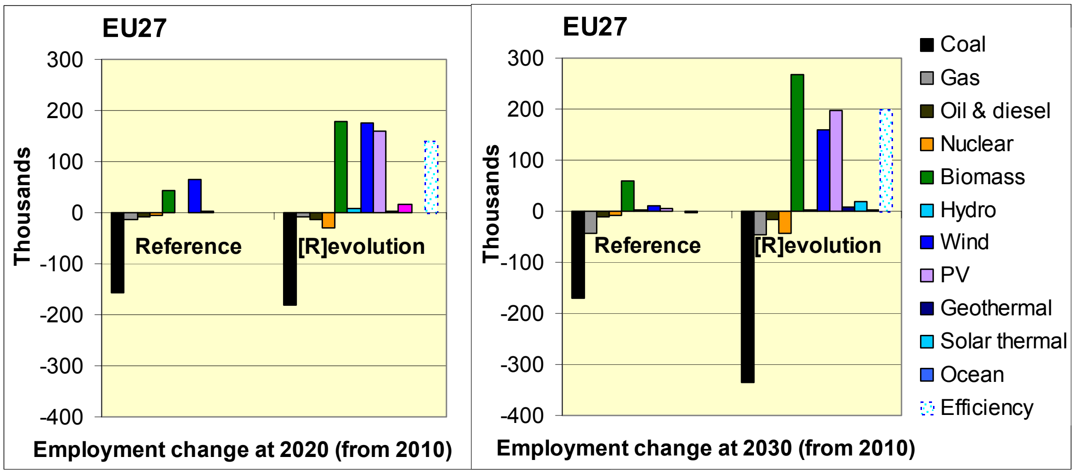


Table 59 EU-27: employment and electricity generation at 2010, 2020, and 2030

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	2020	2030	2010	2020	2030
JOBS (thousands)						
Coal	399	243	229	293	217	63
Gas	81	68	37	112	73	36
Nuclear, oil & diesel	71	58	53	69	29	11
Renewable	373	481	449	589	912	1,031
Energy supply jobs	**923**	**850**	**768**	**1,062**	**1,232**	**1,140**
Energy efficiency jobs	-	-	-	16	140	200
TOTAL JOBS	**923**	**850**	**768**	**1,078**	**1,372**	**1,340**
ELECTRICITY GENERATION TWh						
Coal	1,165	1,270	1,428	950	606	189
Gas	816	1,152	1,330	897	1,157	1,162
Nuclear, oil, diesel	1,087	960	925	1,057	476	178
Renewable	586	969	1,171	681	1,355	1,991
Total electricity generation (TWh)	**3,655 TWh**	**4,351 TWh**	**4,855 TWh**	**3,585 TWh**	**3,594 TWh**	**3,519 TWh**

Note: Base case energy efficiency jobs are not calculated, so the energy efficiency jobs shown are only those ***additional*** *to the reference scenario.*

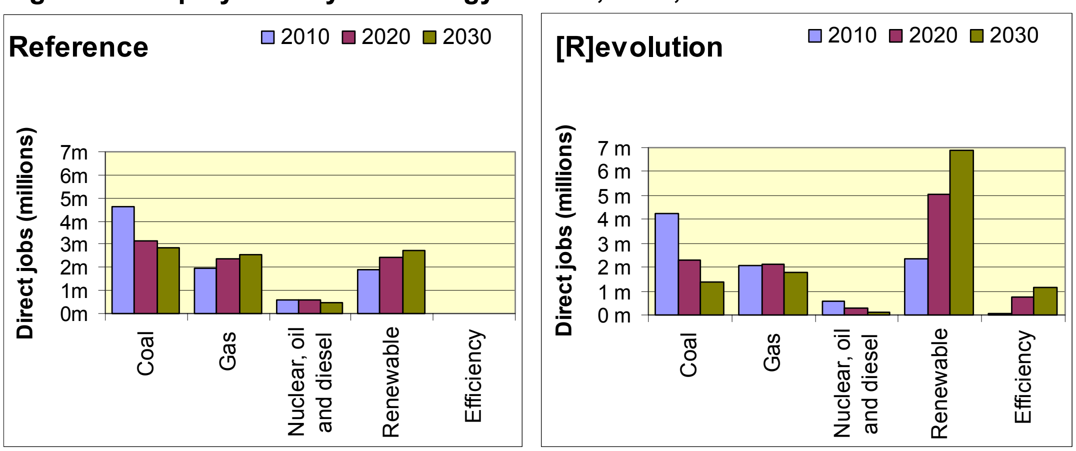
7 Employment in the energy sector - technology results

There are 10.5 million jobs in the [R]evolution scenario in 2020, 2 million more than in the Reference scenario. Jobs in coal reduce substantially between 2010 and 2020 in both scenarios, but this is more than compensated in the [R]evolution scenario by growth in the renewable energy and energy efficiency sectors.

Direct jobs by technology types are shown for the Reference and [R]evolution scenarios in Figure 47 and Figure 48. By 2020, more than half of direct jobs in the [R]evolution scenario are in renewable energy, even though renewable energy accounts for only 36% of electricity generation. In the Reference, scenario renewable energy accounts for about one third of energy sector jobs and 22% of electricity generation. The higher percentage of employment relative to generation reflects the greater labour intensity in the renewable sector.

Electricity generation and direct jobs are shown for coal, gas, renewable energy, energy efficiency, and other technology groups in Figure 47. A more detailed distribution of employment between technologies is shown in Figure 48.

Figure 47 Employment by technology in 2010, 2020, and 2030



In 2010 coal is the largest employer in both scenarios, accounting for nearly half of energy sector employment. Job numbers in the coal sector drop substantially by 2020, with coal employment falling to 34% in the Reference and only 21% in the [R]evolution scenario. In the [R]evolution scenario, the reduction in coal jobs, although greater than in the Reference, is more than compensated for by the strong growth in the renewable sector.

In the [R]evolution scenario, wind power employment grows the most, and has the highest number of direct jobs in both 2020 and 2030. Renewable CHP (mostly biomass) has the next highest employment by 2030, closely followed by solar PV.

