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Impact of the Decarbonisation of the Energy System on Employment in Europe

Arno Behrens, Caroline Coulie, Fabio Genoese, Monica Alessi, Julian Wieczorkiewicz and Christian Egenhofer

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Abstract

This paper presents a methodology for calculating the potential impact of the new socio-ecological transition away from fossil fuels on employment in EU energy supply. The methodology is based on "employment factors" (i.e. labour intensities) of different energy technologies. These employment factors are applied to changing energy mixes as projected by the decarbonisation scenarios of the European Commission's *Energy Roadmap 2050*. In particular, we analyse quantitative (number of jobs) and qualitative (qualification levels) impacts on employment in extraction and processing of primary (fossil) fuels and in the power sector for the years 2020, 2030 and 2050. The results show that the energy sector will provide not only more jobs as the new socio-ecological transition unfolds, but also jobs requiring higher-level qualifications when compared with the current energy sector.

Research for this paper was conducted as part of the NEUJOBS project, financed by the European Commission's 7th Framework Programme. Its objective is to analyse likely future developments in the European labour market(s), in view of major transitions that will impact employment and European societies in general. Unless otherwise indicated, the views expressed are attributable only to the authors in a personal capacity and not to any institution with which they are associated. This paper is also published on the NEUJOBS website (www.neujobs.eu) as Deliverable 11.2.

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Table of abbreviations

°C	Degrees Celsius
AMPERE	Assessment of Climate Change Mitigation Pathways and Evaluation of the Robustness of Mitigation Cost Estimates
APPA	Asociación de Productores de Energías Renovables
ARE	Agencja Rynku Energii
CAP	Common Agricultural Policy
CCS	Carbon capture and storage
Cedefop	European Centre for the Development of Vocational Training
CIM	Construction, installation, manufacturing
CO_2	Carbon dioxide
COSME	EU programme for the Competitiveness of Enterprises and Small and Medium-sized Enterprises
CSP	Concentrated solar power
D	Deliverable
DENA	Deutsche Energie-Agentur
DG	Directorate-General
DGRV	Deutscher Genossenschafts- und Raiffeisenverband
DST	Diversified supply technologies scenario
ECF	European Climate Foundation
Ed(s).	Editor(s)
EGSS	Environmental goods and services sector
ELENA	European Local Energy Assistance
EPRI	Electric Power Research Institute
EPSU	European Federation of Public Service Unions
EREC	European Renewable Energy Council
ETS	Emissions Trading System
EU	European Union
EWEA	European Wind Energy Association
GDP	Gross domestic product
GHG	Greenhouse gas(es)
GW	Gigawatt
GWh	Gigawatt-hour
High-RES	High renewable energy sources scenario
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
ILO	International Labour Organization
ISCED	International Standard Classification of Education
ktoe	Kilo tonnes of oil equivalent
kW	Kilowatt
kWh	Kilowatt-hour

LDCs	Least developed countries
LFS	Labour Force Survey
Mtoe	Million tonnes of oil equivalent
MW	Megawatt
NACE	Statistical classification of economic activities in the European Community
NEUJOBS	Employment 2025: How will multiple transitions affect the European labour market
NGO	Non-governmental organisation
OCGT	Open-cycle gas turbine
OECD	Organisation for Economic Co-operation and Development
OGP	International Association of Oil and Gas Producers
O&M	Operation and maintenance
PL	Poland
PV	Photovoltaic
RES	Renewable energy sources
RES-E	Renewable energy sources for electricity production
SBS	Structural Business Statistics
SECURE	Security of Energy Considering its Uncertainty, Risk and Economic implications
SET	Socio-ecological transition
SME	Small and medium-sized enterprises
TWh	Terawatt-hour
UN	United Nations
UNDESA	United Nations Department of Economic and Social Affairs
UNEP	United Nations Environment Programme
UNESCAP	United Nations Economic and Social Commission for Asian and the Pacific
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNGA	General Assembly of the United Nations
US	United States
VET	Vocational education and training
WCED	World Commission on Environment and Development
WP	Work Package

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Introduction

European energy policy aims to address environmental sustainability, security of supplies and economic competitiveness as its three principle objectives. Increasing the share of renewable energy sources (RES) in the energy mix is a central element of the current EU energy policy framework. In fact, RES will play a key role in achieving the long-term EU target of reducing domestic greenhouse gas (GHG) emissions by 80% by 2050 (compared with 1990). It is undisputed that the increasing substitution of fossil fuels with RES and other low-carbon energy sources will decrease EU GHG emissions. Similarly, there is evidence that RES can benefit security of supply by reducing dependence on fossil fuel imports from third countries. However, the impact of such a substitution on competitiveness, growth and jobs is less clear. The banking crisis, followed by the economic and then the sovereign debt crises, has caused policy-makers to refocus their priorities on economic growth and combating rising unemployment. The costs of energy are now of primary concern, given their impact on competitiveness of EU industry. Similarly, in 2013 the unemployment rate of the EU has reached its highest level since the start of the crisis in 2008. These developments have intensified the debate about the links of energy policy to growth and employment and in particular about how the EU can decarbonise its economy without negatively affecting industry and businesses and thus employment (see Egenhofer et al., 2013).

This paper analyses how the long-term decarbonisation of the energy sector may impact employment levels and related educational qualifications required in Europe. It focuses on employment impacts on the extraction and processing of primary (fossil) fuels in Europe, as well as on conversion activities in the power sector. This is done for the years 2020, 2030 and 2050. The paper assesses both new jobs created by the increasing share of electricity in final energy consumption as well as jobs destroyed in fossil fuel extraction and processing and in carbon-intensive power generation. It thus takes into account both positive and negative effects on employment and provides figures about the net employment effect of the new socio-ecological transition away from fossil fuels in the energy supply sector. The paper identifies European trends, but the methodology applied for the EU is also tested on the member-state level in three case studies presented in the Annex.

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Energy in the context of the NEUJOBS project

This paper is a deliverable of Work Package 11 on "Energy and Green Jobs" of the NEUJOBS project (NEUJOBS WP11). The objective of NEUJOBS is "to analyse future possible developments of the European labour market(s) under the main assumption that European societies are now facing or preparing to face four main transitions that will have a major impact on employment" (NEUJOBS, 2013). One of these four transitions is the so-called socio-ecological transition (SET), which is the focus of this paper. A SET is a transition from one socio-ecological regime to another, where a regime is defined as "a specific fundamental pattern of interaction between (human) society and natural systems" (Fischer-Kowalski and Haberl, 2007). Such a regime can also be characterised by the dominant energy sources and conversion technologies (Fischer-Kowalski et al., 2012). Although there are different socio-ecological regimes and, correspondingly, different SETs (see Section 2.1), NEUJOBS is concerned with a "new" transition "away from fossil fuels, towards solar and other low-carbon energy sources" (Fischer-Kowalski et al., 2012).

It has already been discussed in NEUJOBS D1.1 (Fischer-Kowalski et al., 2012) and NEUJOBS D11.1 (Behrens et al., 2013) that the new socio-ecological transition goes beyond the energy sector. In fact, it requires a comprehensive change in the patterns of social organisation and culture, production and consumption as humanity progresses beyond the current industrial model towards a more sustainable society. There are thus many more causes and effects of a SET than purely energy related ones. However, the energy sector is at the heart of the SET away from fossil fuels. This warrants the approach taken in NEUJOBS WP11 of looking at different decarbonisation options – within the context of a SET – and analysing what these options could imply for the labour market. Decarbonisation in NEUJOBS WP11 is thus not considered to be a proxy for a more complex SET, but a key response strategy to current environmental and social challenges – albeit one of several such strategies – and therefore also a key component of a SET.

When discussing the energy sector, a distinction needs to be made between energy supply and energy demand. NEUJOBS WP11 focuses exclusively on energy supply, and in particular on the power sector. Supply includes all aspects related to the production and supply of energy, including the extraction of natural resources, conversion activities (mainly electricity generation) and transport (including transmission and distribution). Demand, on the other hand, covers final consumption by sector. In the EU27, final consumption in 2011 was divided between transport (33%), industry (26%), households (25%), services (13%), agriculture (2%) and fishing (0.1%) (European Commission, 2013a). The potential impact of the SET on employment within the housing sector is assessed in NEUJOBS WP14 (including energy savings technologies). The impact of the SET on employment in the transport sector is examined in NEUJOBS WP15, including the effect of socio-ecological trends on job location, commuting and land use.

NEUJOBS WP11 is divided into three deliverables. The first deliverable (D11.1) reviews various decarbonisation scenarios for the energy sector and thus serves as a background document for assessing the impacts of a transition away from fossil fuels towards low-carbon energy technologies on employment in Europe. This paper (D11.2) assesses the impact of selected decarbonisation scenarios on employment in Europe. It is the core deliverable of WP11. Finally, the third deliverable (D11.3) provides concrete policy options to address labour market issues during the transition to a low-carbon energy sector in the EU.

The policy context

As early as 1996, the EU adopted a long-term target of limiting the global temperature increase to a maximum of 2°C above pre-industrial levels (Council of the European Union, 1996). This position has been reiterated on several occasions, including at the Environmental Council meeting held in October 2013 (Council of the European Union, 2013). Since 2009 in Copenhagen and later in Cancún (UNFCCC, 2010, 2011), countries have made similar pledges that aim to limit the increase in global average temperature to 2°C by the end of the century compared with pre-industrial levels.

To achieve this global objective, on several occasions the EU has stated that developed countries as a group would need to reduce their emissions by between 80% and 95% by 2050 (European Council, 2009, 2011). In addition, the EU adopted its Climate and Energy Package in 2007-09, which set out the EU's strategy and policies up to 2020. The EU is currently discussing a new climate and energy framework for the post-2020 period, based on Commission proposals for new energy and climate objectives to be met by 2030 (European Commission, 2014).

Results of the decarbonisation scenario analysis

Before assessing the potential impacts of a decarbonisation of the energy sector on employment in Europe, it is useful to summarise some key results of the scenario analysis conducted for NEUJOBS D11.1 (Behrens et al., 2013). The paper takes a broad range of scenarios into account – from international institutions (European Commission, IEA, IIASA), European research projects (AMPERE, SECURE), NGOs (European Climate Foundation, Greenpeace) and industry (Eurelectric) – all of which depict a decarbonisation of the EU energy sector in line with the projected EU contribution to limiting global warming to 2°C above pre-industrial levels.

The paper concludes that decarbonisation of the EU economy is possible using currently known technologies. Regarding energy demand, the study shows that demand is likely to decrease by some 2-6% until 2020, and by 20-30% by 2050 (compared with 2010). The share of RES increases from around 10% in 2011 to around 20% in 2020 and to somewhat above 40% by 2050. Fossil fuels will continue to play an important role, but their share in the energy mix is likely to decrease from more than three quarters in 2011 to around 70% in 2020 and to 40-50% in 2050.

The power sector is likely to be the main enabler of decarbonisation and many scenarios assume a decarbonisation by up to 95% by 2050 (compared with 1990). These savings will need to be achieved in the face of growing electricity demand. In fact, all decarbonisation scenarios project growing electricity generation, mainly driven by increasing demand in transport and heating/cooling. By 2020, electricity demand is likely to grow by about 5-10%, while the increase may be in the range of 30-50% by 2050 (both compared with 2010). Energy efficiency and the upscaling of RES are the two key strategies to decarbonise the power sector. Regarding RES, their share in power generation is generally projected to increase from about 20% in 2020 to 35% in 2020 and 60-85% in 2050. Wind and hydro will be the most important RES in power generation in 2020. By 2050, biomass and solar PV will also contribute significantly to the electricity mix. There is large uncertainty about the importance of nuclear and carbon capture and storage (CCS) in power generation.

It is important to note that the rising share of variable RES, such as wind and solar PV, will require an increase in installed electric capacity larger than the increase in power output. This is due to lower capacity factors of intermittent RES. In order to have sufficient levels of back-up capacity (and provided that there is no change in power market design), electrical capacity is projected to increase by about 20-30% by 2020 and by 80-100% by 2050, both compared with 2010. As electric capacity expands faster than generated output, the capacity/generation ratio[1] increases substantially in most scenarios. While it is still at around 2.2-2.4:1 in 2010, it increases to around 2.5-2.7:1 by 2020 and reaches some 3-4:1 by 2050. This means that each unit of electricity produced in 2050 may need to be backed-up by up to four equivalent units of installed capacity to cover for intermittencies. However, the flexibility of the electricity system needed to enable the supply-demand balance with high levels of renewable generation will not only be achieved through additional generation capacity, but also through better interconnection of transmission lines, more flexible distribution, demand-side response and management, and storage.

Scope of this paper

This paper is divided into four chapters. The first chapter situates the green jobs approach within the concepts of sustainable development, the green economy and green growth. Following a definition of these concepts, the chapter gives an account of the argumentation in Europe linking the transition to a green, low-carbon and resource-efficient economy with developments in the labour market. Chapter 2 focuses on the energy sector, starting with a definition of a socio-ecological transition and a brief overview of past transitions in Europe and how they lead to changing energy bases of societies. The chapter then provides an overview of the current EU energy sector in general and its power sector in particular, before describing the main changes to be expected within the power sector as decarbonisation progresses. Chapter 3 is the core of this paper, looking at current patterns of employment in the power sector as well as future developments both quantitatively and qualitatively. Based on the Reference scenario and two representative decarbonisation scenarios of the *Energy Roadmap 2050* (European Commission, 2011a) it calculates the potential impacts of the decarbonisation of the energy sector on (direct) employment in Europe. Its main focus is on the EU as a whole, but it also includes a section on regional implications based on the results of the three case studies presented in Annex I. Chapter 3 only deals with employment aspects related to the extraction of natural resources, conversion activities and transmission and distribution in the power sector. It covers neither long-distance transport of gas (through pipelines) nor the supply chain of power generation (e.g. supply of materials for power plants). Given the latter, it only briefly touches on the potential effects of exports of low-carbon technologies on employment in Europe. It also includes a brief section on some of the potential fiscal implications. Finally, Chapter 4 presents key findings and conclusions. The methodology used for calculating the employment impacts in the EU is also tested in the context of three member state case studies, which are presented in the Annex. These case studies allow for linking the findings for the EU with the situation in Poland, Sweden and Spain, which are in different geographical regions and have quite different energy backgrounds and energy futures.

NEUJOBS targets two time horizons: 2025 and 2050. However, the approach adopted for the whole of WP11 is to focus on 2020 and 2050, in order to align with the milestones of current EU energy and climate change policies. 2020 is the target year of

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[1] The capacity/generation ratio puts the installed capacity in relation with the projected generated electricity output. It is calculated by converting installed capacity into a theoretical generation maximum, which would be reached if total installed capacity produced electricity at full capacity for every single hour of the year (a total of 8,760 hours), i.e. if the capacity factor for all installed capacity was 100%.

the energy and climate change package adopted in 2009 and most studies use it as a time horizon. Similarly, 2050 provides a reference year for decarbonisation of the EU economy as referred to in various scenarios and roadmaps. In addition, this study also provides figures for 2030 in order to link with the ongoing debate about the EU's 2030 climate and energy framework.

The assessment is based on a comprehensive literature review, our own calculations based on publicly available statistics, as well as on interviews with experts from governments and industry as well as their associations (see Annex 2). The authors thank interviewees for their time and input.

1. From sustainable development to green jobs

The green jobs approach is linked to the sustainable development, green growth and green economy concepts. This chapter defines these concepts and explains how they frame the research on employment in the context of the transition to a low-carbon energy system.

1.1 Origin of the sustainable development concept and its theoretical offsprings

This section outlines the evolution of the concept of sustainable development, and its ramification for the similar but separate concepts of green growth and green economy.

1.1.1 Sustainable development

In order to address growing concerns over the "accelerating deterioration of the human environment and natural resources and the consequences of that deterioration for economic and social development" (UNGA, 1987), the UN convened in 1983 the World Commission on Environment and Development (WCED), chaired by Norwegian Prime Minister Gro Harlem Brundtland, and including representatives from both developed and developing countries. In 1987, the Commission "produced the landmark publication *Our Common Future* (or the Brundtland report) that provided a stark diagnosis of the state of the environment" (Drexhage and Murphy, 2010: 7). The report introduced the first definition of sustainable development as "[development that] meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987: par. 27). Acceptance of the report by the United Nations General Assembly gave the term political salience, and "the Brundtland report provided the momentum for the landmark 1992 Rio Summit that laid the foundations for the global institutionalization of sustainable development" (Drexhage and Murphy, 2010: 8). The Summit adopted the Rio Declaration on Environment and Development (the "Rio Declaration"), which set out 27 principles of sustainable development, and Agenda 21, a global plan of action for sustainable development addressing "the social and economic dimensions of sustainable development, conservation and management of natural resources, the role of major groups, and means of implementation" (Drexhage and Murphy, 2010: 8).

However, the concept of sustainable development does not constitute *per se* an approach to achieve sustainability. It has no articulated economic philosophy or strategy, leaving it open to interpretation. Two main and quite similar economic approaches to sustainable development have emerged from this concept, namely "green growth" and "green economy" (see AtKisson (2012) for a comparison of the approaches). Both are based on the concept that, to a large extent, the pursuit of economic growth can be compatible with the concept of sustainable development. These two approaches, however, are not universally accepted by mainstream environmentally oriented critics who question their actual sustainability.