Figure 48 Employment by technology in 2020

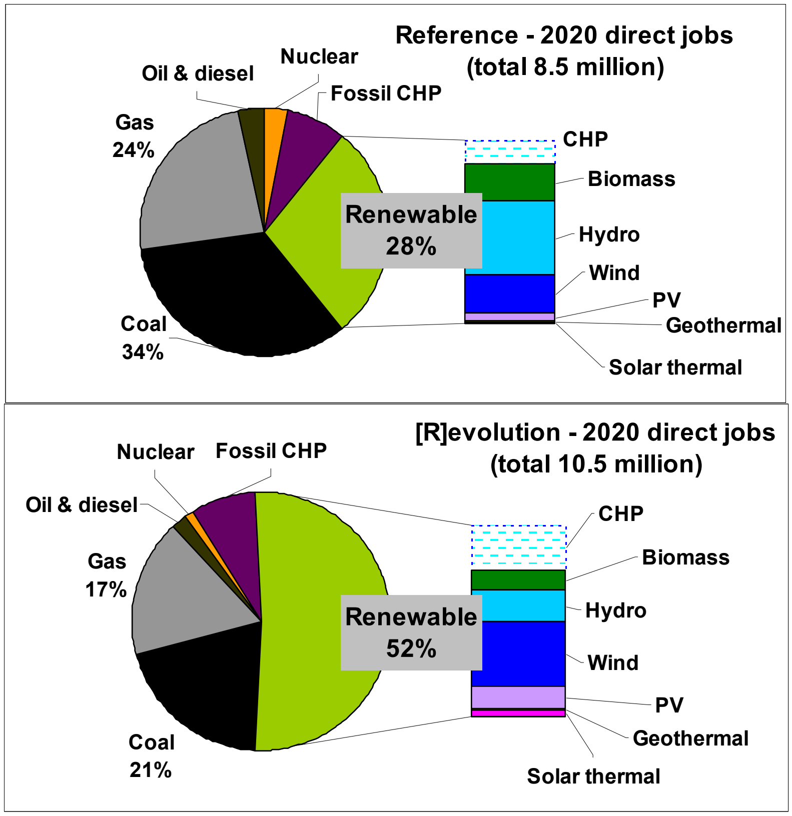


Table 60 World: electricity generation and jobs at 2010, 2020, and 2030

WORLD	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	2020	2030	2010	2020	2030
JOBS (millions)						
Coal	4.65 m	3.16 m	2.86 m	4.26 m	2.28 m	1.39 m
Gas	1.95 m	2.36 m	2.55 m	2.08 m	2.12 m	1.80 m
Nuclear, oil and diesel	0.61 m	0.58 m	0.50 m	0.56 m	0.31 m	0.13 m
Renewable	1.88 m	2.41 m	2.71 m	2.38 m	5.03 m	6.90 m
Energy supply jobs	**9.1 m**	**8.5 m**	**8.6 m**	**9.3 m**	**9.7 m**	**10.2 m**
Energy efficiency jobs	0.0 m	0.0 m	0.0 m	0.1 m	0.7 m	1.1 m
TOTAL JOBS	**9.1 m**	**8.5 m**	**8.6 m**	**9.3 m**	**10.5 m**	**11.3 m**
ELECTRICITY GENERATION TWh						
Coal	9,283	12,546	16,030	8,751	8,953	7,784
Gas	4,447	6,256	7,974	4,704	6,126	6,335
Nuclear, oil, diesel	4,004	4,133	4,079	3,814	2,309	1,003
Renewable	4,047	5,871	7,286	4,254	8,355	14,002
Total electricity generation (TWh)	**21,780 TWh**	**28,807 TWh**	**35,369 TWh**	**21,523 TWh**	**25,743 TWh**	**29,124 TWh**

7.1 *Detailed results – selected technology*

Detailed results for coal, wind, and solar PV direct jobs are shown in Table 61 to Table 63. Appendix 3 gives detailed results for every other technology, including the installed capacity, annual incremental capacity, investment, jobs, and electricity generation at 2010, 2020, and 2030.

Coal

There is a significant reduction in coal sector jobs by 2020 and 2030 in both scenarios, as can be seen in Table 61 (note this does not include CHP, so numbers will not be identical to coal jobs presented in previous sections).

In the **Reference scenario** coal employment by 2020 is reduced by 1.3 million jobs, more than a third. This is despite an **increase** in generation of nearly 40%. By 2030 there is a further reduction of 200,000 jobs. There are three reasons for this major reduction in the Reference scenario coal jobs:

- Jobs per MW across all technologies falls as prosperity and labour productivity increases, which is reflected in the regional job multipliers. Regional job multipliers are applied to OECD employment factors in non-OECD regions. These regional multipliers are higher in earlier years, and fall over the study period as the difference between labour productivity in the OECD and other regions falls (see section 3.7 for more details). If regional multipliers are not used, coal employment by 2020 falls by only 5% relative to 2010, rather than 32%. This is mainly because of China, which has a high proportion of the world's coal employment in 2010, and has a rapid increase in labour productivity projected between 2010 and 2020. As labour productivity reaches a par with OECD countries, employment per MW falls to OECD levels. This has the greatest impact on job numbers.
- The decline factors applied to each technology correspond to the reduction in price of that technology. An annual decline of 0.9% is applied between 2010 and 2020 and 0.3% between 2020 and 2030 (for more details see Section 3.6. The effect is to reduce employment per MW by 9% in 2020 and 12% in 2030; employment per MW in solar PV, for comparison, falls by 55% by 2020 and 65% by 2030.). This does not affect coal sector employment substantially, as it is a relatively low annual decline; if no decline factors are used then coal employment falls by 25% rather than 32% between 2020 and 2030.
- Annual growth in coal generation falls from 71 GW per year in 2010 to 58 GW per year in 2020. This means construction and manufacturing jobs fall, reflecting the slower annual growth in 2020. If growth was maintained coal sector jobs would fall 26% rather than the 32% projected.

In the [R]evolution scenario, the reduction in coal sector jobs occurs mainly because growth in coal capacity is almost zero, and by 2030 there is a slight **reduction** in coal capacity. This means that construction, installation and manufacturing jobs in the coal sector fall to almost zero. The reduction in coal jobs is compounded by the same influences that operate in the Reference scenario, as the change in regional employment multipliers and decline factors exaggerate the effect of zero growth.

Table 61 Capacity, investment, and direct jobs – COAL

Coal (excludes CHP)	Unit	Reference 2010	2020	2030	[R]evolution 2010	2020	2030
Energy parameters							
Installed capacity	GW	1,477	2,054	2,665	1,400	1,460	1,263
Generated electricity	TWh	8,575	11,771	15,117	8,110	8,313	7,067
Share of total supply	%	40%	46%	52%	38%	32%	24%
Market & Investment							
Annual increase in capacity	MW/a	71	58	61	58	24	3
Annual investment	US$/a	149,848	103,290	104,294	134,828	53,028	20,306
Direct jobs							
Construction and manufacturing	jobs	2.01 m	1.11 m	0.94 m	1.76 m	0.50 m	0.05 m
Operations and maintenance	jobs	0.26 m	0.27 m	0.29 m	0.25 m	0.20 m	0.14 m
Fuel		1.93 m	1.49 m	1.38 m	1.90 m	1.25 m	0.88 m
Total jobs		**4.20 m**	**2.87 m**	**2.60 m**	**3.91 m**	**1.94 m**	**1.07 m**

Wind and PV

Wind and solar PV generation both show strong growth in the [R]evolution scenario, reflecting the rapid increase in these technologies. Wind and solar PV reach 15% and 5%, respectively, of total electricity generation by 2030. Growth is much more modest in the Reference scenario, with the effect that increases in employment at 2020 are followed by reduction in 2030. Capacity increases in the Reference scenario are not strong enough to offset the reduction caused by regional job multipliers and decline factors.

The strongest influence on jobs in wind and solar PV are the decline factors, which reduce the projected employment per MW to take account of the falling cost of the technologies (see section 3.6 for details). If decline factors were not applied, solar PV jobs would be more than three times greater by 2030, an extra 3 million jobs. Decline factors are used because the cost of PV is expected to fall by 50% by 2020 and 70% by 2030.[5] The effect on wind power jobs is less marked, because the technology is further along the commercialization path. If decline factors were not used, wind jobs would be 0.3 million higher in 2020, and 0.8 million higher in 2030.

[5] It is assumed that employment per MW will fall at the same rate as the cost per MW falls.

Table 62 Capacity, investment, and direct jobs – WIND

WIND	Unit	Reference 2010	2020	2030	[R]evolution 2010	2020	2030
Energy parameters							
Installed capacity	GW	114	293	295	154	802	1,405
Generated electricity	TWh	274	887	1,260	362	2,255	4,398
Share of total supply	%	1%	3%	4%	2%	9%	15%
Market & Investment							
Annual increase in capacity	MW/a	11	18	19	19	65	84
Annual investment	US$/a	23,526	30,418	26,226	35,058	94,923	111,818
Direct jobs							
Construction and manufacturing	jobs	0.29 m	0.36 m	0.41 m	0.43 m	1.26 m	1.38 m
Operations and maintenance	jobs	0.07 m	0.15 m	0.18 m	0.09 m	0.43 m	0.65 m
Total jobs		**0.36 m**	**0.51 m**	**0.59 m**	**0.52 m**	**1.68 m**	**2.03 m**

Table 63 Capacity, investment, and direct jobs – PV

PV	Unit	Reference 2010	2020	2030	[R]evolution 2010	2020	2030
Energy parameters							
Installed capacity	GW	10	49	86	21	269	921
Generated electricity	TWh	13	68	120	26	386	1,351
Share of total supply	%	0%	0%	0%	0%	1%	5%
Market & Investment							
Annual increase in capacity	MW/a	2	4	5	4	25	67
Annual investment	US$/a	8,731	9,967	6,689	19,289	60,323	96,019
Direct jobs							
Construction and manufacturing	jobs	0.08 m	0.08 m	0.09 m	0.18 m	0.54 m	1.39 m
Operations and maintenance	jobs	0.00 m	0.01 m	0.02 m	0.01 m	0.06 m	0.20 m
Total jobs		**0.08 m**	**0.10 m**	**0.10 m**	**0.19 m**	**0.61 m**	**1.59 m**

8 Sensitivity analysis

The key input to the job calculations are the employment multipliers, the regional multipliers, and the decline factors. We undertook sensitivity analysis on the job projections in both scenarios in 2010, 2020, and 2030. Input values were varied to determine the sensitivity of the results to changes in the inputs.

The variations tested in the sensitivity analysis are as follows:

Employment factors

- Fossil fuels employment factors were varied by ± 20% (a lower variation is tested than other technologies because of the relative maturity of the technology)
- Biomass, hydro, wind and PV employment factors were varied by ± 40%
- The energy efficiency factor was varied by ± 40%
- Decline factors (for all technologies) were varied by ± 40%

Regional job multipliers

- The gross effect of the regional jobs multipliers is tested, by setting all multipliers to one (so OECD factors are used everywhere).
- The effect of using one factor (the whole of economy excluding agriculture) for everything, including biomass fuels, is tested. In this analysis multipliers derived from whole of economy (excluding agriculture) are used for everything except biomass fuels, which uses multipliers derived from agriculture, forestry and fisheries data.