1.1.2 *Green growth*

The concept of green growth was first introduced by the consultancy McKinsey & Company and proposes a low-carbon strategy to achieve climate change objectives. It was subsequently championed by the United Nations as an implementation strategy at the 2002 World Summit on Sustainable Development in Johannesburg. The Global Green Growth Institute in South Korea is currently the main research centre working on developing the concept of green growth (AtKisson, 2012). The green growth approach is centred on emission reduction approaches and focuses primarily on energy.

As summarised by AtKisson (2012), the green growth approach can be criticised for being too limited due to its quasi-exclusive focus on emission reductions and energy, and as such for not ensuring sustainability. It mainly consists of a "top-down" government-driven strategy with little involvement of the wider stakeholder community. The ultimate goal is growth defined in a very similar way to the traditional growth concept, but within the limits of a low-carbon and more resource-efficient path. Green growth exponents also emphasise its higher job-generating capacities compared with traditional growth paths. Green growth considers that market failures and pricing of resources are the key issues to be addressed.

The green growth concept has primarily been embraced by industrialised countries as a way out of the present economic recession, due to its combined promise of economic growth and employment generation without fundamental challenges to the basic premises of existing economic structures. While green growth can lead to a more resource-efficient economy, it still represents an unsustainable path to development; the physical limits of the planet would just be met at a slower pace (AtKisson, 2012).

1.1.3 *Green economy*

In order to combine the positive aspects of a green growth strategy, with actual sustainable development, a new initiative by the United Nations Economic and Social Commission for Asian and the Pacific (UNESCAP) was launched in 2008, namely the "Green Economy" (Allen and Clouth, 2012). This initiative complements the green growth approach seeking to ensure that the sum of all economic activities ultimately lead to maintaining economic development within the limits of what the planet can sustain. It considers it possible to include selective de-growth, i.e. curtailing activities in certain sectors. While green growth still essentially leaves the market to determine the growth path, the "green economy" concept accepts the need for some government intervention and requests other indicators beyond GDP growth. UNEP defines green economy as "result[ing] in improved human wellbeing and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP, 2011). However, agreement on green economy indicators proves difficult, and at present green growth remains the main strategy.

In sum, the difference between the two concepts is that green growth is a development strategy striving to introduce sustainable development in economic activities already implemented in many regions of the world, while the green economy concept is a more comprehensive approach that gives a vision of the economy we should strive for.

1.1.4 Europe's green growth policy approach

The EU has embraced the concepts of sustainability and green growth in its economic strategy documents. The latest Europe 2020 strategy follows the "green growth" approach, seeking to achieve smart, sustainable and inclusive growth. The strategy targets the dual objective of helping Europe achieve economic growth and increase employment, while also keeping in line with its commitments in the area of climate change. The employment dimension is included in the headline declarations of the Commission's climate and energy package: "It is estimated that meeting the 20% renewable energy target could have a net effect of creating around 417,000 additional jobs, while getting on track to achieve the 20% energy efficiency improvement in 2020 is forecast to boost net employment by some 400,000 jobs" (European Commission, 2013b).

The strategic documents of the EU are based on the concepts of "sustainable growth" and "green growth", but while these terms have a specific historical and theoretical foundation, the EU has adapted them and developed its own interpretation. This section compares the concepts as defined in Section 1.1 above with the EU's interpretation.

1.1.4.1 The 1993 White Paper on competitiveness and growth

The green technology path predates by two decades the newest Europe 2020 strategy, well before the green growth concept was developed. After the creation of the single market in 1992, the EU sought to work out its development strategy, aware that its growth rates were below potential. The growing awareness of the lack of sustainability in the Western economic model led to the White Paper of 1993 on competitiveness and growth (European Commission, 1993). In the White Paper the EU sets out its economic development vision, which incorporates the need for a more sustainable socio-economic and environmental development path, seeking growth within the context of a knowledge-based, innovative and clean economy.

The strategy was based on two pillars: knowledge and innovation on the one hand, and sustainability on the other. The first pillar is largely based on the writings of the economist Joseph Schumpeter, who stipulates that economic growth is driven by innovation. The strategy went beyond the focus on resource efficiency (including energy efficiency and pollution abatement) to outline benefits in terms of growth, competitiveness and employment. To some extent, this can be considered a first step towards the sustainable development concept, within the bounds of the European economic reality, and resembles the green growth strategy concept emerging a decade later. Energy efficiency and resource efficiency are already presented as important tools to expand competitiveness[2] as well as reducing the ecological damage in Europe originating from industries.

The publication of the White Paper, while influential to some extent, did not lead to significant policy actions. Growth rates were still sluggish compared with the US, while emerging economies became an increasing competitive challenge for Europe, threatening its trading position in many sectors.

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[2] "Ecotechnologies will soon provide a major competitive advantage" (European Commission, 1993).

1.1.4.2 *The Lisbon strategy*

As a response to the lack of structural reform in member states, the EU launched in 2000 the so-called Lisbon strategy, which set the ambitious objective to "[by 2010] become the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion" (European Parliament, 2000). The Lisbon strategy was based on the same principles as the White Paper.

The Lisbon strategy, however, did not include particular obligations for member states, or targets, or a clarification of what the "most dynamic knowledge economy" meant in practical terms. Member states officially committed to following the general recommendations through national policy reforms. However, a mid-term review in 2004 (the "Wim Kok report") showed progress to be very limited. This led to an attempt to strengthen the strategy with a stronger focus on growth and jobs ("the Lisbon II strategy").

Nevertheless, the lack of solid commitments and the focus on often-chaotic emergency policy responses to the financial crisis led again to a lack of tangible results. However, the severity of the financial crisis and its impacts laid bare the structural weaknesses of member states. Weak innovative capacity, lack of skills, inflexible and low-skilled labour markets were linked not only to economic depression, but also to the prospect of a long recession and an erosion of European trade competitiveness. This led to a new impetus and to the introduction of the Europe 2020 strategy, a growth strategy for the period 2010-2020.

1.1.4.3 *The Europe 2020 strategy*

Europe 2020 focuses on overcoming the economic crisis and is still significantly linked to the 1993 White Paper. It has strengthened its sustainability objectives, and in particular the focus on energy and resource efficiency, which is influenced by the EU policy on climate change, as well as concerns about energy security. The main focus is on decoupling growth and resource consumption, which would allow the pursuit of economic growth while at the same time decreasing its damaging effects on the environment. Europe 2020 thus follows primarily the green growth approach, but it also integrates some elements of sustainable development in its environmental and social dimensions. It is based on three growth pillars: smart, sustainable and inclusive growth. These aim at developing an economy based on knowledge and innovation, promoting a more resource-efficient, greener and more competitive economy, fostering high-employment, as well as delivering social and territorial cohesion. It is not, however, a green economy strategy. Europe 2020 has as a primary overarching goal to foster growth and employment and is set up as a strategy to re-launch the economy and foster competitiveness, and not as such to ensure real sustainability, as defined by the green economy concept.

In order to achieve the three growth pillars, the EU has listed the following five headline targets, giving a quantitative meaning and focus to the strategy. By 2020 the EU should:

- employ 75% of 20-64 year olds;
- invest 3% of the EU's GDP in research and development;
- reduce GHG emissions by 20% or even 30% compared with 1990 levels, create 20% of EU energy needs from RES and increase energy efficiency by 20%;

- reduce school dropout rates to below 10% and ensure that at least 40% of 30–34 year olds complete tertiary education; and
- reduce poverty and lift at least 20 million people out of the risk of poverty or social exclusion.

Contrary to its predecessors, this strategy articulates its priorities through specific targets, which are to be translated into national targets in each EU member state. These targets are also reflected in the seven flagship initiatives, which provide the framework for the actions of the EU and member states towards the objectives of Europe 2020. Table 1 relates the flagship initiatives to the three pillars of Europe 2020.

Table 1. The Flagship initiatives

Smart Growth	*Sustainable Growth*	*Inclusive Growth*
Digital Agenda for Europe	Resource-efficient Europe	An agenda for new skills and jobs
Innovation Union	An industrial policy for the globalisation era	European platform against poverty and exclusion
Youth on the move		

Source: European Commission, 2012a.

All initiatives integrate aspects of "green growth", such as the reinforcement of the research into renewable energy for Horizon 2020 called for by the Innovation Union flagship initiative, but the Resource-efficient Europe initiative (European Commission, 2011b) is the core of the green growth component. This initiative aims to change the way the economy works by reducing its reliance on non-renewable energy and finite resources, while promoting the efficient use of all inputs and reducing pollution and waste. The flagship initiative seeks to focus on developing the green technology market. This should lead to a more sustainable as well as more competitive Europe by:

- boosting economic performance while reducing resource use;
- identifying and creating new opportunities for economic growth and greater innovation, and boosting the EU's competitiveness;
- ensuring security of supply of essential resources; and
- fighting against climate change and limiting the environmental impacts of natural resource use (European Commission, 2011b).

The Resource-efficient Europe initiative includes a wide range of components in many different policy areas. Several EU-level initiatives related to energy efficiency, the transition to a low-carbon economy, reform of the Common Agricultural Policy (CAP), and the strategy to make the EU a "circular economy", are expected to contribute to the implementation of this initiative. Key benchmarks for the initiative form part of the Europe 2020 headline targets, which are:

- a 20% reduction in greenhouse gas emissions (30% if the conditions are right);
- a 20% share of renewable energy sources in final energy consumption; and
- a 20% improvement in energy efficiency.

The focus of the European Commission's flagship initiative on resource efficiency and more sustainable technologies is reflected in the different communications outlining strategies for the research, economic and industrial policies focusing on green technology development (European Commission, 2012b and 2012c).

The Resource-efficient Europe initiative is supported by the 2012 Employment Package (European Commission, 2012d) regarding the link between green growth and jobs. It is detailed in the next section.

1.2 The green jobs approach

As explained above, in Europe, a first mention of the employment benefits of opting for sustainable development can be found in the 1993 White Paper (European Commission, 1993); the first sentence combines the concept of sustainable development with the needs of international competition and job creation.[3] The underlying logic of green growth (creation of jobs through environmental protection-related activities) is already included.[4]

The link between green growth and jobs was recently reinforced in the 2012 Employment Package (European Commission, 2012d), which the European Commission introduced to support the Europe 2020 strategy's flagship initiatives, through synergies between employment and the sectors tackled by the initiatives. "The changeover to a green, low carbon and resource-efficient economy" is one of the "longer term structural transformations" that reshape economic activities in Europe and thus affect the labour market (European Commission, 2012d: 2).

In an accompanying document to the 2012 Employment Package (European Commission, 2012e), the Commission defines green jobs as "jobs that depend on the environment or are created, substituted or redefined (in terms of skills sets, work methods, profiles greened, etc.) in the transition process towards a greener economy" (European Commission, 2012e: 4).

However, there is currently no commonly agreed definition of green jobs. The definitions proposed by the International Labour Organization (ILO) and the United Nations Environment Programme (UNEP) are the most quoted:

- ILO: Jobs are green when they help reduce negative environmental impact, ultimately leading to environmentally, economically and socially sustainable enterprises and economies (ILO, 2013).
- UNEP: Green jobs are those that contribute appreciably to maintaining or restoring environmental quality and avoiding future damage to the Earth's ecosystems (Renner et al., 2008: 35).

A definition with moving boundaries, however, allows for different methodologies to estimate the number of green jobs, leading to difficulties in comparing the results of studies. Moreover, the use by ILO and UNEP of broad categories shows that it is difficult to classify green jobs at the individual level. Among other issues, it also raises the question of whether "brown jobs" in the value chain can be considered as green as long as they ultimately contribute to one of the purposes included in the definition (e.g. jobs in the steel industry that supply wind turbine manufacturers). This question,

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[3] "This White Paper sets out to foster debate and to assist decision-making at decentralised national or Community level - so as to lay the foundations for sustainable development of the European economies, thereby enabling them to withstand international competition while creating the millions of jobs that are needed" (European Commission, 1993: Preamble).

[4] "[...] several estimates agree that some three million new jobs could be created in the Community, covering local services, improvements in the quality of life and environmental protection" (European Commission, 1993: 20).

however, is outside the scope of this paper, which focuses on direct jobs only (i.e. not on jobs in the supply chain, see Section 3.1.1.1).

2. A changing energy sector

This chapter outlines the evolution of the energy sector in the context of socio-ecological transitions. It gives an overview of past transitions and their impact on energy use, before describing the state of the current energy sector in Europe today with a focus on the power sector. Finally, the chapter analyses what kind of changes can be expected in the power sector as the "new" SET unfolds.

2.1 Energy transitions

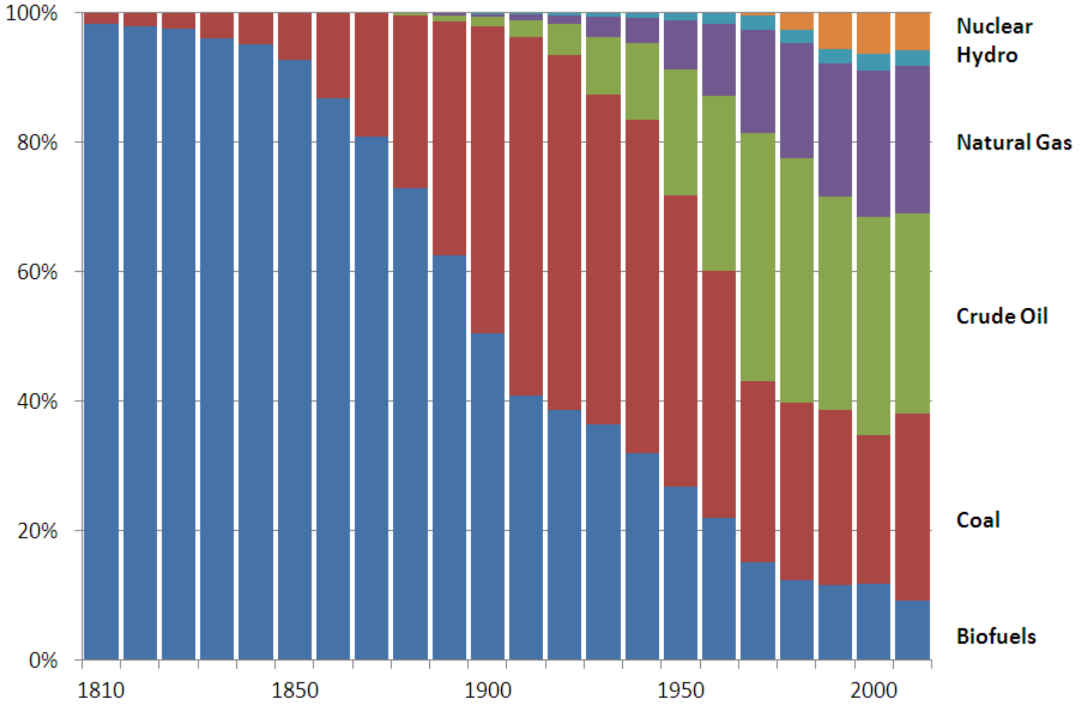
The energy sector has been subject to substantial changes as societies have progressed from one socio-ecological regime to another. This section will give a brief overview of various socio-ecological regimes, past socio-ecological transitions from one such regime to another, as well as the implications of these transitions for energy use.

As noted in the introduction, a regime is defined as "a specific fundamental pattern of interaction between (human) society and natural systems" (Fischer-Kowalski and Haberl, 2007). Historically, human societies have been organised within three socio-ecological regimes: hunter-gatherers, the agrarian regime and the industrial regime (which can be divided into the coal-based industrial regime and the oil-based industrial regime). In addition, a post-industrial sustainability regime can be seen as a new fourth regime in the future (Behrens, 2011).

Various socio-ecological regimes can coexist in different parts of the world. While only few hunter-gatherer societies/tribes still exist today, agrarian societies are more widely spread, particularly in some of the least developed countries (LDCs). The most common system of societal organisation is the industrial society with high levels energy and resource use. In fact, many countries are still in the process of industrialisation today (e.g. China, India, Turkey). Industrialisation is associated with a large number of environmental and societal challenges, including climate change, biodiversity loss, pollution of land and water bodies, etc. This may require a comprehensive change in the patterns of social organisation and culture, production and consumption as humanity progresses beyond the current industrial model towards a more sustainable society.

Based on the distinction between different socio-ecological regimes, two grand historical regime changes, or socio-ecological transitions, have been described by Sieferle et al. (2006). The first was the Neolithic Revolution some 4,500-10,500 years ago, transforming hunter-gatherers into agrarian societies (Diamond and Bellwood, 2003). Hunter-gatherers live off food and materials obtained from wild animals and plants. This regime is thus based on passive solar energy utilisation, i.e. humans do not actively interfere with ecosystems (or only to a very limited extent). With the transition to agrarian societies, humans progressively colonised terrestrial ecosystems with the aim to harvest food and feed for human reproduction. This kind of active solar energy utilisation allowed for a raise in annual per capita energy consumption, though at very high human labour inputs (up to 100% of the labour power of a population) (Fischer-Kowalski et al., 2012). As shown in Figure 1 (albeit on the global scale), the main source of energy in this system is biomass, used both to generate thermal energy (e.g. through the combustion of wood) and mechanical energy (as food and feed for humans and animals). In addition, wind and hydro power (i.e. wind mills and water wheels) play a limited role.

Figure 1. Visualising transitions in global energy consumption by energy source, 1800-2008



Source: adapted from Smil (2010).