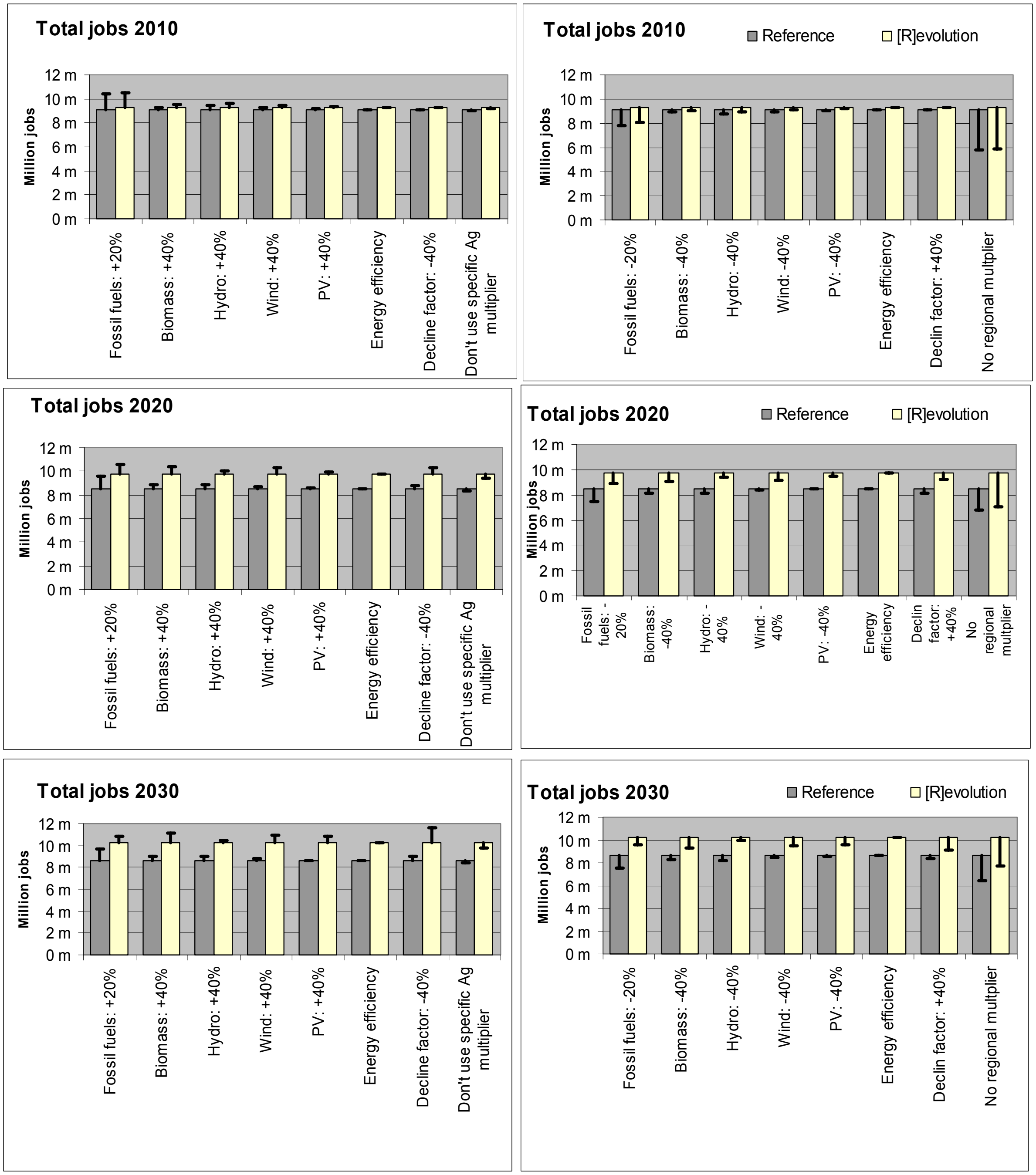
Sensitivity analysis results

Figure 49 shows the results of the sensitivity analysis on total job numbers in 2010, 2020, and 2030 for both the Reference and the [R]evolution scenarios. The figure contains bar graphs which indicate the total number of jobs for each scenario and time. The error bars indicate the amount of expected change resulting from varying the specified input.

Varying any of the factors usually increases or decreases jobs by similar proportions in both scenarios, so the relationship between the total jobs in the Reference and the [R]evolution scenario remains the same. The most significant exception is that decreasing the decline factors has a much greater effect on the [R]evolution scenario than it does on the Reference scenario in 2030. If the decline in employment per unit of generation is slower than predicted, the [R]evolution scenario will have considerably greater gains in employment than projected in the original analysis. The same does not apply to the Reference scenario.

The use of regional multipliers has the greatest effect on both scenarios, as total world jobs projected would be decreased significantly if these multipliers are not used. This effect is particularly strong in 2010. However, evidence from the coal and PV sector suggest that the multipliers underestimate the adjustment needed to differentiate the OECD and developing regions. For example, the regional multiplier for China is calculated as 2.6 in 2010, while industry data for employment per MW in PV manufacturing varies by a factor of three between the OECD and China (see Section 3.7).

Figure 49 Sensitivity analysis by multiplier, both scenarios



9 References

Abbreviation used	Reference
ACEEE 2008	Ehrhardt-Martinez, K. and Laitner, J.A.S. 2008. The Size of the U.S. Energy Efficiency Market: Generating a More Complete Picture. ACEEE May 2008 Report Number E083
Bedzek 2007	Bezdek R. 2007. Renewable Energy and Energy Efficiency: Economic Drivers for the 21st Century (Boulder, CO: American Solar Energy Society, 2007)
BMU 2008a	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. 2008. Short-and Long-Term Impacts of the Expansion of Renewable Energy on the German Labour Market. Gross Employment 2007 - A first estimate - March 14, 2008
BMU 2008b	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. 2008. Development of renewable energy sources in Germanyin 2007. Graphics and tables. Version: 15.12.2008
CALPRG 2002	Heavner, B and Churchill, S. 2002. Renewables Work. Job Growth from Renewable Energy Development in California. CALPIRG Charitable Trust, 2002
CEC 2009	Clean Energy Council. 2009. The net employment impacts of climate change policies. Report by Access Economics Pty Limited
CoFFEE 2008	Bill, A., Mitchell, W., Welters R., Rutovitz J., and Evans G. 2008. A Just Transition to a Renewable Energy Economy in the Hunter Region, Australia. Centre of Full Employment and Equity.
Deloitte 2008	Deloitte, 2008. Outlook for the Uranium Industry, for the Australian Uranium Association
DTI 2004	UK Department for Trade and Industry. 2004. Renewable Supply Chain Gap Analysis: Summary Report.
Dupressoir et al, 2007	Sophie Dupressoir et al. 2007 Climate Change and Employment: Impact on Employment in the European Union-25 of Climate Change and CO2 Emission Reduction Measures by 2030. Brussels: European Trade Union Confederation (ETUC), Instituto Sindical de Trabajo, Ambiente y Salud (ISTAS), Social Development Agency (SDA), Syndex, and Wuppertal Institute.
EIA 2008 (PV)	Energy Information Administration. 2008. Solar Photovoltaic Cell/Module Manufacturing Activities, 2007 Release Date: December 2008
EIA 2009a (nuclear)	Energy Information Administration. 2009a. Monthly Energy Review April 2009 Table 8.1 Nuclear Energy overview
EIA 2009b (hydro)	Energy Information Administration. 2009b. Electric Power Annual 2007. Table 2.1. Existing Net Summer Capacity by Energy Source and Producer Type, 1996 through 2007. Released: January 21, 2009
EmployRes 2009	Ragwitz M et al. 2009. EmployRES. The impact of renewable energy policy on economic growth and employment in the European Union Final report Contract no.: TREN/D1/474/2006
EPIA 2008a	European Photovoltaic Industry Association and Greenpeace. 2008. Solar Generation V – 2008

EPIA 2008b SolarGeneration V and PV Technology Platform 2008,

EPRI 2001 EPRI (Electric Power Research Institute). 2001. California Renewable Technology Market and Benefits Assessment. California Energy Commission , 2001.

EREC 2008 European Renewable Energy Council 2008 Renewable Energy Technology Roadmap 20% by 2020. Page 16

EWEA 2009 European Wind Energy Association. 2009. Wind at work. Wind energy and job creation in the EU.

GEA 2005 Geothermal Energy Association. 2005. Geothermal industry employment: survey results & analysis. By Cédric Nathanaël Hance for the Department of Energy - Geothermal Program.

GPI & EREC 2008 Greenpeace International and the European Renewable Energy Association. 2008. Energy [R]evolution. A sustainable global energy outlook.

GPI & ESTELA 2009 Greenpeace International, SolarPACES, ESTELA. 2009. Concentrating solar power. Global outlook 2009.

IEA 2007 International Energy Agency 2007. World Energy Outlook 2007 p60 & 62

IEA 2008 International Energy Agency 2008. World Energy Outlook 2008

ILO 2007 International Labour Organisation, 2007, Key Indicators of the Labour Market, Fifth Edition software.

JEDI model NREL JEDI model, downloaded 30/4/09.

Kammen 2004 Kammen, D, Kapadia K, and Fripp, M. 2004. Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate? RAEL Report, University of California, Berkley.

KEMA 2008 KEMA. 2008. The U.S. Smart Grid Revolution. KEMA’s Perspectives for Job Creation. Prepared for the GridWise Alliance.

MITRE 2003 MITRE Overview Report. 2003. Meeting the targets and putting renewables to work. European Commission.

NEI 2009 Nuclear Energy Institute. 2009. Fact Sheet. Nuclear Power Plants Contribute Significantly to State and Local Economies. Washington.

NREL National Renewable Energy Laboratory

NREL 2006 L. Stoddard, J. Abiecunas, and R. O'Connell, 2006, Economic, Energy, and Environmental Benefits of Concentrating Solar Power in California, National Renewable Energy Laboratory

Pembina 2004 Pembina Institute. 2004. Canadian Renewable Electricity Development: Employment Impacts. Prepared for Clean Air Renewable Energy Coalition.

REN21 2008 REN21. 2008. Renewables 2007 Global Status Report (Paris: REN21 Secretariat and Washington, DC:Worldwatch Institute)

REN21 2009 REN21. 2009. Renewables Global Status Report: 2009 Update (Paris: REN21 Secretariat).

REPP 2001 Singh, V., with BBC Research and Consulting & Fehrs, J. (2001). The work that goes into renewable energy. Washington, DC: Renewable Energy Policy Project (REPP).

Sawin 2008 Sawin J. 2008. Another Sunny Year for Solar Power. Published Worldwatch, Vital Signs Online, May 2008

Schwer & Riddel 2004 Schwer, R. K. and Riddel, M. 2004.The potential economic impact of constructing and operating solar power generation facilities in Nevada prepared for National Renewable Energy Laboratory. Center for Business and Economic Research, University of Nevada, 2004.

SERG 2007 W.M.J. Batten and A.S. Bahaj, 2007, An assessment of growth scenarios and implications for ocean energy industries in Europe, Sustainable Energy Research Group, School of Civil Engineering and the Environment, University of Southampton

SPOK ApS 2008 Soerensen, H.C. (SPOK ApS) 2008, Co-ordination action on ocean energy, Work Session 5 Environmental, Economics, Development Policy and Promotion of Opportunities. Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)

US Census 2002 US Census Bureau, Issued December 2004. 2002 Economic Census, Electric Power Generation, Transmission and Distribution: 2002.

Wade 2004. Wade J et al. 2000. National and Local Employment Impacts of Energy Efficiency Investment Programmes. European Commission.

WNA 2009 World Nuclear Association, 2009. World Nuclear Power Reactors 2007-09 and Uranium Requirements, http://www.world-nuclear.org/info/reactors.html accessed 1/5/09

Appendix 1 List of countries for regional analysis

OECD North America
Canada, Mexico, United States
Latin America
Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, St. Kitts-Nevis-Anguila, Saint Lucia, St. Vincent and Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela
OECD Europe
Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom
Africa
Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Democratic Republic of Congo, Cote d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, United Republic of Tanzania, Togo, Tunisia, Uganda, Zambia, Zimbabwe
Middle East
Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, Yemen
India
India
China
People's Republic of China including Hong Kong
Developing Asia
Afghanistan, Bangladesh, Bhutan, Brunei, Cambodia, Chinese Taipei, Fiji, French Polynesia, Indonesia, Kiribati, Democratic People's Republic of Korea, Laos, Macao, Malaysia, Maldives, Mongolia, Myanmar, Nepal, New Caledonia, Pakistan, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Sri Lanka, Thailand, Vietnam, Vanuatu
Transition economies
Albania, Armenia, Azerbaijan, Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, Estonia, Serbia and Montenegro, the former Republic of Macedonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Romania, Russia, Slovenia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan, Cyprus*, Malta*
OECD Pacific
Australia, Japan, Korea (South), New Zealand

Appendix 2 Coal employment and production data

Table A 1 Coal employment and production, detailed country and region data

	Production	Domestic production	Coal for electricity	% of lignite in electricity production	Employment	Productivity	Employment factor (existing)	Employment factor (new)	Employment factor (existing)	Employment factor (new)
	million tons	%	Tons/ GWh		'000s	Tons / person /year	Jobs per GWh		Jobs per GWh	
Australia	371 m	257%	659	51%	27	13,800	**0.05**	**0.02**	0.04	0.02
India	466 m	92%	745	6%	464	1,004	**0.74**	**0.32**	0.59	0.25
China	2,525 m	97%	516	-	3,600	701	**0.74**	**0.02**	0.55	0.02
South Africa	247 m	138%	492	-	60	4,110	**0.12**	**0.08**	0.11	0.07
Middle east	3 m	20%	365	3%	n/a					
Latin America	90 m	198%	425	20%	n/a					
Japan	44 m	20%	299	-	n/a					
OECD Europe	550 m	84%	678	66%	298	1,843	**0.37**	**0.17**	0.34	0.16
Germany	209 m	82%	704	77%	42	4,968	**0.14**	**0.06**	0.13	0.06
UK	23 m	31%	377	-	35	658	**0.57**	**0.49**	0.52	0.45
Poland	165 m	109%	715	56%	170	970	**0.74**	**0.33**	0.68	0.31
Greece	65 m	100%	1974	100%	6	10,936	**0.18**	**0.03**	0.17	0.03
France	5 m	19%	328	-	3	1,571	**0.21**	**0.21**	0.19	0.19
Czech Rep	66 m	109%	860	92%	18	3,764	**0.23**	**0.09**	0.21	0.08
Slovak Rep	4 m	39%	728	65%	5	811	**0.90**	**0.40**	0.82	0.36
Finland	14 m	77%	264	-	20	705	**0.37**	**0.46**	0.34	0.42
Italy	5 m	16%	316	-	n/a					
Transition economies	347 m		772	56%	237		**0.53**	**0.22**	0.43	0.18
Russia	317 m	127%	710	47%	200	1,583	**0.45**	**0.20**	0.37	0.17
Bulgaria	26 m	85%	1307	95%	35	753	**1.74**	**0.43**	1.42	0.35
Slovenia	5 m	86%	941	91%	2	2,261	**0.42**	**0.14**	0.34	0.12
OECD North America	1,238 m	104%	403	9%	88	14,116	**0.03**	**0.02**	0.03	0.02
USA	1,168 m	103%	399	8%	83	14,080	**0.028**	**0.023**	0.02	0.02
CANADA	70 m	112%	485	20%	5	14,757	0.03	**0.0218**	0.03	0.02