The second major regime change was the Industrial Revolution in the 18th and 19th centuries, in which agrarian societies were transformed into industrial societies. The key of this regime change was the transition from solar energy utilisation to fossil fuels, first coal and in the 20th century increasingly oil and gas (see Figure 1). This lifted the pressure on land as the limiting factor for the production of energy and food/feed. Indeed, Sieferle et al. (2006) note that unlike other fuels, fossil fuels were no longer in competition with other forms of land use and freed up large areas of land for agricultural production to feed growing populations. However, this positive effect of gaining independence from land as a limiting factor for energy production was accompanied by the negative effect of environmental externalities in the form of pollution and GHG emissions. Fischer-Kowalski and Hüttler (1999) give an overview of the main concerns related to the resource and energy use of contemporary industrial societies. These concerns mainly focus on the exhaustion of resources, pollution and the sheer scale of turnover and growth of the material and energy throughput of the socio-economic system (also due to the increasing role of emerging economies).

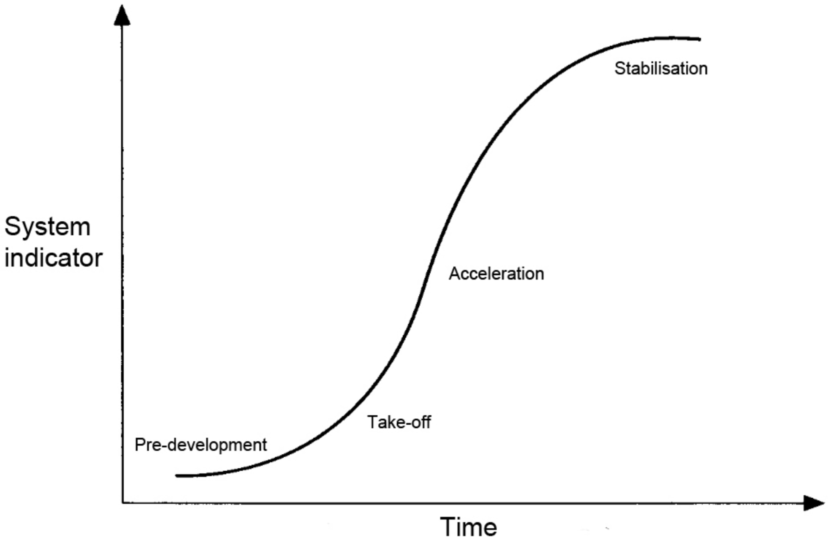
Restructuring the industrial metabolism with the aim of reducing the pressures on the natural environment from societal activities will require yet another grand socio-ecological regime change, geared towards the long-term sustainability of the society-environment interaction (Behrens, 2011). It has therefore been defined as a transition "away from fossil fuels, towards solar and other low-carbon energy sources" (Fischer-Kowalski et al., 2012). This will entail a substantial restructuring of the EU energy system, which is still largely based on fossil fuels, towards renewable energy sources and other low-carbon energy technologies. Behrens et al. (2013) have given an overview of what such a sustainability-based energy system may look like. However, as with previous transitions, the availability of new technologies will not be sufficient to start the transformation process. Fundamental change can only be achieved if technology is able to achieve positive feedback with complementing technical, cultural, economic and social developments (Sieferle et al., 2006).

The next subsections of this chapter will give an overview of the current EU energy system, and in particular of the power sector. This will be the picture of a mature, stabilised industrial society highly dependent on fossil fuels. Later on in this chapter, there will also be an assessment of how the power sector will need to change as the "new" socio-ecological transition unfolds.

2.2 The current EU energy supply sector

Before describing future trends in the EU energy supply sector, it is useful to give a brief account of its current state from the view of transition theory. Transition research has identified several theories or models of how socio-ecological transitions proceed. Historical analyses of such transitions suggest different phases. A typical model describing these phases is the S-curve, as shown in Figure 2. It describes four phases of a transition, starting from the pre-development phase, continuing to the take-off phase and, after an acceleration phase, settling into a stabilisation phase. Loorbach (2007) explains that there is little visible change other than experimentation in the pre-development phase. In the take-off phase, the system begins to change, while it is the acceleration phase where "structural changes take place in a visible way through an accumulation of socio-cultural, economic, ecological and institutional changes" (Loorbach, 2007: 19). These changes eventually lead to a new equilibrium in the stabilisation phase, where the speed of societal change decreases.

Figure 2. The four phases of a socio-ecological transition

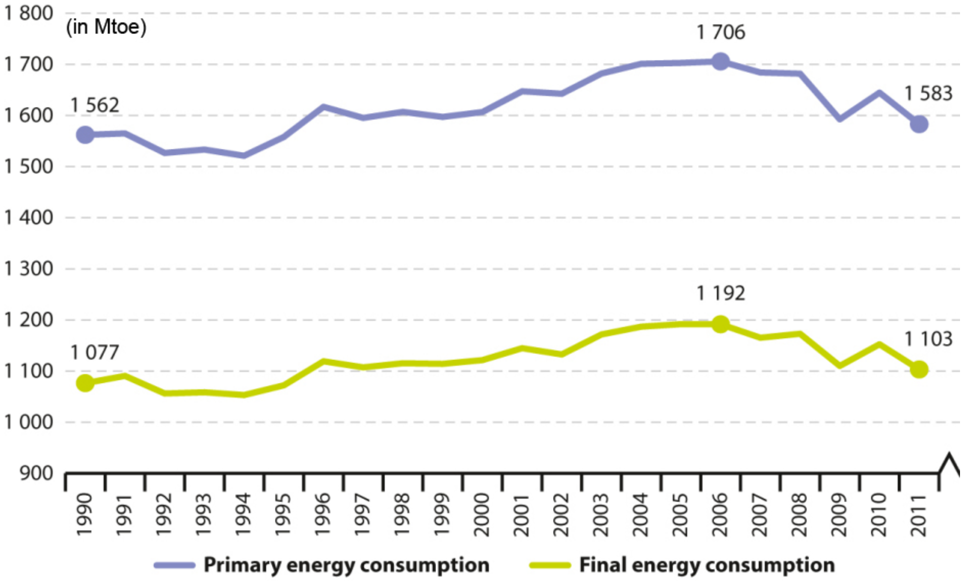


Source: adapted from Loorbach, 2007.

According to this logic, most EU member states have reached the stabilisation phase of the industrial regime and are characterised by high but relatively constant levels of consumption. This is true in terms of both resource and energy consumption. According to Fischer-Kowalski et al. (2012), the shift from the acceleration phase to the stabilisation phase can be observed since the early 1970s and is closely linked to the oil crises in that decade. Equally, they find that signs of a new transition to sustainability are still sparse.

Figure 3 shows that both primary energy consumption and final energy consumption continued to increase since 1990 and reached an all-time high in 2006. Since then they have decreased, partly due to the economic crisis and partly due to energy efficiency measures.

Figure 3. Development of primary energy consumption and final energy consumption in the EU27, 1990-2011 (Mtoe)



Source: Eurostat (2013a).

The EU remains one of the biggest energy-consuming regions in the world. In 2011, the EU member states were responsible for nearly 17% of global demand for primary energy (IEA, 2013) with total final energy consumption of the EU27 reaching 1,103 Mtoe (Eurostat, 2013b). As illustrated by Table 2, the transport sector accounted for the largest share (33%) of total final energy consumption, followed by industry (26%) and the residential sector (25%).

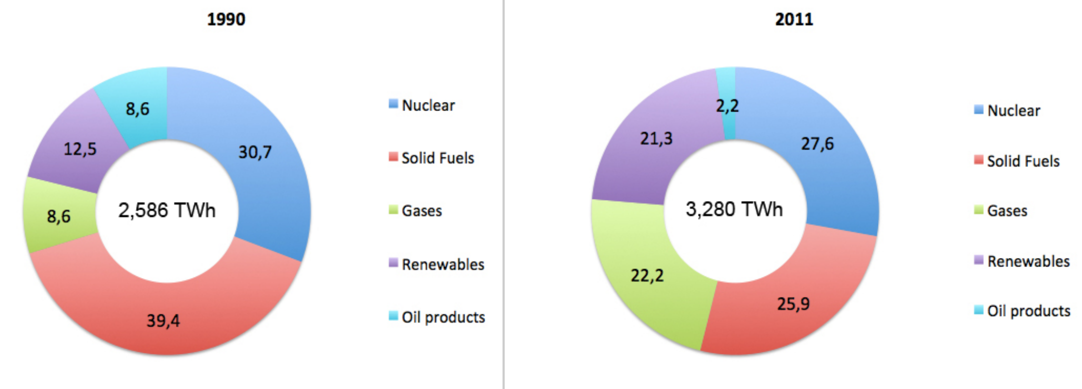
Table 2. Final energy consumption in the EU27 (2011 data)

Sector	*Final energy consumption (Mtoe)*	*Share of final energy consumption*
Transport	364	33%
Industry	287	26%
Residential	273	25%
Services	141	13%
Agriculture	24	2%
Non-specific	14	1%
Total	1,103	100%

Source: Eurostat, 2013b.

According to the European Commission (2013a), the power sector alone consumed the equivalent of 314 Mtoe, accounting for 26% of the EU's final energy consumption. Power is thus a major component of EU energy consumption and demand for electricity increased substantially between 1990 and 2011. In 1990, electricity generation in the EU27 was at 2,586 TWh, rising to 3,280 TWh in 2011, representing a 27% increase over that period (European Commission, 2010, 2013a). The high dependence of electricity generation on fossil fuels is reflective of the industrial regime in its stabilisation phase. In fact, the share of fossil fuels in gross electricity generation of the EU27 only decreased by about six percentage points, from 57% in 1990 to 50% in 2011.[5] While the role of coal (and oil) decreased to the benefit of gas over this period, coal remains the second largest source of electricity in 2011 (26%) after nuclear power (28%). Other sources of power generation are natural gas (22%), RES (21%) and oil products (2%). Figure 4 shows how the composition of the electricity mix shifted between 1990 and 2011.

Figure 4. Gross electricity generation in the EU27 by fuel (%)



Sources: European Commission, 2010 and 2013a.

Signs of a decarbonisation of the power sector are the increasing penetration of RES in the power mix. Hydro, wind power and biomass play the largest role, while solar, geothermal and other RES remained marginal in 2011. However, it should also be noted that the decline of the share of nuclear power has counterbalanced the GHG emissions reductions caused by an increasing share of RES to some (albeit limited) extent. Table 3 summarises the contribution of each fuel type to EU27 gross electricity generation in 2011.

Table 3. Electricity production by source in the EU27 (2011 data)

Fuel type	*Power production (in TWh)*	*Share of total production*
Nuclear	906.8	28%
Solid fuels	848.7	26%
Gases	726.5	22%
Oil products	73.6	2%
Hydro	335.2	10%
Wind	179.0	5%
Biomass	132.6	4%
Solar	46.3	1%
Geothermal	5.9	0.2%
Ocean	0.5	0.02%
Total	3,279.6	100%

Source: Eurostat, 2013b.

In terms of structure, the EU power system is largely centralised. This means that large-scale and centralised power plants contribute the bulk of electricity generation.

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[5] The difference is due to rounding.

There are few electricity producers located close to consumers. In fact, adding the shares of nuclear, coal, gas, oil and (large) hydro shows that 88% of electricity in the EU was produced in large generation facilities in 2011. Through an interconnected grid, the electricity generated is transmitted and distributed to largely "passive" consumers with very little demand response. This centralised approach also has an influence on the structure of the electricity grid. The current power grid has been designed to mainly transmit single-direction flows from large-scale power generators, at a high voltage level, to consumers at a lower voltage level. It has not been designed to transmit a large amount of electricity in the opposite direction, i.e. from a low voltage level to a high voltage level. This is especially the case for the distribution grid. The centralised system grew historically because it offered a more cost-efficient way to satisfy the electricity demand, mainly because of economies of scale and better reliability (e.g. fewer blackouts). However, its high dependence on fossil fuels has raised environmental criticism and a transition towards a decentralised power system has already begun (Altmann et al., 2010). This transition can especially be observed in Germany. Here, decentralised solar photovoltaic systems have reached an installed capacity of more than 30 GW. This is comparable to about 30 nuclear power plants.

As will be shown in the next section, a transition to a decentralised power system will facilitate the uptake of small, renewable generation capacity with a potentially positive effect on GHG emissions. Currently, however, high dependence on fossil fuels still causes electricity and heat production to contribute the largest share (37%) to CO_2 emissions in the EU, followed by transport (24%) and construction and manufacturing (15%) (IEA, 2012a). This underlines the importance of the power sector to decarbonisation of the EU economy in the context of a new socio-ecological transition towards sustainability.

2.3 The future EU energy supply sector

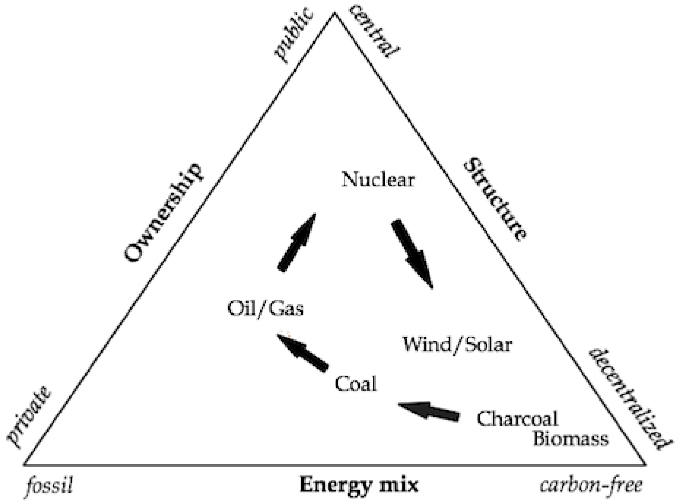
One of the main goals of current EU policy is the transformation of the European energy sector to a competitive low-carbon system. This is to be achieved within an overarching long-term objective of reducing EU GHG emissions by 80-95% by 2050 (compared with 1990).

There is a general consensus that RES will be a major driver for achieving this goal. On the policy level, the Renewable Energy Directive (Directive 2009/28/EC) sets a binding EU-wide target to increase the share of renewable energy in the EU's total energy consumption to 20% by 2020. According to a proposal of the European Commission, this share should increase in the context of an EU-wide binding target to 27% by 2030 (European Commission, 2014). This would result in an increase in the share of renewable energy in the electricity sector from 21% today to some 34% in 2020 and at least 45% in 2030. RES are thus likely to play an ever-increasing role in power generation (see also the scenario analysis by Behrens et al. (2013)), which may be an indication that the energy system is moving into the pre-development phase of the new SET towards sustainability.

However, the current centralised generation paradigm is not likely to facilitate this transition. Although it could technically support large generation facilities producing low-carbon electricity based on coal with CCS, nuclear fission and – eventually, maybe – nuclear fusion, it is much more likely that a more distributed electricity generation system will develop, driven by the ongoing liberalisation of the EU electricity (and gas) market as well as by concerns over GHG emissions. The drive for increasingly decentralised generation is further enhanced by developments in distributed generation technologies, constraints on the construction of new transmission lines, as well as increased customer demand for highly reliable electricity (IEA, 2002).

Burger and Weinmann (2013) describe the changes in the energy mix, structure and ownership as an energy system trajectory (see Figure 5). According to their view, early civilisations collected wood and produced charcoal in a local setting. Their energy system was thus highly decentralised, private and largely carbon-free. With the depletion of forestry reserves and the introduction of the steam engine, coal replaced biomass as the most important energy source. Similarly, as the industrial revolution unfolded, larger power plants were needed for manufacturing and electricity provision. The rise of oil and gas in the second half of the 20th century further changed the energy system to an ever more centralised and public system based on fossil fuels. With the introduction of nuclear power plants and large hydro, economies of scale reached their peak in a highly centralised system, albeit with an increasing share of low-carbon fuels. This trend continues with climate change as the driving force behind the increasing penetration of wind and solar. However, these new RES flourish in an increasingly liberalised market setting where private investors build small-scale supply structures. Burger and Weinmann (2013) thus argue that the configuration of the energy system in the future could return to where it started: decentralised, carbon-free and privately owned.

Figure 5. The energy system trajectory



Source: adapted from Burger and Weinmann (2013).

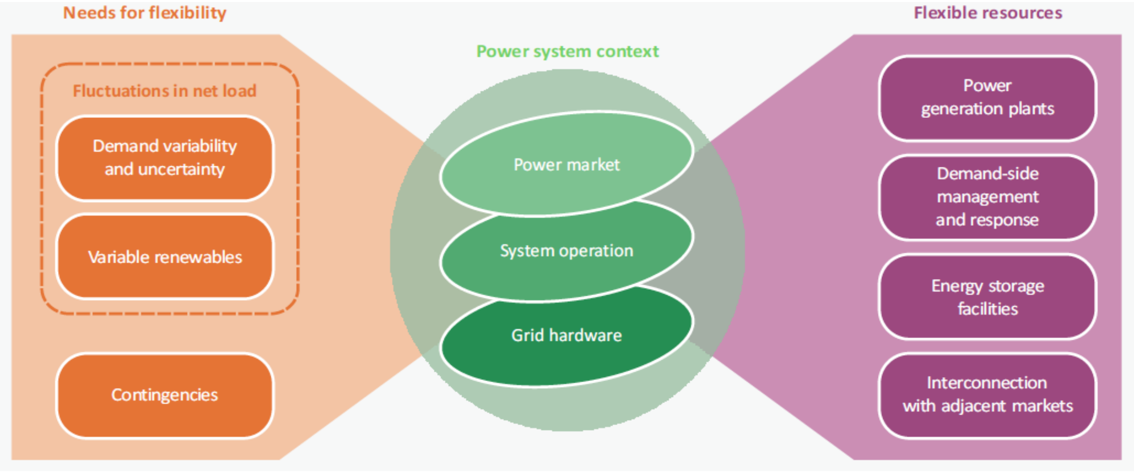
Many definitions of distributed (or decentralised) generation exist, usually referring to small-scale generation units located close to the load. The EU "electricity directive" (2009/72/EC) defines distributed generation as generation plants connected to the distribution system. Ackermann et al. (2001) go a step further by also including electric power generation units connected directly to the network on the customer side of the meter. In practice, there is consensus that distributed generation units are connected to the distribution network, are not large-scale, have strong local dependencies (e.g. based on local RES), often generate power used by the producer, and are generally owned by relatively small actors on the electricity market (Altmann et al., 2010). These distributed power sources may also be connected to a "smart grid" linking several self-optimising micro-grids to ensure that supply matches demand at all times based on real-time information systems (Larsen and Sønderberg Petersen, 2005).