Appendix 3 Energy sector scenario employment – further detail

Table A 2 Regional employment by type

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	2020	2030	2010	2020	2030
WORLD						
CMI	3.6 m	2.7 m	2.4 m	3.56 m	3.34 m	3.59 m
Export	-	-	-	-	-	-
O&M	1.4 m	1.76 m	1.98 m	1.55 m	2.50 m	3.10 m
Fuel supply	4.1 m	4.06 m	4.21 m	4.17 m	3.92 m	3.53 m
Energy supply jobs	**9.1 m**	**8.52 m**	**8.62 m**	**9.28 m**	**9.75 m**	**10.22 m**
Energy efficiency jobs	-	-	-	0.06 m	0.72 m	1.13 m
TOTAL JOBS	**9.1 m**	**8.52 m**	**8.62 m**	**9.34 m**	**10.47 m**	**11.35 m**
OECD North America						
CMI	210	213	220	184	575	458
Export	4.1	1.9	1.5	7.5	14.8	10.2
O&M	223	283	313	239	402	536
Fuel supply	228	248	258	229	250	265
Energy supply jobs	**665**	**745**	**793**	**659**	**1,241**	**1,269**
Energy efficiency jobs	-	-	-	35	105	141
TOTAL JOBS	665	745	793	694	1,346	1,410
Latin America						
CMI	219	212	199	215	170	257
Export	0.0	0.0	0.0	0.0	0.0	0.0
O&M	142	188	230	191	372	468
Fuel supply	179	251	333	174	177	195
Energy supply jobs	**541**	**651**	**762**	**579**	**719**	**920**
Energy efficiency jobs	-	-	-	2	95	138
TOTAL JOBS	541	651	762	581	814	1,058
OECD Europe						
CMI	208	261	353	277	402	448
Export	18.7	10.4	9.4	26.3	60.8	75.8
O&M	245	328	317	271	366	390
Fuel supply	278	255	262	298	269	186
Energy supply jobs	**749**	**854**	**942**	**872**	**1,097**	**1,099**
Energy efficiency jobs	-	-	-	16	105	179
TOTAL JOBS	749	854	942	888	1,202	1,278

Table A2 regional employment by type, continued

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	2020	2030	2010	2020	2030
Africa						
CMI	251	273	354	262	307	532
Export	0.0	0.0	0.0	0.0	0.0	0.0
O&M	103	189	287	104	206	305
Fuel supply	413	594	716	417	513	484
Energy supply jobs	**767**	**1,056**	**1,357**	**783**	**1,025**	**1,321**
Energy efficiency jobs	-	-	-	0	79	164
TOTAL JOBS	767	1,056	1,357	783	1,104	1,485
Middle East						
CMI	97	103	96	84	89	158
Export	0.0	0.0	0.0	0.0	0.0	0.0
O&M	38	55	72	39	82	134
Fuel supply	293	457	586	298	410	417
Energy supply jobs	**427**	**615**	**753**	**421**	**581**	**709**
Energy efficiency jobs	-	-	-	2	74	81
TOTAL JOBS	427	615	753	422	655	790
Transition economies						
CMI	275	136	122	144	96	216
Export	0.0	0.0	0.0	0.0	0.0	0.0
O&M	185	168	169	223	355	378
Fuel supply	678	630	569	702	632	491
Energy supply jobs	**1,138**	**934**	**860**	**1,068**	**1,083**	**1,086**
Energy efficiency jobs	-	-	-	0	63	102
TOTAL JOBS	1,138	934	860	1,068	1,146	1,188
India						
CMI	395	316	297	396	343	327
Export	20.7	8.0	5.5	23.8	43.1	45.5
O&M	80	99	108	80	153	200
Fuel supply	322	297	295	362	368	365
Energy supply jobs	**817**	**719**	**706**	**862**	**908**	**938**
Energy efficiency jobs	-	-	-	0	42	65
TOTAL JOBS	817	719	706	862	949	1,003

Table A 3 G8 and EU27 employment by type

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	2020	2030	2010	2020	2030
EU27						
CMI	0.4 m	0.3 m	0.2 m	0.4 m	0.5 m	0.4 m
Export	0.0 m	0.0 m	0.0 m	0.0 m	0.1 m	0.1 m
O&M	0.3 m	0.3 m	0.3 m	0.3 m	0.4 m	0.5 m
Fuel supply	0.3 m	0.2 m	0.2 m	0.3 m	0.3 m	0.2 m
Energy supply jobs	**0.9 m**	**0.8 m**	**0.8 m**	**1.1 m**	**1.2 m**	**1.1 m**
Energy efficiency jobs	-	-	-	0.0 m	0.1 m	0.2 m
TOTAL JOBS	**0.9 m**	**0.8 m**	**0.8 m**	**1.1 m**	**1.4 m**	**1.3 m**
G8 (summary)						
CMI	0.5 m	0.4 m	0.5 m	0.6 m	0.7 m	0.8 m
Export	0.0 m	0.0 m	0.0 m	0.0 m	0.0 m	0.0 m
O&M	0.5 m	0.6 m	0.6 m	0.5 m	0.7 m	0.9 m
Fuel supply	0.5 m	0.5 m	0.5 m	0.5 m	0.4 m	0.4 m
Energy supply jobs	**1.4 m**	**1.4 m**	**1.5 m**	**1.5 m**	**1.9 m**	**2.1 m**
Energy efficiency jobs	-	-	-	0.0 m	0.2 m	0.3 m
TOTAL JOBS	**1.4 m**	**1.4 m**	**1.5 m**	**1.6 m**	**2.1 m**	**2.4 m**
Canada						
CMI	15	18	11	8	21	21
Export	-	-	-	-	-	-
O&M	37	41	42	36	42	49
Fuel supply	10	9	7	9	8	9
Energy supply jobs	**63**	**68**	**60**	**54**	**71**	**79**
Energy efficiency jobs	-	-	-	18	19	10
TOTAL JOBS	**63**	**68**	**60**	**72**	**89**	**89**
France						
CMI	10	22	19	13	35	29
Export	1	1	1	1	4	4
O&M	34	38	35	33	31	30
Fuel supply	3	2	2	4	4	4
Energy supply jobs	**48**	**62**	**57**	**51**	**73**	**68**
Energy efficiency jobs	-	-	-	11	19	25
TOTAL JOBS	**48**	**62**	**57**	**62**	**92**	**93**
Germany						
CMI	107	66	108	107	68	105
Export	5	3	3	9	27	33
O&M	76	88	98	76	87	99
Fuel supply	87	87	91	87	85	84
Energy supply jobs	**275**	**244**	**299**	**278**	**266**	**321**
Energy efficiency jobs	-	-	-	-	11	9
TOTAL JOBS	**275**	**244**	**299**	**278**	**277**	**330**