Some of the key benefits of such a decentralised system include higher electrical efficiency (by avoiding losses associated with transmission lines), lower variable and maintenance costs for certain technologies (e.g. wind and solar power), and possibly lower emissions through a higher share of RES. Moreover, a decentralised system offers the chance to let citizens participate in the local development and exercise more control over it. Investments in decentralised power generation technologies like wind and solar power are relatively small and can therefore be made by local residents or cooperative societies mainly owned by residents instead of big companies. In Germany, the number of newly created cooperative societies in the energy sector increased from eight per year in 2006 to 150 per year in 2012. In most cases, the share of private equity is very high, well above 50%. As of 2012, these energy cooperatives have invested €1,200 million in total (DGRV, 2013).

However, the transition from a centralised to a decentralised/distributed system of generation will require substantial changes in network infrastructure. The current distribution grid was designed to transmit electricity from a high voltage level (where the generators are located) to a low voltage level (where the consumers are located). The increasing share of decentralised production will invert the direction of flows. To handle these events, the grid infrastructure needs to be upgraded. For example, more flexible local power transformers have to be installed to decouple voltage control for the low voltage system from the voltage control for the medium voltage grid (DENA, 2012). In general, more grid services will have to be provided at a lower voltage level. Decentralised plants have to take over grid services such as frequency control and balancing, as these are currently provided by centralised power plants. This will require additional technology for both plant and grid monitoring. Finally, both local supply and local demand will have to become more flexible, through the use of smart meters operating in smart grids, for example (EPRI, 2011). In fact, over the whole energy system, it will be crucial to maintain the balance between supply and demand in electricity grids at all times, additional flexibility will be required in electricity systems to integrate variable renewable electricity generation (RES-E) into markets and grids. Additional flexibility of the power system will also be required due to demand variability and uncertainty, as well as general contingencies. The IEA describes power system flexibility as the "extent to which a power system can modify electricity production or consumption in response to variability, expected or otherwise. In other words, it expresses the capability of a power system to maintain reliable supply in the face of rapid and large imbalances, whatever the cause" (IEA, 2011a: 35). Providing sufficient power system flexibility will be a crucial aspect for the power sector to maintain security of supply in the context of decarbonisation.

As shown in Figure 6, the need for more flexibility can be met by four flexible resources (IEA, 2012b): generation, demand response, storage and interconnections. Both centralised and distributed generation technologies can provide back-up capacity when RES-E supply is insufficient. In particular, open-cycle gas turbines (OCGTs) have relatively short start-up times (less than 20 minutes in the case of OCGTs) and can thus help balance supply and demand for power quickly when needed. Similarly, RES units can reduce power production in times of oversupply. On the demand side, load shifting and peak shaving can provide additional flexibility, provided that consumers have the right (price) information to adapt their behaviour where possible. In addition, energy storage technologies (e.g. pumped hydro, compressed air energy storage) can be used to decouple demand and supply. They can store power from variable RES when supply is too high and release it again as needed, thus contributing to balancing electrical energy and power. Finally, extending the grid can increase the flexibility of a power system, as fluctuations in wind power production even out when connecting regions with different wind regimes.

Figure 6. Overview of flexibility needs and resources



Source: IEA, 2012b.

A key feature of a future power system based on RES will be the rising levels of electric capacity to provide lower capacity factors of RES.[6] In fact, Behrens et al. (2013) observe that all decarbonisation scenarios analysed in their study project an increase in installed electric capacity larger than the increase in power output. Their scenario analysis reveals that by 2020, EU electricity demand is projected to grow by 5-10% compared with 2010, while electrical capacity is projected to increase by 20-30% over the same time period. By 2050, electricity demand may have increased in the range of 30-50% compared with 2010, while electric capacity could double by then (Behrens et al., 2013). The largest increase in electric capacity is projected in the European Commission's High-RES scenario (see Chapter 3), which might require additions of 170% by 2050 (compared with 2010).

Figure 7 shows the average capacity factor of power plants, i.e. the ratio between actual full load hours and the total number of hours per year (8,760), for two scenarios published in the European Commission's *Energy Roadmap 2050* (the Diversified supply technologies scenario, and the High-RES scenario). Unsurprisingly, there is a downward trend in average capacity factors as the share of variable RES in total installed capacity increases (in particular, wind and solar). Moreover, there is an evident difference between the two scenarios after 2020. Due to the higher share of RES, the load factor is up to eight percentage points lower in the High-RES scenario. This means that, on average, power plants will run at full load for only 2,317 hours per year in 2050. Currently, the average full load hours approximately amount to 4,000.

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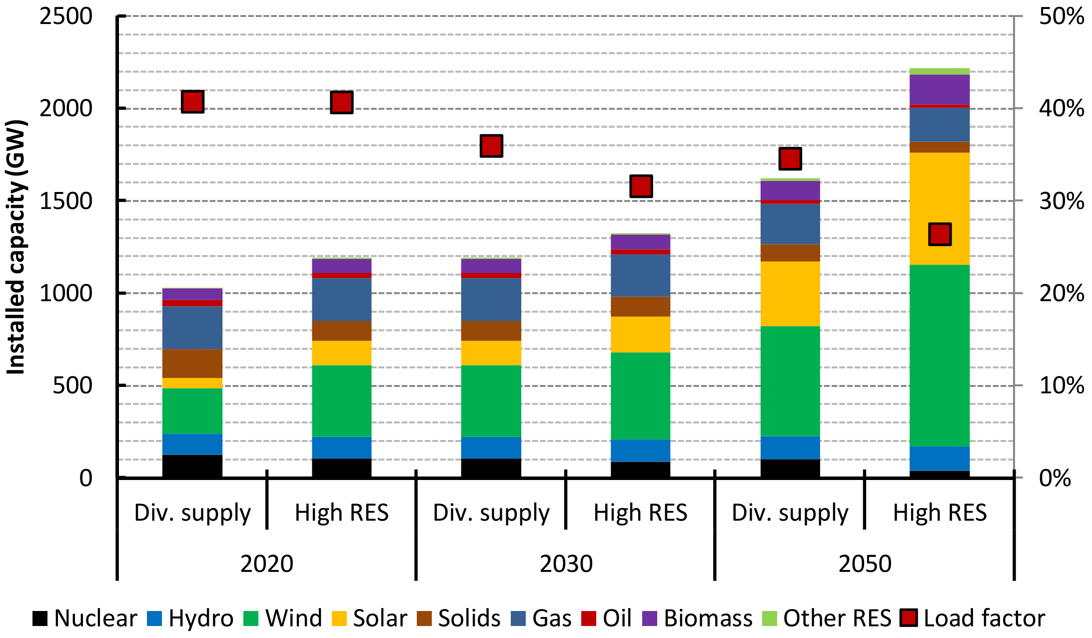
[6] As previously mentioned, wind and solar units are not dispatchable. Their generation (measured in watt-hours) depend on the availability of wind and solar radiation, which, in turn, depends on the location and the latitude of the plant. In Germany, solar photovoltaic units typically reach 1,000 full load hours. This means that a unit with an installed capacity of 10 kW will yield an annual electricity production of 10,000 kWh. For wind turbines, the full load hours range between 1,800 and 2,200. In contrast, dispatchable units like coal-fired power plants can reach much higher full load hours. Assuming a technical availability of 90% (due to maintenance and revisions), in theory values of up to 7,884 full load hours are technically feasible (based on a total of 8,760 hours per year).

Figure 7. Installed generation capacities (in GW) and capacity factors (in %) in 2020, 2030 and 2050



Source: European Commission, 2011a.

To summarise, as the energy supply system becomes increasingly decarbonised, decentralised and privatised in the future, more capacity will be required but the utilisation of this capacity will decrease. The exact extent of increasing capacity and declining utilisation will depend on the availability of flexibility options.

3. Effects on employment in the energy sector

This chapter describes what the current and future features of the energy sector outlined in the last chapter might mean in terms of employment. It starts with the current employment situation in the EU's energy supply sector and continues with an assessment of how employment levels and employment structure might develop as the energy sector continues to decarbonise through the years 2020, 2030 and 2050.

3.1 Employment in the current EU energy supply sector

Before assessing the impact of decarbonisation on the energy supply sector it is necessary to describe the status quo. Employment can be defined by the following characteristics:

- employment levels;
- employment structure; and
- labour intensity.

"Employment level" refers to the number of people employed in a sector. The "employment structure" of a sector is the distribution of workers over some selected qualitative variable (e.g. education level, occupation, gender, age). "Labour intensity" refers to the number of people involved in a production process per unit of output. In this section, the current employment characteristics of the EU energy supply sector are presented.

3.1.1 *Employment levels*

3.1.1.1 *Methodology and data sources*

In general, employment levels can be measured in three ways: direct employment, indirect employment, and induced employment. Direct employment figures use the primary activity to group employment levels. For example, direct employees in the wind industry are environmental engineers, manufacturing technicians, wind turbine installers, and so on. Indirect employment figures cover all jobs in the whole supply chain of the respective primary sector. For instance, a worker in the steel industry works indirectly for the wind industry if the produced steel is used to construct wind turbines. Finally, the jobs that result from the spending on goods and services by workers of the income generated by their primary activity are called "induced employment". This study focuses on direct employment figures in order to assess the impact of decarbonisation on the power sector. Indirect or induced employment figures are less suitable because of limited data availability and the issue of correctly assigning jobs to specific technologies. As the effects of decarbonisation are typically grouped by technology, it is more straightforward to assign technologies to jobs using direct employment figures. For example, the increase of solar or wind power is a typical result of decarbonisation scenarios. This figure can then be related to jobs in solar or wind power.

Eurostat provides three different statistical sets for direct employment figures: the Labour Force Survey (LFS) (Eurostat, 2013c), Structural Business Statistics (SBS) (Eurostat, 2013d) and national accounts (Eurostat, 2013e). Data in the LFS originate from European private households and cover employment, unemployment and inactivity. The LFS is the only module in Eurostat exclusively dedicated to the labour market. Data in SBS come from enterprises and cover business activities in industry, construction, trade and services.[7] National accounts come from member states and are compiled by Eurostat. They are not used in this study, because the categories are highly aggregated for the energy sector and data is incomplete.

Complete data in Eurostat's SBS are only provided until 2009. Incomplete data for 2010 and 2011 in SBS tables are thus substituted with estimates from DG Energy published in the last edition of the *EU Energy in Figures: Statistical Pocketbook* (European Commission, 2013a).

In order to calculate future employment levels, job numbers per energy activity should ideally be provided at very low levels of aggregation. Eurostat's LFS figures are more aggregated than those provided by SBS and DG Energy, and thus provide a lower level of detail. However, SBS and DG Energy figures can be used to break down LFS figures to derive a higher level of disaggregation or a better resolution. An explanation of the use of SBS and DG Energy figures to disaggregate LFS data is provided in Annex 3. This allows for comparable results of DG Energy estimates and LFS data.

The following categories in NACE Rev. 2 – the most recent version of the classification system of economic activities of Eurostat – are relevant to the energy sector (European Commission, 2008):

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[7] Due to the difference in methodology, figures in the LFS are generally higher than in SBS. In this report, data from the LFS forms the high end of employment ranges, while data from SBS forms the low end.

- B05 Mining of coal and lignite: "extraction of solid mineral fuels through underground or open-cast mining" and "operations leading to a marketable product" (e.g. grading, cleaning, compressing) (European Commission, 2008: 106).
- B06 Extraction of crude petroleum and natural gas: including "the production of crude petroleum, the mining and extraction of oil from oil shale and oil sands and the production of natural gas and recovery of hydrocarbon liquids, [...] the activities of operating and/or developing oil and gas field properties" (European Commission, 2008: 107). This category excludes oil and gas field services, oil and gas well exploration, test drilling and boring (see B09.1); this category is further divided in two groups:
    - B06.1 Extraction of crude petroleum: excluding the refining of petroleum products (see C19.2); and
    - B06.2 Extraction of natural gas.
- B07.21 Mining of uranium and thorium ores:[8] "mining of ores chiefly valued for uranium and thorium content [...]; concentration of such ores; manufacture of yellowcake"[9] (European Commission, 2008: 108); excluding enrichment activities.
- B08.92 Extraction of peat: peat digging and preparation of peat for transport and storage purposes (European Commission, 2008); manufacture of peat briquettes is included in C19.2.
- B09.1 Support activities for petroleum and natural gas extraction: "oil and gas extraction service activities provided on a fee or contract basis" (European Commission, 2008: 111) (e.g. exploration, directional drilling and redrilling, test drilling, liquefaction and regasification of gas for transport, draining and pumping services).
- C19 Manufacture of coke and refined petroleum products: "transformation of crude petroleum and coal into usable products" (European Commission, 2008: 138). This concerns mainly oil refining; this category is further divided in two groups:
    - C19.1 Manufacture of coke oven products: operation of coke ovens; production of coke and semi-coke, pitch and pitch coke, coke oven gas, crude coal and lignite tars; agglomeration of coke; and
    - C19.2 Manufacture of refined petroleum products: "manufacture of liquid or gaseous fuels or other products from crude petroleum, bituminous minerals or their fractionation products" (European Commission, 2008: 139); also including the manufacture of peat briquettes and hard-coal and lignite fuel briquettes.
- D35.1 Electric power generation, transmission and distribution: "generation of bulk electric power, transmission from generating facilities to distribution centres and distribution to end users" (European Commission, 2008: 202); also including the trade of electricity; excluding power generated through the incineration of waste.

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[8] That class is part of the energy sector but no data on employment is available on Eurostat. It will not be mentioned further in this study.

[9] Yellowcake is the fuel used in nuclear power plants.

- D35.2 Manufacture of gas; distribution of gaseous fuels through mains: "manufacture of gas and the distribution of natural or synthetic gas to the consumer through a system of mains" (European Commission, 2008: 202); also including the trade of gas; excluding the manufacture of industrial gases and long-distance transportation of gas through pipelines.[10]

This classification will be used in the next sections, as well as in the case studies. Based on this classification, Table 4 summarises key stages of supply side energy flows that are reflected in the analysis and a few which were not possible to take into account.

Table 4. Key stages of supply side energy flows included in the NACE Rev. 2 categories used in this paper

Activity	*Included*	*Not included*
Coal and lignite	Domestic EU extraction	Extraction outside EU
		Transport from extraction site to processing site
	Processing of both domestic and imported volumes (e.g. cleaning, sizing, compressing, etc.)	
	Manufacture of coke oven products	
	Manufacture of briquettes	
		Transportation of products to end users
Oil	Exploration	
	Drilling	
	Development and operation of oil fields	
	Domestic EU extraction	Extraction outside EU
		Operation of pipelines
		Shipment from extraction site
	Refining of both domestic and imported volumes (including the recovery of hydrocarbon liquids)	
		Distribution of refined products to end users
Natural gas	Exploration	
	Drilling	
	Development and operation of gas fields	
	Domestic EU production	Production outside EU
		Operation of pipelines

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[10] D35.1 "Electric power generation, transmission and distribution" and D35.2 "Manufacture of gas; distribution of gaseous fuels through mains" are two groups that are part of the division D35 "Electricity, gas, steam and air conditioning supply" in NACE. Group D35.3 "Steam and air conditioning supply" is not considered part of the energy sector in this study. The reasons are that it includes activities such as the production and distribution of cooled air, the production and distribution of chilled water for cooling purposes, and the production of ice, for food and non-food purposes (European Commission, 2008), which do not have the supply of energy as their main purpose. Moreover, it is not technology-specific, i.e. it is not relevant for the transition to low-carbon technologies for energy supply.

		Shipment from production site
	Manufacture of gas	Manufacture of industrial gases
		Long-distance transportation through pipelines
	Distribution of gas to final users	
	Trade of gas to final users	
Electricity (incl. RES)	Production of electricity in the EU	Production of electricity through the incineration of waste
	Transmission of electricity	
	Distribution of electricity	
	Trade of electricity	

Source: based on European Commission, 2008.

Table 4 shows that the above-mentioned NACE Rev. 2 categories include most stages of the energy flow, however data by individual stage (i.e. extraction, processing, conversion, transport, distribution, etc.) are not always available. In some instances, data are provided at high levels of aggregation (i.e. some of the above categories may be summarised into more aggregated categories). In these cases, the codes of the relevant categories will be provided in tables (where possible) to improve transparency (see, for example, Table 5).