Table A3, G8 and EU27 employment by type, continued

	REFERENCE SCENARIO			[R]EVOLUTION SCENARIO		
	2010	2020	2030	2010	2020	2030
Italy						
CMI	31	38	21	33	38	32
Export	-	-	-	-	-	-
O&M	18	26	27	18	29	37
Fuel supply	8	8	7	8	9	10
Energy supply jobs	**57**	**72**	**56**	**59**	**76**	**79**
Energy efficiency jobs	-	-	-	2	12	22
TOTAL JOBS	**57**	**72**	**56**	**61**	**88**	**102**
Japan						
CMI	41	41	46	56	84	78
Export	1			2	3	6
O&M	66	65	69	65	70	80
Fuel supply	32	30	29	33	31	33
Energy supply jobs	**140**	**136**	**145**	**155**	**188**	**197**
Energy efficiency jobs	-	-	-	16	26	50
TOTAL JOBS	**140**	**136**	**145**	**171**	**214**	**247**
Russia						
CMI	99	65	45	109	94	137
Export	-	-	-	-	-	-
O&M	94	88	85	97	165	184
Fuel supply	209	192	177	200	156	113
Energy supply jobs	**401**	**345**	**307**	**406**	**415**	**434**
Energy efficiency jobs	-	-	-		50	63
TOTAL JOBS	**401**	**345**	**307**	**406**	**465**	**497**
UK						
CMI	30	14	30	32	50	59
Export	1			1	3	4
O&M	15	17	27	16	47	61
Fuel supply	24	20	18	24	25	15
Energy supply jobs	**70**	**51**	**74**	**73**	**125**	**138**
Energy efficiency jobs	-	-	-		6	14
TOTAL JOBS	**70**	**51**	**74**	**73**	**130**	**152**
US						
CMI	145	162	194	199	350	347
Export	-	-	-	-	-	-
O&M	149	194	229	158	263	376
Fuel supply	89	105	124	91	89	103
Energy supply jobs	**382**	**460**	**547**	**448**	**703**	**827**
Energy efficiency jobs	-	-	-	1	70	111
TOTAL JOBS	**382**	**460**	**547**	**449**	**772**	**938**

Appendix 4 Detailed results by technology

Figure A 1 Employment by technology, detailed results

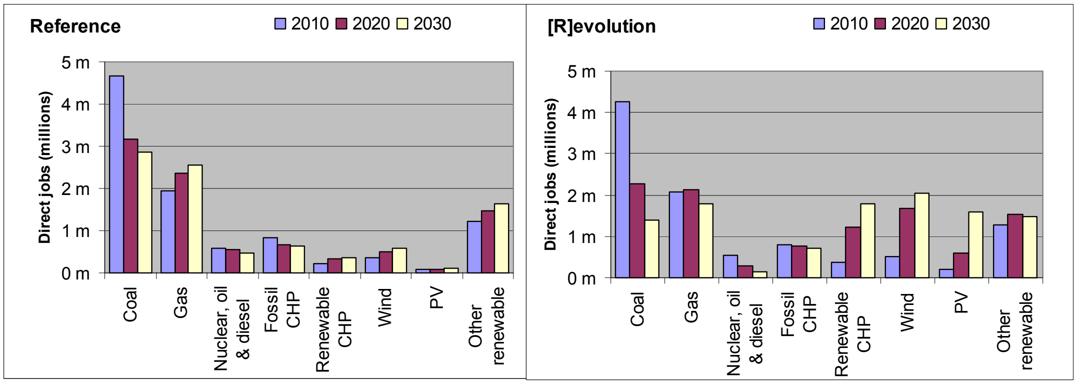


Table A 4 Capacity, investment, and direct jobs – GAS

GAS	Unit	Reference 2010	2020	2030	[R]evolution 2010	2020	2030
Energy parameters							
Installed capacity	GW	979	1,404	1,814	1,025	1,284	1,320
Generated electricity	TWh	3,304	4,925	6,376	3,474	4,383	4,406
Share of total supply	%	15%	19%	22%	16%	17%	15%
Market & Investment							
Annual increase in capacity	MW/a	35	42	41	44	27	12
Annual investment	US$/a	67,901	47,176	54,743	74,043	34,410	29,557
Direct jobs							
CMI	jobs	0.28 m	0.30 m	0.27 m	0.32 m	0.14 m	0.05 m
O&M		0.09 m	0.12 m	0.15 m	0.03 m	0.26 m	0.65 m
Fuel	jobs	1.22 m	1.60 m	1.77 m	1.28 m	1.46 m	1.27 m
Total jobs		**1.59 m**	**2.02 m**	**2.19 m**	**1.63 m**	**1.86 m**	**1.97 m**

Table A 5 Capacity, investment, and direct jobs – Oil and diesel

Oil and diesel	Unit	Reference 2010	2020	2030	[R]evolution 2010	2020	2030
Energy parameters							
Installed capacity	GW	426	402	343	400	262	145
Generated electricity	TWh	1,077	963	803	1,017	615	313
Share of total supply	%	5%	4%	3%	5%	2%	1%
Market & Investment							
Annual increase in capacity	MW/a	5	3	2	2	0	0
Annual investment	US$/a	189,112	131,728	122,825	179,462	115,619	95,526
Direct jobs							
CMI	jobs	0.05 m	0.03 m	0.02 m	0.02 m	0.00 m	0.00 m
O&M & fuel	jobs	0.32 m	0.26 m	0.21 m	0.31 m	0.18 m	0.09 m
Total jobs		**0.37 m**	**0.29 m**	**0.24 m**	**0.33 m**	**0.18 m**	**0.09 m**

Table A 6 Capacity, investment, and direct jobs – NUCLEAR

Nuclear	Unit	Reference 2010	2020	2030	[R]evolution 2010	2020	2030
Energy parameters							
Installed capacity	GW	369	392	405	352	213	88
Generated electricity	TWh	2,824	3,068	3,173	2,688	1,647	678
Share of total supply	%	13%	12%	11%	12%	6%	2%
Market & Investment							
Annual increase in capacity	MW/a	2	4	4	1	1	0
Annual investment	US$/a	45,052	31,000	28,608	36,848	5,622	0
Direct jobs							
CMI	jobs	0.06 m	0.11 m	0.08 m	0.05 m	0.02 m	0.00 m
O&M & fuel	jobs	0.15 m	0.16 m	0.16 m	0.15 m	0.09 m	0.04 m
Total jobs		**0.21 m**	**0.27 m**	**0.24 m**	**0.20 m**	**0.12 m**	**0.04 m**