3.1.1.2 Results

The total number of direct jobs provided by the EU energy sector in 2011 is estimated at between 1.5 million (DG Energy) and 2.2 million (Eurostat, LFS), representing a share of 0.7-1% of the total employed workforce in that year. DG Energy estimates and LFS data provide the low and high ends of the range, respectively, of employment levels summarised in Table 5. DG Energy and LFS data are roughly confirmed by estimates of industry associations.[11] There is a certain level of inaccuracy, because some industry estimates of direct jobs are derived from estimates that also include indirect jobs. Table 5 presents the range of employment levels resulting from the figures presented above. It shows that electric power generation, transmission and distribution (summarised in the category "electricity") is by far the largest employer, providing for roughly 55-60% of all direct jobs in the energy sector. The extraction of primary fossil fuels employs less than a quarter of all direct jobs, while other oil and gas activities (including oil refining, manufacture and distribution of gas) provide less than 20%.

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[11] See the list of industry associations in Annex 2. Given the role of associations of representing the interests of their members, their figures may be biased in favour of the represented industry. This is the reason why industry associations' figures are balanced against Eurostat data in this report.

Table 5. Direct employment in the energy sector, 2011

Activity	*Range*	*DG Energy*	*LFS*	*Industry*
Mining of coal and lignite [B05]	229,000 – 345,000	229,401	345,000	238,200[12]
Oil and gas extraction[13] [B06 + B09.1]	113,000 – 187,000	113,171	186,939	91,765[14]
Oil and gas other activities[15] [C19.2 + D35.2]	269,000 – 410,000	269,236	410,477	564,985[16]
Electricity [D35.1]	888,000 – 1,221,000	888,358	1,221,148	1,100,000[17]
Other[18] [B08.92 + C19.1]	21,000 – 27,000	20,593	26,669	n. a.
Total	1,500,000 – 2,200,000	1,520,759	2,190,233	1,994,950

Sources: European Commission (2013a); Eurostat (2013c, 2013d); industry associations.

3.1.2 *Employment structure*

3.1.2.1 *Methodology and data sources*

The employment structure of the energy sector can be assessed in terms of occupation type or education level. For an analysis of occupation types, jobs in an establishment, industry or country are organised in a clearly defined set of groups according to the tasks and duties undertaken (ILO, 2012). An analysis of educational levels, on the other hand, refers to the educational attainment of the labour force and thus to its levels and distribution of the knowledge and skills base.

For the purpose of this paper, education levels are preferred over occupation types because the latter may not provide sufficient information about the structure of education levels in the sector. For example, an occupational classification (e.g. managers) may include workers with different levels of education (a manager of an SME, for example, may have a low, medium or high level of education). In this chapter, the structure of employment is thus presented following the approach based on education level. This is in line with the purpose of the paper, which is to assess whether the transition to a low-carbon energy system in Europe causes a shift in the required levels of education of the labour force.

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[12] For 2012 (Euracoal, 2013).

[13] Oil and gas are aggregated to reflect the nature of the production fields, which most of the time produce both oil and gas. Figures from DG Energy and LFS include jobs in extraction and in support activities to extraction.

[14] Derived from unpublished data obtained during interview with OGP expert (2013).

[15] Other activities in oil include refining and marketing, and other activities in gas include manufacture of gas, distribution of gas, and trade of gas through mains.

[16] 285,256 jobs in oil, derived from 534 million hours worked in the downstream oil sector in 2012 (Burton and den Haan, 2013), assuming that people worked 36 hours per week; 279,729 jobs in gas (Eurogas, 2012).

[17] Estimation based on Eurelectric data (Eurelectric, 2012). An explanation of this estimate is provided in Annex 4. The estimate includes people employed in all power generation sources; it may double count workers that are already included in figures for employment in fossil fuels.

[18] Manufacture of coke oven products, and extraction of peat.

A common classification of education levels is the International Standard Classification of Education (ISCED) developed by UNESCO. In this classification, education programmes are grouped in levels of education following their degree of complexity and specialisation (UNESCO-UIS, 2012). Education levels can then be linked to broader qualification levels. Table 6 shows the relationship between levels of education in the 1997 version of ISCED[19] and levels of qualification used by Cedefop.[20]

Table 6. Relationship between Cedefop levels of qualification and ISCED levels of education

Qualification level (Cedefop)	*ISCED-97*	
Low	1	Primary education or first stage of basic education
	2	Lower secondary education or second stage of basic education
	3C	Programmes of short duration not designed to lead to ISCED 5
Medium	3 – excl. 3C	Upper secondary education
	4	Post-secondary non-tertiary education
High	5	First stage of tertiary education
	6	Second stage of tertiary education

Source: Cedefop, 2012a.

The three levels of qualification used by Cedefop range from low, to medium, to high education levels. The qualification level of a worker is defined as the highest education level obtained (Cedefop, 2012a). This classification corresponds to six ISCED levels of education, ranging from primary education to second stage of tertiary education. In the following sections of this paper, we will refer to Cedefop's classification.

3.1.2.2 *Results*

The results on the current employment structure will be presented in two parts. First for the entire EU energy supply sector, which implicitly includes RES in the power sector, and then specifically for the renewable energy sector, thus reflecting the importance of that sector in the new SET away from fossil fuels.

The EU energy supply sector

The Skills Forecasts online database of Cedefop (2013) provides estimations for the number of low, medium and highly qualified workers per energy activity. Table 7 presents Cedefop results for qualifications in the energy sector.[21]

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[19] ISCED was revised in 2011, but sources for this study use the 1997 version.

[20] Cedefop is the European Centre for the Development of Vocational Training.

[21] Cedefop's breakdown of activities is based on NACE Rev. 1.1, a previous version of NACE that differs slightly from the description of the energy sector based on NACE Rev. 2 (see section 3.1.1.1). Codes in brackets indicate the NACE Rev. 2 categories covered by Cedefop activities.

Table 7. Structure of qualification levels in the energy sector, 2012 (%)

Activities	*Low-qualified*	*Medium qualified*	*Highly qualified*
Mining of coal and lignite [B05 + B08.92]	10	75	15
Oil and gas extraction [B06 + B09.1 + part of B07.21] [22]	11	47	42
Manufactured fuels [C19 + part of B07.21] [23]	11	46	43
Electricity, steam and hot water supply[24] [D35.1]	8	55	37
Manufacture of gas and distribution through mains [D35.2]	7	60	33

Source: Cedefop, 2013.

According to this data, oil and gas extraction and the manufacture of fuels have the highest share of highly qualified workers. However, the distribution of levels of qualification is roughly similar for all energy activities, with the exception of coal and lignite mining activities, which employ by far the lowest share of highly qualified workers. More generally, around 10% of the labour force employed in the energy sector in 2012 were low-qualified, around 50-60% were medium qualified and around 40% were highly qualified.

Compared with the average of the overall EU economy, the energy sector employs a relatively higher-qualified labour force. Indeed, when taking into account all economic sectors of the EU in 2012, 22% of the labour force was low-qualified, 48% medium qualified, and 30% highly qualified (Cedefop, 2013).

The renewable energy sector

Given the increasing share of RES in power generation projected in most decarbonisation scenarios, the employment structure of the renewable energy sector is analysed in more detail in this section.[25]

In general, recent studies indicate that the renewables sector employs a relatively high share of highly qualified workers. Lehr and O'Sullivan (2009) surveyed renewable energy sector companies in Germany in 2007-2008 and show that one third of the labour force in the sector holds high-level qualifications. The Observatory for Sustainability in Spain surveyed companies of the renewable energy sector in Spain in 2009 and find that 50% of the sector's workforce has a tertiary degree (Jimenéz Herrero and Leiva, 2010). A third study, RenewableUK (2013), focuses on the wind and marine energy sector in the UK. Based on a survey of companies in the sector in 2013, it shows

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[22] The part of B07.21 that is included is the mining of uranium and thorium ores (Cedefop, 2012a).

[23] The part of B07.21 that is included is the manufacturing of nuclear fuel (Cedefop, 2012a).

[24] Aggregated by Cedefop (Cedefop, 2012a).

[25] A difficulty in analysing the employment structure of the renewable energy sector is the significant share of workers that acquires qualifications through vocational education and training (VET). VET does not correspond to a level of education of the ISCED scale in particular. In ISCED-97, VET is found under levels 2 "Lower secondary education", 3 "Upper secondary education", and 4 "Post-secondary non-tertiary education". The 2011 revision of ISCED also includes "advanced VET" in levels 5 and 6 of education (see also Table 6).

that 43% of the people employed in the UK wind and marine energy industries are highly qualified. Table 8 summarises the results of the three studies.

Table 8. Structure of qualification levels in the renewable energy sector in Germany, Spain and the UK (%)

Study	*Medium and low-qualified*	*Highly qualified*
Germany (all RES, 2007/2008)[26]	54	33
Spain (all RES, 2009)	50	50
United Kingdom (wind and marine energy, 2013) [27]	16	75

Sources: Jimenéz Herrero and Leiva (2010); Lehr and O'Sullivan (2009); RenewableUK (2013).

These studies indicate that the share of highly qualified workers employed in the renewable energy sector is substantially higher than in coal mining (33-75% in the renewables sector compared with 15% in coal and lignite mining activities). In a scenario in which fossil fuel-based power generation would be mainly replaced by RES-E after 2020, the hypothesis is that low and medium qualified jobs in coal mining may be replaced by highly qualified jobs in RES.

3.1.3 *Labour intensity of various activities*

This section defines the number of jobs per unit of energy for different energy activities. A distinction is made between the "primary energy sector" and "power generation". This distinction reflects the difference in activities.

Activities in the primary energy sector include the mining, refining, manufacturing and distribution of fossil fuels. For renewables, a relevant activity in primary fuels would be the manufacturing and distribution of biomass and biogas. However, separate employment data availability for these activities is scarce, which is why we focus on employment in power generation for biomass and biogas. For other renewable energy technologies like wind and solar, there are no activities in primary fuels simply because no combustibles are required to produce electricity.[28] For nuclear, relevant activities in the primary sector include the mining, treatment and manufacturing of uranium. Again, there is a lack of separate employment figures for these activities, which is why nuclear is disregarded for the primary energy sector.[29]

Power generation includes activities related to the construction, operation and maintenance of a power plant – be it renewable or conventional.

Labour intensity in the primary energy sector is expressed in jobs per unit of volume of energy that is supplied. Labour intensity in the power sector is expressed in jobs per unit of electric installed capacity.[30]

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[26] The shares of low, medium, and highly qualified workers do not sum to 100%. This is because 14% of the study's sample gave "no response".

[27] The remaining 9% have other types of qualifications.

[28] The issue is thus not related to the conversion of produced electricity into primary energy. There are simply no activities related to the treatment of wind or solar energy.

[29] Due to the high energy density of nuclear fuels, the number of jobs per primary energy provided is relatively low.

[30] There might be double counting of jobs in primary activities of fossil fuels in the primary energy sector and in the power sector. For instance, jobs in coal mining are counted in coal as a primary fuel,

3.1.3.1 Methodology and data sources

Labour intensity in the primary energy sector is calculated by relating the number of jobs to the volumes of energy that are supplied (in ktoe). Employment in extraction activities – mining of solid fuels and extraction of oil and gas – refers to primary energy produced domestically in the EU (i.e. excluding imports). Employment in the refining, manufacturing, and distribution of fuels concerns the (domestic) processing of both domestic production and imported volumes.[31]

Labour intensity in the power sector is calculated by relating the number of jobs to the electric capacity installed in the EU (in MW).

The two labour intensity ratios defined for primary energy activities and for the power sector in this section are equivalent to the employment factors used in the calculations for future employment in Section 3.2.2 (and in the case studies in Annex 1).

3.1.3.2 Results

Table 9 presents the labour intensity of primary energy activities. Figures for direct jobs are based on Table 5 (see Section 3.1.1.2).

Table 9 shows that the mining of solid fuels is the most labour-intensive activity. As noted above, this figure only refers to mining activities within the EU's borders. The (domestic) extraction of oil and gas is much less labour intensive, though still twice as labour intensive as activities related to the processing of (both domestically produced and imported) oil and gas.

Table 9. Labour intensity of primary energy activities in 2011, jobs/ktoe

Activity	*Jobs/ktoe*	*Direct jobs*	*ktoe*
Mining of coal and lignite [B05]	1.37 – 2.06	229,000 – 345,000	167,400[32]
Oil and gas extraction [B06 + B09.1]	0.49 – 0.81	113,000 – 187,000	229,800[33]
Oil and gas other activities [C19.2 + D35.2]	0.27 – 0.41	269,000 – 410,000	1,004,600[34]

Source: own calculations based on European Commission (2013a); Eurostat (2013c, 2013d).

Given the projected increasing electrification of the EU economy, notably by 2050, and increasing levels of power generation from RES, this study analyses the power sector in detail.

Table 10 shows the labour intensity of different power generation sources.[35]

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but also in coal as a power generation source, because the entire value chain of power generation sources is taken into account (see Section 3.1.3.2). However, as employment factors used in calculations of future employment are based on current employment levels, where potential double counting is also included, calculations of future employment in 2020, 2030 and 2050 remain proportional.

[31] Given EU import dependency levels for fossil fuels (85% for oil, 67% for gas, and 41% for solid fuels in 2011 (European Commission, 2013a)), not taking imported volumes into consideration would result in overstated ratios of jobs per unit of energy produced in the EU.

[32] Solid fuels production in 2011 (European Commission, 2013a).

[33] Production of petroleum and products, and gas and derived gases in 2011 (European Commission, 2013a).

[34] Sum of oil and gas production and imports in 2011 (European Commission, 2013a), from which 40,000 ktoe of imported refined products (gasoil and jet fuel) in 2011 are subtracted (Eurostat, 2013b).

Table 10. Labour intensity of power generation sources in 2010/2011 (jobs/MW)[36]

	Jobs/MW	*Direct jobs*	*MW*[37]
Solid fuels [B05 + C19.1]	1.47 – 2.11	244,000 – 350,000	165,700
Gas [B06.2 + part of B09.1 + D35.2][38]	1.21 – 1.69	200,000 – 279,000	165,048
Nuclear	0.95	125,000[39]	132,071
RES, including:		577,581[40]	
Biomass and waste[41]	8.22	198,330	24,134
Small hydropower[42]	1.08	14,755	16,613
Solar PV	2.35	120,436	51,274
Wind	1.45[43]	136,490	94,099

Source: own calculations, based on Eurelectric (2012); European Commission (2013a); Eurostat (2013c, 2013d); Liébard (2012).

Table 10 shows that some RES, and in particular biomass and solar PV, are more labour intensive than fossil-based power generation. Wind power is in the same range, while small hydropower is (slightly) less labour intensive.

The jobs taken into consideration in the calculation of employment factors for power generation sources cover the entire value chain. They thus include, for example, jobs in coal mining, in wind turbine manufacturing, and in fuel supply for biomass.[44] The inclusion of jobs in fuel supply for bioenergy may explain the higher labour intensity compared with other RES.

3.1.4 Conclusions

Analysing Eurostat data and estimates of DG Energy and of industry associations shows that there were 1.5-2.2 million direct jobs in the energy sector as of 2011. With a corresponding share of up to 1% of the total employed labour force in the EU, the

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[35] Data for solid fuels and gas are for 2010, for all other power generation sources they are for 2011. The reason is that Eurostat data aggregates data on installed capacity for all combustible fuels, i.e. solid fuels, oil, gas, biomass and waste. Data on installed capacity for solid fuels and gas separately are available in Eurelectric (2012) for 2010. To ensure consistency of the ratio, job figures for solid fuels and gas are also for 2010.

[36] Note that figures refer to activities related both to the construction, installation and manufacturing (CIM) of power plants, as well as their operation and maintenance (O&M).

[37] Sources: Solid fuels and gas in 2010: Eurelectric (2012); Nuclear, wind, and biomass and waste in 2011: European Commission (2013a); Small hydro and solar PV in 2011: Liébard (2012).

[38] The share of jobs related to gas only in category B09.1 "Support activities for petroleum and natural gas extraction" is equivalent to the share of B06.2 "Extraction of natural gas" in B06 "Extraction of crude petroleum and natural gas".

[39] Figure from Foratom (2010), see Annex 6.

[40] Estimation based on Liébard (2012), detailed in Annex 5.

[41] According to Eurostat, biomass and waste include wood and wood waste, biogas, municipal renewable solid waste, charcoal, and biofuels (European Commission, 2013a). Related job figures include jobs in agriculture, farming and forestry (Liébard, 2012).

[42] Small hydropower includes facilities with a maximum capacity of 10 MW (Liébard, 2012).

[43] Average figure for onshore and offshore wind. Offshore wind is estimated by the European Wind Energy Association (EWEA) to have a labour intensity 2.5-3 times higher than onshore wind (EWEA, 2012).

[44] With the exception of nuclear power, for which employment figures do not take upstream activities into account.

energy sector employs fewer people than, for example, the agriculture, forestry and fishing sector (5.2%) or the information and communication sector (2.8%) (Eurostat, 2013e).

The energy sector shows a homogenous education structure, relying mostly on medium and highly qualified workers. Coal and lignite mining employs the lowest share of highly qualified workers.

Regarding labour intensity, upstream activities in fossil fuels (mining of coal and lignite and the extraction of oil and gas) are almost twice as labour intensive as downstream activities (refining, manufacturing and distribution of fuels). It is uncertain whether replacing domestic fossil fuels with imported fuels leads to job losses. On the other hand, increasing employment may be expected by replacing imported fossil fuels with (domestic) RES. For power generation, RES tend to be somewhat more labour intensive than fossil fuels, depending on the source.

Given the uncertainty associated with the input data and the fact that simplifying assumptions had to be made, these results are also subject to uncertainty and thus need to be treated with care. However, data by Wei et al. (2010) show a similar outcome.[45]

The next section assesses the extent to which changes in the energy sector by 2020, 2030 and 2050 will impact on employment, both in terms of job numbers and required qualification levels.

3.2 Employment in the future EU energy supply sector

In order to achieve the 2050 decarbonisation objectives of the European Commission, the EU energy supply sector will face fundamental changes during the next decades that will also affect employment levels and required qualification levels. In this chapter we assess the impact of decarbonisation on employment in the energy supply sector for the years 2020, 2030 and 2050. The analysis is based on two decarbonisation scenarios published in the *Energy Roadmap 2050* of the European Commission (European Commission, 2011a), as well as on a reference scenario from the same publication.

3.2.1 *Scenarios for the future energy supply sector*

In its *Energy Roadmap 2050,* the Commission presents five decarbonisation scenarios based on five different combinations of low-carbon technologies (energy efficiency, diversified supply technologies, RES, nuclear, CCS). All of them allow a decrease in domestic EU GHG emissions by at least 80% compared with 1990. While the five decarbonisation scenarios are modelled on specific political priorities reflecting different societal preferences, their common emissions constraint allows for a comparison.

Two of the above-mentioned decarbonisation scenarios are selected for the purpose of this analysis, namely the “Diversified supply technologies scenario” and the “High renewable energy sources scenario”. These two scenarios are compared with the baseline scenario of the *Energy Roadmap 2050*, also known as the “Reference scenario”. This section describes these three scenarios, as well as the reasons behind their selection.

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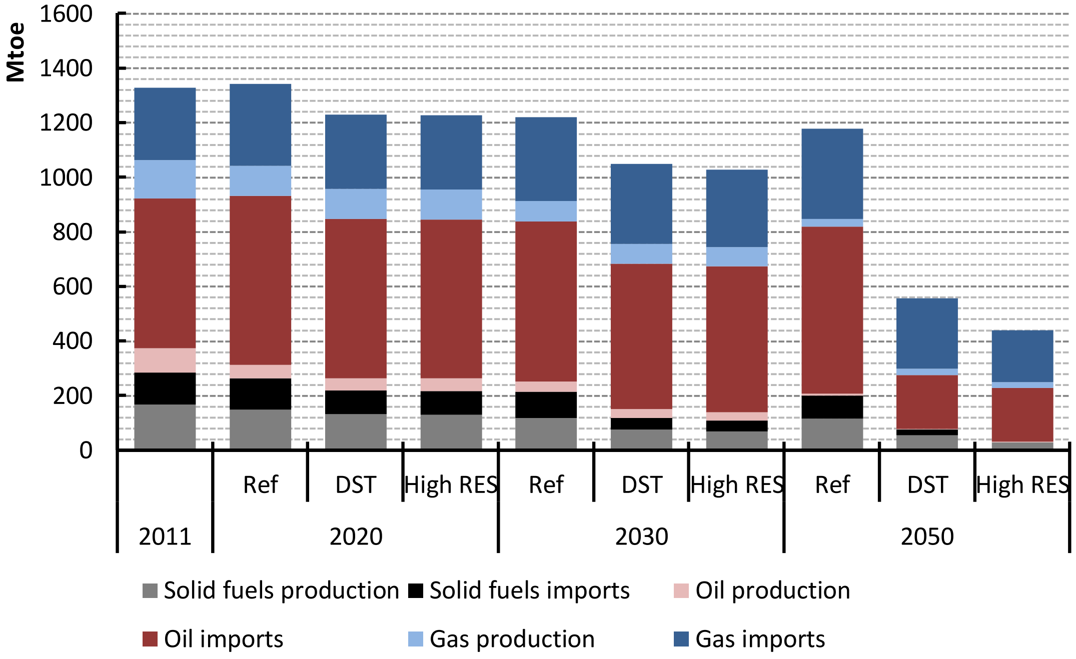
[45] Wei et al. (2010) calculate higher labour intensity ratios for RES than for other sources of US power generation (in job-years/GWh): biomass: 0.21; small hydro: 0.27; solar PV: 0.87; wind: 0.17; nuclear: 0.14; coal: 0.11; natural gas: 0.11.

- *Reference scenario* (Ref): This scenario is based on the continuation of current economic and demographic trends. The "20-20-20" targets regarding GHG emissions reductions and RES deployment are achieved, but no future objectives are set beyond 2020. Sensitivities surrounding volatile prices of imported energy and concerns about economic growth are also taken into account. In this scenario, all investment decisions are determined by market forces, whereas technological progress is driven by policies enacted before March 2010. This scenario serves as baseline for the evaluation of the two decarbonisation scenarios selected for this analysis.
- *Diversified supply technologies scenario* (DST): This scenario is neutral from a technological perspective. Decarbonisation is achieved by means of pricing carbon (i.e. an undefined proxy for policy measures that bring about emission reductions), which is applied to all sectors (ETS and non-ETS). The scenario assumes societal support (member states, investors, citizens) for nuclear energy (except for declared "nuclear sceptics" such as Germany), CCS and RES facilitation policies. This scenario is interesting to assess, as it encompasses the application of a wide range of low-carbon technologies without preference for a specific type of technology.
- *High renewable energy sources scenario* (High-RES): The political ambition behind this scenario is to achieve a very high share of RES (97% of electricity consumption by 2050). Technologies deployed include wind (both on- and offshore), solar PV and concentrated solar power (CSP) and storage, increased uptake of heat pumps, etc. Given the key role of RES in achieving an effective reduction of CO_2 emissions, scrutinising this decarbonisation scenario seems particularly important.

Figure 8 shows that the contribution of primary (fossil) fuels to energy production decreases across all scenarios. In the Reference scenario, the use of primary (fossil) fuels decreases by 12% between 2011 and 2050. This trend is more pronounced in the two decarbonisation scenarios: -58% in the DST scenario, and -67% in the High-RES scenario (compared with 2011). While domestic production of fossil fuels decreases in all three scenarios, the main difference between the Reference scenario and the decarbonisation scenarios is the amount of oil imported, which is much higher in the former than in the latter, particularly in 2050.

In all scenarios, solid fuels play a rather limited role throughout the period analysed. It is interesting to note that in the High-RES scenario, the EU gradually becomes a self-sufficient producer of solid fuels. The reason for this is the low consumption of solid fuels in this scenario (accounting for 7% of all primary fuels in 2050). The contribution of gas remains fairly constant across all scenarios, yet its role increases as oil loses importance.

Figure 8. Energy supplied by primary fuels in 2011, 2020, 2030 and 2050 (Mtoe)



Sources: European Commission (2011a, 2013a).

Figure 9 presents the installed capacity of selected energy technologies for the three scenarios. Although the *total level of* installed *capacity* increases in all scenarios, the largest augmentation occurs in the High-RES scenario and is mainly driven by a large-scale deployment of (variable) wind and solar energy. According to this scenario, in 2050 the joint capacity of these two types of RES amounts to 1,587 GW, i.e. 73% of the total installed electric capacity in that year. Overall, in the High-RES scenario, the total installed capacity rises from 1,157 GW in 2020 to 2,166 GW in 2050 (+46%). A similar development can be observed in the DST scenario, albeit at lower levels than in the High-RES scenario.

The total level of installed capacity increases with the share RES due to the intermittent nature of wind and solar technologies.[46] The capacity factor of these technologies, i.e. the ratio of electricity generation and installed capacity, depends on the weather conditions and cannot be controlled. Therefore, more capacity is needed in the High-RES scenario compared with the DST scenario to fully satisfy electricity demand (at all times) and to ensure the balance of the power system.

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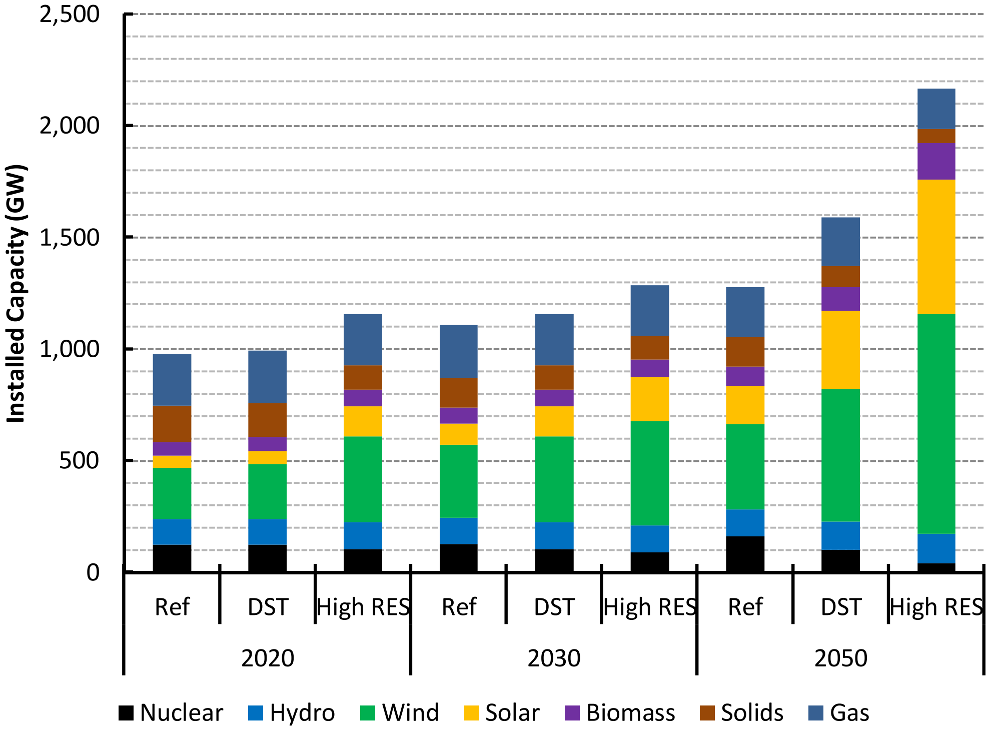
[46] In the *Energy Roadmap 2050*, solar energy includes solar PV and solar thermal (including CSP). Data on solar PV and solar energy are used interchangeably in this study. The reason is that, in 2011, the installed capacity in solar PV was estimated at 51,274 MW (Liébard, 2012), which represents 98% of the 52,066 MW of installed capacity in solar energy reported by European Commission (2013a).

Figure 9. Installed capacity of energy technologies in the power sector in 2020, 2030 and 2050, (GW)



Source: European Commission (2011a).

Throughout the entire period analysed, investments in new capacities are projected to grow in all scenarios (see Figure 10).[47] With the exception of the Reference scenario, wind and solar make up the bulk of new investments. In the two decarbonisation scenarios, approximately 200 GW of new installed capacity come from wind and solar technologies, accounting for about 60% of the total new installed capacity in 2020. The situation changes when extending the timeframe to 2050. In the DST scenario, the capacity of newly built wind and solar installations amounts to 463 GW, adding about 75% of newly deployed capacity. In the High-RES scenario, wind and solar capacities expand by 817 GW, accounting for 86% of all newly installed capacity by 2050. In this scenario, all investments in nuclear energy are discontinued by the end of the 2030s.

Compared with RES, investments in fossil fuel powered units play an inferior role. Estimates for 2020 are rather homogeneous; conventional power plants make up roughly 23-27% of all newly deployed capacity. However, in the long run their contribution varies across the scenarios. In the Reference scenario, the contribution of fossil-fuelled installations remains constant; in 2050, they amount to 26% of all newly installed capacity. In the High-RES scenario, newly built conventional units produce 84 GW of electricity in 2050, representing a mere 9% of all newly installed capacity. A comparable trend appears in the DST scenario: by 2050, new fossil-powered plants

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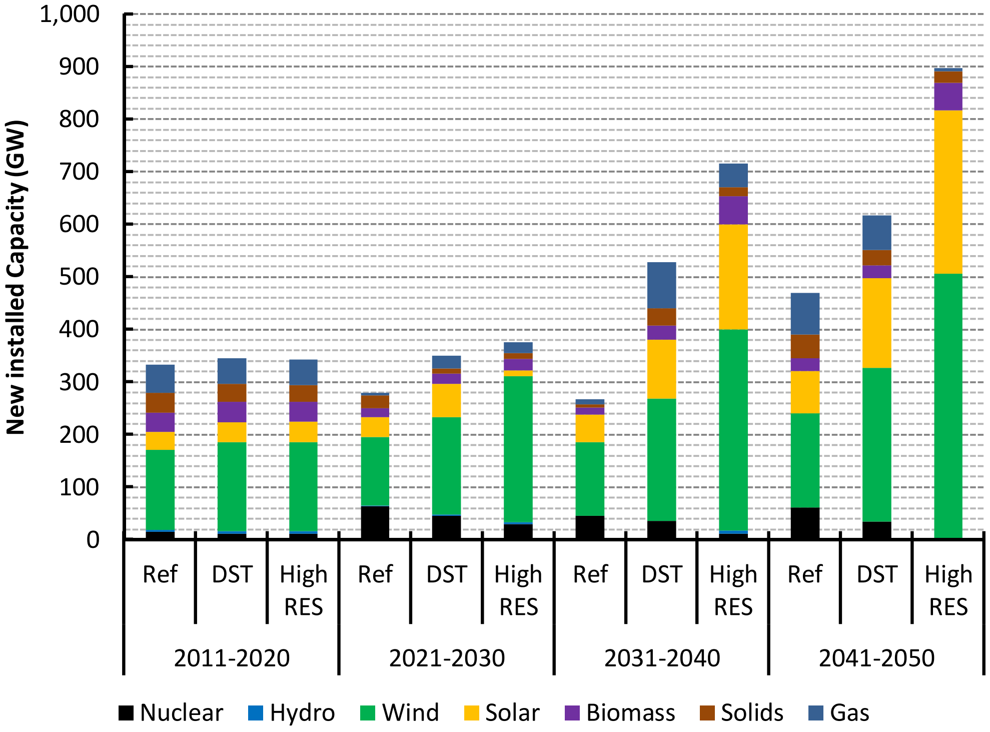
[47] Projections for new capacity come from European Commission (2011a). However, they are available only for groups of technologies: "Renewable energy" covers wind, solar, and hydropower; "Thermal power fossil fuels" include solid fuels, oil, and gas; and "Thermal power RES" includes, among others, biomass. Projections for new capacity in each separate technology were calculated on the basis of the share of each technology in total installed capacity in 2020, 2030, 2040 and 2050.

produce 95 GW of electricity. This corresponds to 15% of all newly installed capacity. The contribution of small-scale hydro is marginal across all the scenarios.

Figure 10. New installed capacity of energy technologies in the power sector for 2011-2020, 2021-2030, 2031-2040 and 2041-2050 (GW)[48]



Source: based on European Commission (2011a).

Conclusions

As outlined in the above section, considerable changes can be expected both in the share of primary (fossil) fuels and in the power sector, which will become increasingly dependent on low-carbon technologies – and mainly RES. The degree of this transformation varies across scenarios. In the Reference scenario, fossil-fuelled and nuclear power installations preserve an important role in the power sector until 2050. In this scenario, primary fossil fuels continue to supply significant volumes of energy. In the DST scenario, conventional and nuclear generation starts losing ground in the 2030s, as RES come online on a large scale. This development is even stronger in the High-RES scenario; in 2050, the power sector is dominated by RES, whereas the importance of fossil fuels is considerably reduced.

3.2.2 Future employment levels

This section assesses the future number of jobs in the energy sector in the three selected scenarios from the *Energy Roadmap 2050* (one reference scenario and two decarbonisation scenarios). It distinguishes between primary fuels and the power sector, before drawing conclusions for the energy sector as a whole.

The methodology chosen for the calculations is the "employment factor" methodology. It consists of multiplying energy units (i.e. ktoe or MW) by technology-specific

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[48] Figures include both additional capacity as well as the replacement of existing plants.

employment factors. The employment factors are equivalent to the labour intensity ratios presented in Section 3.1.3.2 and are expressed in jobs per ktoe for primary fuels and in jobs per MW for the power sector. The methodology of utilising employment factors for projecting future employment levels is used in several other studies on employment in the energy sector (e.g. Wei et al., 2010; Teske et al., 2012).

3.2.2.1 *Primary fuels*

Methodology

The ratio of jobs per ktoe that has been derived from current energy sector figures (see Section 3.1.3.2) is used to calculate the number of jobs linked to the projected volumes of primary fuels in the *Energy Roadmap 2050*. As explained in Section 3.1.1, the job figures (direct employment levels) for primary fuels are derived from different sources, thus showing some variance. In order to account for this variance, we utilise the minimum and maximum employment levels linked to a fuel. Therefore, there is a lower and an upper range for the employment factors in fossil fuels, leading to a lower and upper range in results for the projected employment levels for each scenario.

Results

Overall, it is evident that employment related to primary fuels will decrease in all scenarios between 2011 and 2050 (see Table 11). Not surprisingly, employment will be most affected in the High-RES scenario and least affected in the Reference scenario, where fossil fuels will continue to play a substantial role through 2050. Moreover, substantial differences between the three scenarios begin to materialise only after 2020, as the targets for the current decade have already been set by the EU Climate and Energy Package.

Concrete results by scenarios are presented below, starting with the Reference scenario. In order to improve readability of the section, we first focus only on the lower range of employment levels (see Figure 11).[49] The full range of jobs is presented later in the summary of this section.