Table A 7 Capacity, investment, and direct jobs – BIOMASS (including CHP)

Biomass	Unit	Reference 2010	2020	2030	[R]evolution 2010	2020	2030
Energy parameters							
Installed capacity	GW	70	119	143	95	233	341
Generated electricity	TWh	318	595	841	430	1,084	1,826
Share of total supply	%	1%	2%	3%	2%	4%	6%
Market & Investment							
Annual increase in capacity	MW/a	3	5	3	9	14	11
Annual investment	US$/a	7,339	8,821	9,442	11,331	8,131	8,509
Direct jobs							
CMI	jobs	0.02 m	0.03 m	0.02 m	0.06 m	0.09 m	0.05 m
O&M & fuel	jobs	0.45 m	0.77 m	1.00 m	0.64 m	1.62 m	2.22 m
Total jobs		**0.47 m**	**0.80 m**	**1.02 m**	**0.69 m**	**1.71 m**	**2.27 m**

Table A 8 Capacity, investment, and direct jobs – HYDRO

HYDRO	Unit	Reference 2010	2020	2030	[R]evolution 2010	2020	2030
Energy parameters							
Installed capacity	GW	989	1,215	1,399	978	1,178	1,300
Generated electricity	TWh	3,362	4,164	4,833	3,334	4,010	4,425
Share of total supply	%	16%	16%	17%	15%	16%	15%
Market & Investment							
Annual increase in capacity	MW/a	22	23	18	22	20	12
Annual investment	US$/a	174,007	119,884	113,166	167,366	111,102	92,123
Direct jobs							
CMI	jobs	0.54 m	0.50 m	0.43 m	0.53 m	0.38 m	0.21 m
O&M & fuel	jobs	0.40 m	0.47 m	0.53 m	0.39 m	0.44 m	0.46 m
Total jobs		**0.94 m**	**0.97 m**	**0.97 m**	**0.93 m**	**0.81 m**	**0.67 m**

Table A 9 Capacity, investment, & direct jobs – SOLAR THERMAL

	Unit	Reference 2010	2020	2030	[R]evolution 2010	2020	2030
Energy parameters							
Installed capacity	GW	2	8	12	5	83	199
Generated electricity	TWh	5	26	54	9	267	1,172
Share of total supply	%	0%	0%	0%	0%	1%	4%
Market & Investment							
Annual increase in capacity	MW/a	0	1	0	1	8	12
Annual investment	US$/a	2,418	2,802	2,422	4,289	35,168	59,283
Direct jobs							
CMI	jobs	0.01 m	0.01 m	0.00 m	0.02 m	0.11 m	0.14 m
O&M & fuel	jobs	0.00 m	0.00 m	0.00 m	0.00 m	0.04 m	0.08 m
Total jobs		**0.01 m**	**0.01 m**	**0.01 m**	**0.02 m**	**0.15 m**	**0.22 m**

Table A 10 Capacity, investment, & direct jobs – GEOTHERMAL

	Unit	Reference 2010	2020	2030	[R]evolution 2010	2020	2030
Energy parameters							
Installed capacity	GW	11	17	22	12	33	71
Generated electricity	TWh	72	119	158	82	231	488
Share of total supply	%	0%	0%	1%	0%	1%	2%
Market & Investment							
Annual increase in capacity	MW/a	0	1	1	1	2	4
Annual investment	US$/a	16,489	11,050	11,641	21,068	30,479	45,158
Direct jobs							
CMI	jobs	0.00 m	0.00 m	0.00 m	0.01 m	0.01 m	0.02 m
O&M & fuel	jobs	0.01 m	0.02 m	0.02 m	0.01 m	0.03 m	0.04 m
Total jobs		**0.02 m**	**0.02 m**	**0.02 m**	**0.02 m**	**0.04 m**	**0.06 m**

Table A 11 Capacity, investment, & direct jobs – OCEAN

	Unit	Reference 2010	2020	2030	[R]evolution 2010	2020	2030
Energy parameters							
Installed capacity	GW	0	2	4	1	17	44
Generated electricity	TWh	1	6	12	3	58	151
Share of total supply	%	0%	0%	0%	0%	0%	1%
Market & Investment							
Annual increase in capacity	MW/a	0	0	0	0	2	3
Annual investment	US$/a	15	802	624	1,389	7,362	8,649
Direct jobs							
CMI	jobs	0.00 m	0.00 m	0.00 m	0.00 m	0.01 m	0.01 m
O&M & fuel	jobs	0.00 m	0.00 m	0.00 m	0.00 m	0.00 m	0.00 m
Total jobs		**0.00 m**	**0.00 m**	**0.00 m**	**0.00 m**	**0.02 m**	**0.01 m**

Table A 12 Capacity, investment, and direct jobs – FOSSIL FUEL CHP

FOSSIL FUEL CHP	Unit	Reference 2010	2020	2030	[R]evolution 2010	2020	2030
Energy parameters							
Installed capacity	GW	562	614	742	570	669	772
Generated electricity	TWh	1,954	2,209	2,614	1,980	2,430	2,658
Share of total supply	%	9%	9%	9%	9%	9%	9%
Market & Investment							
Annual increase in capacity	MW/a	11	10	14	12	20	19
Annual investment	US$/a	0	0	0	0	0	0
Direct jobs							
CMI	jobs	0.26 m	0.16 m	0.16 m	0.18 m	0.26 m	0.27 m
O&M & fuel	jobs	0.59 m	0.50 m	0.48 m	0.60 m	0.51 m	0.44 m
Total jobs		**0.85 m**	**0.65 m**	**0.65 m**	**0.78 m**	**0.78 m**	**0.71 m**

Table A 13 Capacity, investment, and direct jobs – RENEWABLE CHP

RENEWABLE CHP	Unit	Reference 2010	2020	2030	[R]evolution 2010	2020	2030
Energy parameters							
Installed capacity	GW	42	69	73	62	190	313
Generated electricity	TWh	153	277	376	228	806	1,594
Share of total supply	%	1%	1%	1%	1%	3%	5%
Market & Investment							
Annual increase in capacity	MW/a	2	3	1	6	13	12
Annual investment	US$/a	0	0	0	0	0	0
Direct jobs							
CMI	jobs	0.01 m	0.01 m	0.01 m	0.04 m	0.08 m	0.07 m
O&M & fuel	jobs	0.20 m	0.32 m	0.37 m	0.34 m	1.14 m	1.73 m
Total jobs		**0.21 m**	**0.33 m**	**0.37 m**	**0.38 m**	**1.22 m**	**1.80 m**