Table 11. Direct employment in primary fuels in 2011, 2020, 2030 and 2050, lower range

		Solids	*Oil extraction*	*Oil refining*	*Gas extraction*	*Gas other*	*Total*[50]
2011		229,000	76,000	118,000	37,000	151,000	611,000
2020	Ref	203,000	42,000	133,000	29,000	153,000	560,000
	DST	182,000	39,000	123,000	29,000	142,000	515,000
	RES	179,000	39,000	123,000	29,000	142,000	512,000
2030	Ref	162,000	31,000	126,000	20,000	142,000	482,000
	DST	104,000	27,000	112,000	19,000	136,000	398,000
	RES	96,000	27,000	112,000	19,000	131,000	385,000
2050	Ref	158,000	7,000	126,000	8,000	133,000	432,000
	DST	74,000	2,000	44,000	6,000	105,000	231,000
	RES	40,000	2,000	44,000	5,000	78,000	170,000

Source: own calculations.

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[49] This does not imply any preference for the lower range over the upper range, but is only meant to improve readability.

[50] Totals may differ from the sum of all sources per row due to rounding.

Trends in the Reference scenario

In the Reference scenario, the employment level related to primary (fossil) fuels decreases throughout the entire period from 2011 until 2050. Applying the lower range of employment factors results in a decrease from 611,000 jobs in 2011 to 560,000 jobs in 2020, 482,000 in 2030 and 432,000 jobs in 2050. Compared with 2011, 8% of all jobs are lost by 2020, 21% by 2030 and 29% by 2050. To a large extent, these job losses are caused by the decreasing production of oil related to the depletion of domestic oil resources (-34,000 jobs by 2020, -45,000 jobs by 2030, and -69,000 jobs by 2050). A slight increase in jobs in oil refining (+8,000 jobs by 2030, constant thereafter) partly makes up for this loss. The other major source of job losses is the production of solid fuels, where some 26,000 jobs may be lost by 2020, 67,000 jobs by 2030 and 71,000 jobs by 2050. Similarly, employment will be reduced in gas extraction (-21% by 2020, -47% by 2030 and -79% by 2050). As with oil, this is also related to the depletion of domestic resources. For other activities related to natural gas (e.g. transmission, distribution and processing of imports), the decline starts only after 2020. Moreover, it is significantly weaker compared with other activities, i.e. -12% by 2050, compared with 2011.

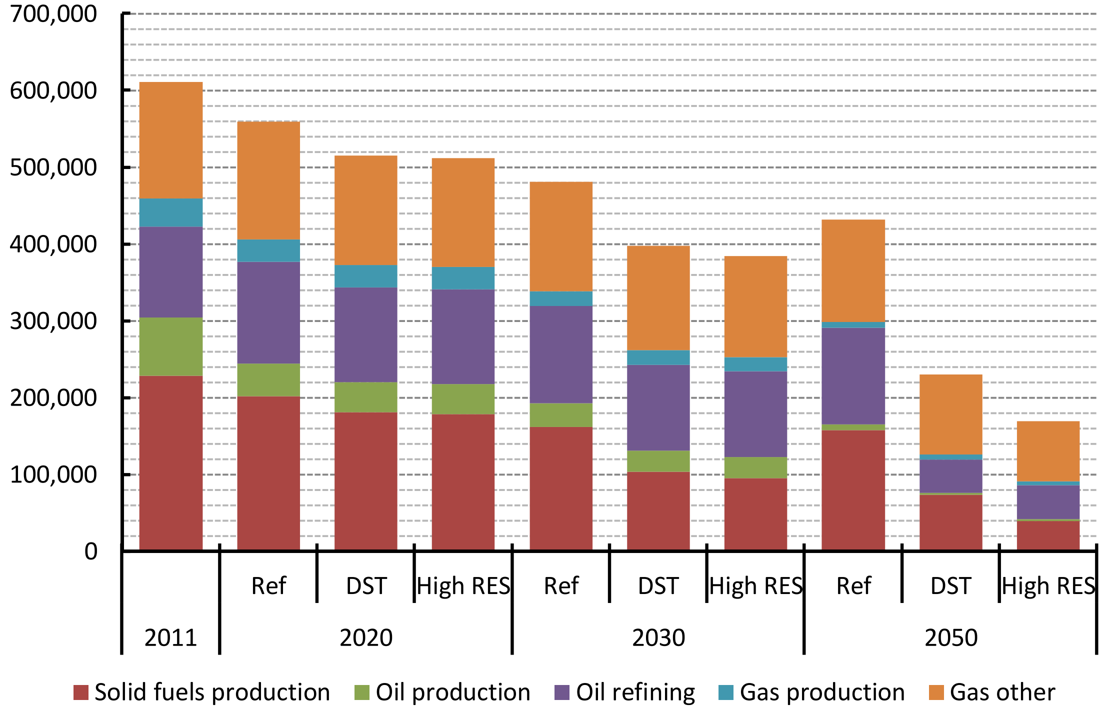
Trends in the DST scenario

Compared with the Reference scenario, the reduction in employment is stronger in the DST scenario because, in general, the share of energy supplied by primary fossil fuels declines more strongly in decarbonisation scenarios. Overall, the number of jobs decreases in every activity related to fossil fuels. By applying the lower range of employment factors, the following trend for total employment can be observed: it amounts to 515,000 in 2020 (-16% compared with 2011), 398,000 in 2030 (-35%) and 231,000 in 2050 (-62%). While the job losses in oil production are on a similar level when compared with the Reference scenario, the decline of jobs in solid fuels production is roughly twice as high in the DST scenario. In the DST scenario, 47,000 jobs in solid fuels production are lost by 2020, 125,000 jobs by 2030 and 155,000 jobs by 2050. Unlike in the Reference scenario, there is no compensation for jobs lost in oil and coal production by increasing employment in oil refining in this scenario. To the contrary, the number of jobs in oil refining decreases by 5% by 2030, and by 63% by 2050 compared with 2011. Regarding the decline of jobs in activities related to gas extraction, the differences with the Reference scenario are marginal. However, the decrease of jobs in downstream activities in the gas sector is stronger than in the Reference scenario: 10% of the jobs are lost by 2030, and 31% of the jobs are lost by 2050.

Trends in the High-RES scenario

The High-RES scenario shows similar results to the DST scenario, i.e. a strong downward trend in all activities related to fossil fuels. Overall, the employment level decreases to 512,000 in 2020 (-16%), 385,000 in 2030 (-37%) and 170,000 in 2050 (-72%). The decline in activities is comparable to the DST scenario but stronger, especially after 2030 and primarily in solid fuels production and gas downstream activities. In the High-RES scenario, 50,000 jobs in solid fuels production are lost by 2020, 133,000 by 2030 and 189,000 by 2050. Similarly, the decrease in gas downstream activities amounts to 6% by 2020, 13% by 2030 and 48% by 2050.

Figure 11. Jobs in primary fuels in 2011, 2020, 2030 and 2050, lower range[51]



Sources: own calculations, based on European Commission (2011a); Eurostat (2013d).

Summary

Taking into account all uncertainties related to the methodology and the available data, there is clear evidence that decarbonisation will lead to job losses in the primary fuels sector (see Table 12). Compared with current employment levels of between 611,000 (lower range of labour intensities) and 943,000 (upper range of labour intensities), decarbonisation may destroy between 96,000 and 153,000 jobs by 2020, between 213,000 and 350,000 jobs by 2030 and between 380,000 and 686,000 jobs by 2050, depending on the decarbonisation scenario and range chosen. Total employment in primary fuels may thus decrease to some 512,000-794,000 in 2020, 385,000-613,000 in 2030, and 170,000-347,000 in 2050. Generally, employment in primary fuels in the decarbonisation scenarios seems to be lower than in the Reference scenario, pointing to the possibility of higher job losses in primary activities as the energy sector decarbonises.

By 2020, there are only minor differences between the three scenarios, as the supplied volumes are roughly the same for all scenarios (and almost identical between DST and High-RES). By 2030, jobs in the DST scenario and the High-RES scenario evolve the same way (385,000-398,000 jobs with the low employment factor, 593,000-613,000 jobs with the high employment factor), while the employment level in the Reference scenario is higher at 482,000-741,000 jobs. As shown in Figure 11, it is primarily the number of jobs in solid fuels that decreases until 2030.[52] By 2050, employment

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[51] The upper range shows higher absolute values but the proportions are the same as for the lower range.

[52] Domestic jobs in coal and lignite will only be lost if decarbonisation translates into a reduction of domestic solid fuel production rather than a reduction of imported fuels (or both). However, the numbers provided by the European Commission (2011a) clearly distinguish between domestic

decreases in all fuels and in all scenarios. The decrease is the strongest for oil production. The main difference between the DST and the High-RES scenarios in 2050 is the lower number of jobs in coal mining and gas downstream activities in the High-RES scenario.

Table 12. Direct employment in primary fuels in 2011, 2020, 2030 and 2050 (million jobs)

	2011	*2020*			*2030*			*2050*		
		Ref	*DST*	*High-RES*	*Ref*	*DST*	*High-RES*	*Ref*	*DST*	*High-RES*
Lower	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.2	0.2
Upper	0.9	0.9	0.8	0.8	0.7	0.6	0.6	0.7	0.3	0.3

Source: own calculations.

It is worth noting that employment in coal and lignite mining has been declining in the EU15 since at least 1995. In the EU15, the workforce in coal and lignite mining declined by two thirds between 2000 and 2012, decreasing from 154,300 workers[53] to 56,200[54] (Eurostat, 2013c).[55] This shows the strong decline of the coal industry in most industrialised European countries. This decline is less pronounced in the EU27: employment in mining of coal and lignite declined from 374,300 workers in 2007[56] to 331,600 in 2012 (Eurostat, 2013c). This shows the more important role that coal plays in central and eastern European countries compared with the EU15. Growing mechanisation substituting for human labour is the main reason for the decrease in employment in solid fuels mining (Renner et al., 2008; Fischer-Kowalski et al., 2012).

3.2.2.2 Power sector

Methodology

Similar to the methodology used for primary fuels, the ratio of jobs per MW of installed capacity derived from the current power sector (see Section 3.1.3.2) is used to calculate the number of jobs linked to the projected installed capacity in the *Energy Roadmap 2050*.

Moreover, a distinction is made between the jobs in construction, installation, and manufacturing (CIM) and the jobs in operation and maintenance (O&M). Separate ratios are prepared for CIM and O&M jobs based on Liébard (2012) and Rutovitz and Harris (2012).[57] Employment factors for O&M can be expressed in jobs per installed capacity (e.g. per megawatt), meaning that the employment is linked to existing power plants, i.e. a certain number of workers/employees is needed to operate and maintain an existing power plant for each year of operation. In contrast, CIM employment factors are typically expressed in *job-years* per installed capacity, as the whole process of construction, installation, and manufacturing is usually not linked to a specific year.

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production and imports in the supply of solid fuels to 2050. Of course, rising domestic extraction costs might result in a further decrease of domestic extraction rather than imports, thus further increasing the number of jobs lost in solid fuels in the EU.

[53] Including workers in the extraction of peat.

[54] Excluding workers in the extraction of peat (about 12,000 (European Commission, 2013a)). The revision of NACE in 2008 separated the extraction of peat from coal and lignite mining.

[55] Data from the LFS, because SBS data for division B05 "Mining of coal and lignite" do not go back earlier than 2005.

[56] Year of the enlargement of the EU to 27 member states.

[57] The methodology used to calculate CIM and O&M ratios is explained in Annex 7.

In order to have comparable figures for both CIM and O&M jobs for a specific year, the job-years in CIM are distributed over the decade in which new power plants go online, i.e. they are divided by ten (see Annex 7 for a more detailed explanation).

As in primary fuels, there is a lower and an upper range of employment factors for fossil fuels.[58] This results from the range of employment levels for fossil fuels (see Section 3.1.1.2).

Results

Similar to the development in primary fuels, it is not surprising that employment related to electricity generated from fossil fuels will decrease in all scenarios between 2011 and 2050. Moreover, the decline will be most visible in the High-RES scenario and less significant in the Reference scenario, where fossil fuels continue to be used in power generation through 2050. Substantial differences between the three scenarios begin to materialise only after 2020, as the targets for the current decade have already been set by the EU Climate and Energy Package.

Concrete results by scenario are presented below. First, general trends will be presented with a focus on absolute figures and the distribution of jobs among CIM and O&M activities. Then the trends in the three scenarios are discussed in more detail and with a focus on the distribution of jobs over different power generation technologies. In order to improve readability of the section, the full range of employment levels is only presented in the tables summarising the results. In the text below, we focus only on the lower range of jobs.

General trends

Table 13 and Table 14 present the general trends for the lower employment factors, both in absolute terms and when comparing the two decarbonisation scenarios with the Reference scenario. Between 2011 and 2020, employment in the power sector is estimated to increase by about 900,000 jobs to a total of 1.8 million. There are only minor differences between the three selected scenarios, as the newly installed capacities are roughly the same for all selected scenarios. By 2030, employment may increase to 2 million jobs in the DST scenario and to 2.4 million in the High-RES scenario. Compared with the Reference scenario, there might thus be 200,000 more jobs in the DST scenario and 600,000 more jobs in the High-RES scenario. Although the calculations for 2050 contain a high degree of uncertainty,[59] they show a further increase in the number of jobs to 3.2 million in the DST scenario and 5 million in the High-RES scenario. Compared with the Reference scenario, some 800,000 jobs may be created in the DST scenario and 2.6 million in the High-RES scenario, where employment is twice as high as in the Reference scenario.

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[58] It is worth noting that it was not possible to distinguish between CCS and conventional power plants regarding the employment factors, because there are no historical employment figures available for CCS power plants. In principle, it is reasonable to expect a similar number of jobs per MW of capacity, as a CCS power plant still remains a centralised power plant.

[59] The employment projections for 2050 are subject to higher uncertainty than projections for earlier years. This is essentially due to the assumption that jobs and (newly) installed capacity are correlated linearly.

Table 13. Direct employment in the power sector in 2011, 2020, 2030 and 2050 (million jobs)

	2011	*2020*			*2030*			*2050*		
		Ref	*DST*	*High-RES*	*Ref*	*DST*	*High-RES*	*Ref*	*DST*	*High-RES*
Lower	0.9	1.8	1.8	1.8	1.8	2.0	2.4	2.4	3.2	5.0
Upper	1.2	1.9	2.0	2.0	1.9	2.1	2.5	2.6	3.4	5.2

Source: own calculations.

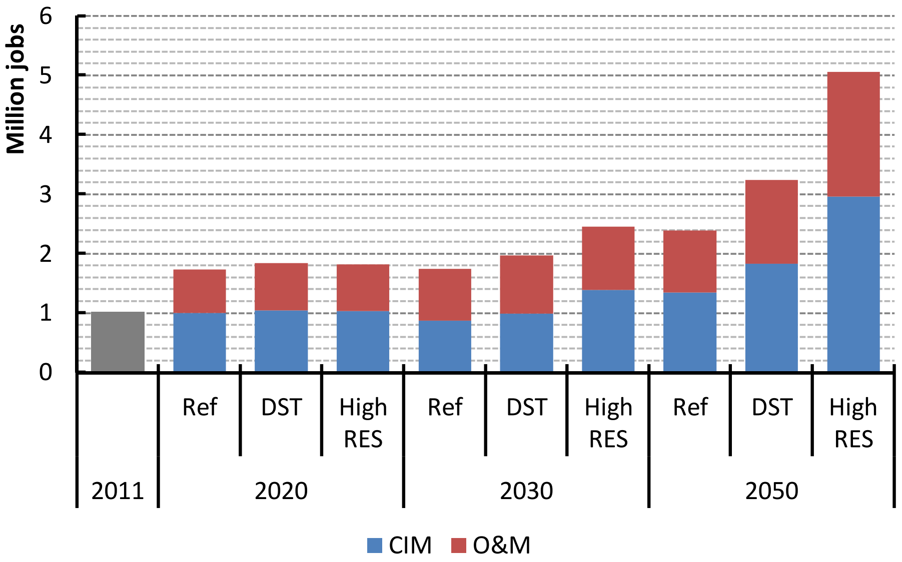
Table 14. Direct employment in the power sector in 2020, 2030 and 2050, difference to Reference scenario (million jobs)

	2020		*2030*		*2050*	
	DST	*High-RES*	*DST*	*High-RES*	*DST*	*High-RES*
Lower range	0.0	0.0	0.2	0.6	0.8	2.6
Upper range	0.1	0.1	0.2	0.6	0.8	2.6

Source: own calculations.

The increase in total employment is equally driven by CIM and O&M jobs, and the share of each in total jobs (about 60% for CIM and about 40% for O&M) remains roughly constant over the entire period until 2050. This is also reflected in Figure 12. This development is not surprising, as CIM jobs involved in the installation of new electrical capacity create new O&M jobs required for the operation and maintenance of these new capacities.

Figure 12. Direct employment in the power sector: CIM and O&M jobs in 2011, 2020, 2030 and 2050, lower range (million jobs)[60]



Source: own calculations.

It is worth noting that the average capacity factor of power plants decreases with an increasing share of RES. In the DST scenario, the average capacity factor decreases from 44% in 2010 to 39% in 2020, 35% in 2030, and to 33% in 2050. In the High-RES scenario, the average capacity factor amounts to 39% in 2020, to 31% in 2030 and to

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[60] The upper range shows higher absolute values, but the proportions are the same as for the lower range.

only 26% in 2050. This raises the question of the impacts of lower capacity factors on the number of O&M jobs.

While it is subject to uncertainty how O&M activities will evolve to 2050, the current structure of O&M *costs* can be used as an indicator for the status quo of O&M *activities*, i.e. the extent to which these are linked to the utilisation of a power plant. A comparison of fixed and variable O&M costs of gas-fired power plants (European Climate Foundation, 2010) shows that variable O&M costs are significantly lower than fixed O&M costs. For example, a gas-fired power plant running for roughly 20% of a year has about 20 EUR/kW of fixed O&M costs and about 2 EUR/kW of variable O&M costs. It is therefore assumed that the number of persons needed to run a power plant remains stable, even if the utilisation of this unit decreases.

However, such a massive increase in unused back-up capacity can be challenged from an efficiency point of view. The deployment of intermittent RES requires back-up capacities. Yet, if there are flexibility mechanisms like demand-side response, storage or better interconnections with adjacent markets, the amount of back-up capacities can be reduced. To activate these flexibility potentials, it is probably necessary to adapt the power market design in order to put a price on reliability and/or give a value to flexibility.

The following paragraphs present the results by scenario and technology in more detail. Table 15 and Figure 13 show the lower range of results for the power sector (i.e. based on the lower range of employment factors).

Table 15. Direct employment in the power sector in 2011, 2020, 2030 and 2050, lower range

		Solids	*Gas*	*Nuclear*	*Biomass*	*Hydro*[61]	*Wind*	*Solar*	*Total*[62]
2011		244,000[63]	200,000[64]	125,000	182,000	15,000	136,000	120,000	1,022,000
2020	Ref	207,000	211,000	84,000	600,000	9,000	470,000	179,000	1,760,000
	DST	185,000	207,000	78,000	632,000	10,000	518,000	197,000	1,827,000
	RES	182,000	204,000	78,000	612,000	11,000	520,000	199,000	1,806,000
2030	Ref	145,000	201,000	189,000	544,000	3,000	472,000	219,000	1,773,000
	DST	80,000	160,000	142,000	591,000	4,000	629,000	349,000	1,955,000
	RES	79,000	156,000	101,000	608,000	6,000	884,000	608,000	2,442,000
2050	Ref	225,000	253,000	199,000	681,000	3,000	613,000	449,000	2,423,000
	DST	144,000	229,000	117,000	798,000	8,000	985,000	948,000	3,229,000
	RES	108,000	203,000	17,000	1,325,000	13,000	1,684,000	1,695,000	5,045,000

Source: own calculations.

Trends in the Reference scenario

In the Reference scenario, employment in solid fuel based power generation shows a decrease by 2030 (-41% compared with 2010) and a recovery by 2050, where it reaches a similar level as in 2010 (see Table 15). The jobs related to activities in gas-fired power plants remain at the level of 2010 until 2030 and increase afterwards to 27% above 2010 levels by 2050. The deployment of new nuclear power plants after 2020 results in a

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[61] Small-scale facilities only.

[62] Totals may differ from the sum of all sources per row due to rounding.

[63] 2010 data.

[64] 2010 data.

substantial increase in related employment by 2030 (+51% compared with 2011) but only small increases thereafter. Jobs related to RES-E will already capture a share of over 70% of total employment in the power sector by 2020. This share will then be more or less constant until 2050. Biomass, wind and solar power are the largest employers. While employment in wind and biomass will skyrocket by 2020 (+244% and +230%, respectively, compared with 2011), employment in solar power installations will only take off after 2030 (+272% by 2050 compared with 2011).

Trends in the DST scenario

Table 15 also shows that the DST scenario, a decarbonisation scenario, foresees a stronger shift of employment to RES than the Reference scenario, but a stronger shift to nuclear than the High-RES scenario. Consequently, employment in the coal sector decreases faster than in the Reference scenario by 2030 (-67% compared with 2010). Similar to the Reference scenario, it picks up after 2030 but stays far below the Reference scenario levels in 2050 (-41% compared with 2010). Employment related to gas-fired power plants increases slightly by 2020 (+3% compared with 2010), falls considerably by 2030 (-20% compared with 2010) and recovers afterwards to reach 14% above 2010 levels in 2050. A similar but less pronounced increase has been projected in the Reference scenario. Employment related to nuclear power plants is also projected to follow a similar pattern to that in the Reference scenario, but the increase after 2020 is less pronounced by 2030 (+13% compared with 2011) and fades away completely afterwards to -6% by 2050 compared with 2011. Finally, employment in the RES-E related activities triples by 2020 (compared with 2011), mainly driven by wind and biomass. Employment in biomass stagnates thereafter. Further increases until 2030 are mainly driven by solar power. Between 2030 and 2050, employment in solar and wind drives total employment in RES, which reaches +504% by 2050 compared with 2011.

Trends in the High-RES scenario

Compared with the DST scenario, calculations for the High-RES scenario project a much stronger shift of employment from fossil-based power generation to RES, while employment in nuclear is almost phased out by 2050. As in the DST scenario, 68% of the jobs in coal-based generation disappear by 2030 in the High RES scenario, but the recovery afterwards is much slower in this case and by 2050, some 56% fewer people will be employed in this technology than in 2010. Developments in employment related to gas-fired power plants follow the same patterns as in the DST scenario until 2030, but increases afterwards are much lower and employment in this technology only recovers to 2010 levels by 2050. In contrast to the other two scenarios above, there is only a very slight recovery of employment in the nuclear industry between 2020 and 2030, while it collapses between 2030 and 2050 to reach -86% by 2050, compared with 2011. Despite this decrease in jobs in fossil- and nuclear-based generation, the total employment level is the highest among all the selected scenarios. This is due to the increase in RES-based power generation. Similar to the other scenarios, these increases are mainly driven by wind and biomass until 2020. In the High-RES scenario, employment in biomass stagnates until 2030 but picks up considerably until 2050. After 2030, solar power becomes an important employer, reaching the same level as employment in biomass by 2030 and as employment in wind power by 2050. Total employment in RES-E triples between 2011 and 2020, and increases by 365% by 2030 and by 941% by 2050 (both compared with 2011).[65]

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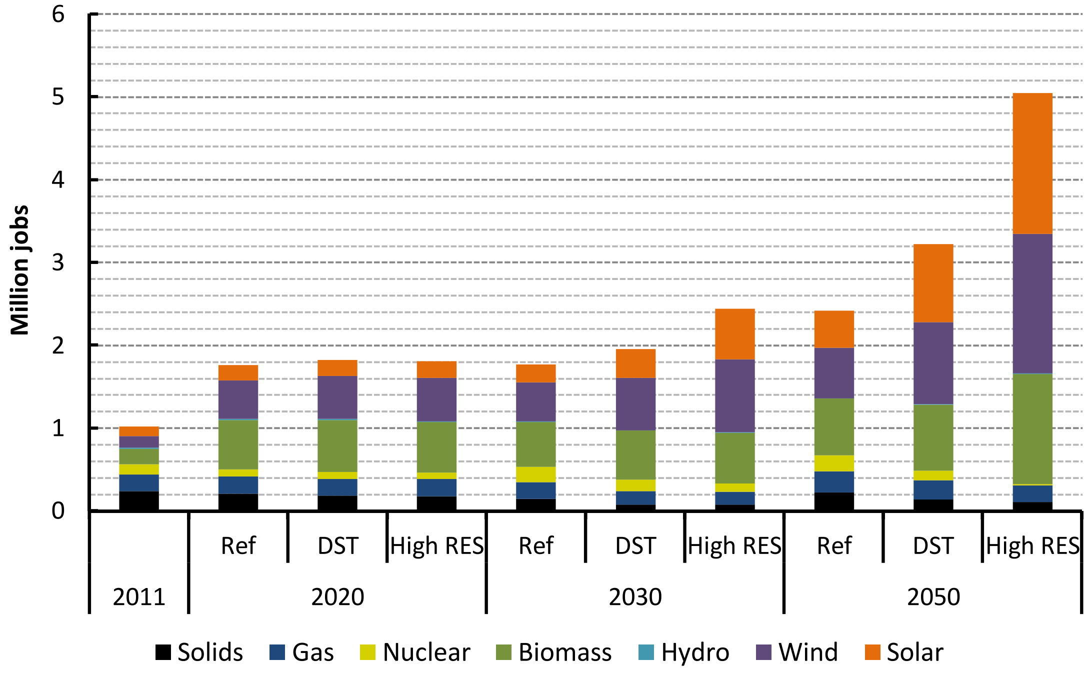
[65] Results may be overestimated, because they do not take into account a possible decrease in labour intensity due to the maturing of (e.g. RES) technologies.

Figure 13. Direct employment in the power sector in 2011, 2020, 2030 and 2050, lower range (million jobs)



Source: own calculations.

Summary

In contrast to primary fuels, the power sector is likely to create jobs. Compared with current employment levels of between 0.9 million (lower range of labour intensities) and 1.2 million (upper range of labour intensities), decarbonisation may create between 800,000 and 900,000 additional jobs by 2020, between 900,000 and 1.6 million additional jobs by 2030, and between 2.2 and 4.1 million additional jobs by 2050, depending on the decarbonisation scenario and range chosen. The total number of jobs in the power sector could thus increase to between 1.8 and 2 million in 2020, between 2 and 2.5 million in 2030, and between 3.2 and 5.2 million in 2050, depending on the decarbonisation scenario. Compared with the Reference scenario, this means additional jobs in the ranges of 32,000 to 55,000 in 2020, 138,000 to 669,000 in 2030 and 800,000 to 2.6 million in 2050.

Due to the political agreement on binding RES targets for 2020, substantial differences between the three scenarios only begin to materialise after 2020. By that year, between 21-28% of jobs in the power sector are related to fossil fuels in the two decarbonisation scenarios, compared with 24-31% in the Reference scenario. The fastest decrease in the share of jobs linked to fossil fuels in power generation is in the High-RES case, where it declines to 10-13% in 2030 and 6-8% in 2050. In the DST scenario, the share only decreases to 12-17% by 2030 and 12-16% by 2050. Not surprisingly, the share of fossil fuel related jobs is the highest in the Reference scenario, where it is roughly constant at 20-26% in 2030 and 2050.

The share of RES-E related jobs, on the other hand, increases substantially in all scenarios, but by most in the High-RES scenario. In 2011, about 38-44% of all employees in the power sector worked in RES-E related activities. This share increases to 68-74% by 2020 in the two decarbonisations scenarios, and almost similarly to 65-71% in the Reference scenario. While the share of RES-E jobs in the Reference scenario stays more or less constant until 2050, it increases in the DST scenario to 77-80% in 2030 and 81-85% in 2050. Higher shares are achieved in the High-RES scenario, with 83-86% in 2030 and 91-94% in 2050. In the High-RES scenario, almost all workers in the power sector will be involved in activities related to RES-E by 2050.

3.2.2.3 Total energy sector

A summary of the findings is listed in Table 16. It shows total employment in the energy sector for all scenarios, i.e. summing up employment in primary fuels and in the power sector, both for the lower range and for the upper range.

Table 16. Direct employment in the energy sector in 2011, 2020, 2030 and 2050 (million jobs)

		Ref.			*DST*			*High-RES*		
	2011	*2020*	*2030*	*2050*	*2020*	*2030*	*2050*	*2020*	*2030*	*2050*
Lower range	1.5	2.3	2.3	2.9	2.3	2.4	3.5	2.3	2.8	5.2
Upper range	2.2	2.8	2.7	3.3	2.8	2.7	3.7	2.8	3.1	5.4

Source: own calculations.

The results presented in Table 16 show that decarbonisation in the context of a new SET can lead to substantial employment creation, particularly in the long term. Compared with current employment levels of about 1.5-2.2 million, decarbonisation may create up to 800,000 additional jobs in the energy system by 2020, up to 1.3 million additional jobs by 2030, and up to 3.7 million additional jobs by 2050, depending on the decarbonisation scenario and range chosen. While the results of the two decarbonisation scenarios are similar to the Reference scenario until 2020, differences begin to materialise by 2030, and in particular by 2050. However, as noted before, results for 2050 are subject to high uncertainty due to the linear approach (i.e. constant employment factors) in calculating job projections.

The results clearly show that more jobs are created in the High-RES scenario than in any other scenario. In this scenario, there are up to 800,000 more jobs in 2020, 1.3 million more jobs by 2030 and 3.7 million more jobs by 2050 (all compared with 2011). Comparing the results for the High-RES scenario with the Reference scenario shows that up to 500,000 additional jobs may be created in the context of a decarbonisation by 2030, and possibly even up to 2.3 million additional jobs by 2050. In the DST scenario, there may be 100,000 more jobs by 2030 compared with the Reference scenario and 600,000 additional jobs by 2050.

Results in Table 16 are net results, that is, they take into account both job losses and job creation. However, the net effect of the transition to a low-carbon energy system on employment in the full economy will also depend on dimensions that are not covered by this study, i.e. indirect employment, and budget and substitution effects. Budget effects occur when households have more disposable income and spend it in consumer-related sectors, thereby fostering the creation of jobs in the economy. Substitution effects occur when spending more on one good or service displaces spending on another consumer-related sector, thereby having impacts on employment in the affected sectors (e.g. higher energy prices for consumers may displace spending on holidays). Indirect effects relate to parts of the value chain that are not covered by this study, e.g. jobs related to the manufacturing of power plants or the machines related to the manufacturing. These general equilibrium effects are not fully quantifiable, of course, and thus not part of this study.

Similarly, the results shown in Table 16 are based on constant employment factors, i.e. today's employment factors are projected on future volumes of primary energy and on future installed capacities in the power sector. Disregarding any potential future reductions in labour intensity, this is done due to a lack of reliable information on how labour intensities might develop in the future for different energy technologies (especially in the long run until 2050). In essence, this means that future employment figures may be overestimated – by how much is uncertain. However, historical evidence (EurObserv'ER, 2013) shows a decrease in labour intensity of RES over the period 2008-2011 (the years for which employment figures are available). The highest reduction was achieved in solar PV, where labour intensity (direct employment) decreased by an average of 13% annually between 2008 and 2011. Labour intensity of wind power decreased by about 1% per year in the same timeframe. Finally, labour intensity of biomass and waste decreased by about 9% annually from 2009 to 2011. Further improvements are expected in the future. Rutovitz and Harris (2012) suggest that labour intensity in biomass could decrease by 1.1% annually between 2015 and 2020, and afterwards by 0.7% annually until 2030. For wind onshore, the decrease may be 2.8% annually between 2015 and 2020, and 0.2% between 2020 and 2030. The decrease is stronger for wind offshore, where labour intensity could decline by 7.2% annually over the period 2015-2020, and by 4.5% annually between 2020 and 2030. Similar reduction rates are projected for solar PV, where labour intensity may decrease by 6.4% annually between 2015 and 2020, and by 4.9% annually between 2020 and 2030. Given that these estimates are characterised by high uncertainty, this paper bases its calculations on constant employment factors of the year 2011.

3.2.3 *Future employment structure*

Overall, jobs that disappear in conventional energy sources are replaced with jobs in RES, for all levels of qualification. In decarbonisation scenarios, the amount of jobs created in RES increases the demand for a highly qualified workforce in the energy sector.

In the **Reference scenario**, between 67,000 and 101,000 jobs are lost between 2011 and 2030 in the mining of solid fuels, affecting mainly medium qualified workers (75% of the sector's workforce). Additionally, there are losses of between 58,000 and 96,000 jobs in oil and gas extraction by 2030 (compared with 2011), affecting both medium and highly qualified workers (47% and 42% of the sector workforce, respectively, see Table 7). This means that by 2030, between 77,500 and 121,000 medium qualified jobs may disappear, while between 24,000 and 40,000 highly qualified jobs may be lost in primary fuels.

However, between 2010 and 2030 in the Reference scenario, close to 800,000 jobs are created in RES-E. Given the employment structure of the renewable energy sector, with a share of at least 33% of highly qualified workers (see Table 8), medium and highly qualified jobs lost in primary fuels are theoretically fully replaced by jobs in the renewable energy sector.

In the **DST and the High-RES scenarios**, more jobs are lost in primary fuels than in the Reference scenario. On the other hand, the amount of jobs created in the RES sector is more significant. RES may not only maintain the distribution of qualification levels, but may actually increase the demand for highly qualified workers. Indeed, in 2030, there are about 100,000 more jobs in the DST scenario and 500,000 more jobs in the High-RES scenario than in the Reference scenario (lower range). Considering that the renewable energy sector has a higher share of highly qualified workers (33% to 75%) than most activities in primary fuels (see Section 3.1.2.2), this results in a net increase of highly qualified workers.

With the level of qualifications in the energy sector going up, there may be a risk of skills shortages. Indeed, as the share of highly qualified workers in the general labour market increases (Cedefop, 2011), the energy sector could be in competition with other sectors for the recruitment of a highly qualified workforce. In particular, shortages of engineers and technicians are common to the renewable energy sector (ILO and EU, 2011). The problem can be traced back upstream, with a lack of qualified trainers for renewable technologies (ibid.). Fortunately, dynamics recently at play in the labour market ease the risk of skill shortages. First, an increase in the supply of highly skilled workforce is observed in the EU. The growth in supply of medium and highly skilled workforce is even expected to outpace the growth in demand for highly skilled workers (European Commission, 2011c). Second, the economic crisis has had a positive effect on skills shortages, by facilitating the filling of vacancies in some occupations (Cedefop, 2012b). Finally, certain existing skills are transferable to the renewable energy sector, with or without the need for retraining. Examples of portable skills include welding, surface treatment and outfitting skills in the oil and gas industry usable in the wind turbine sector (Cedefop, 2010a). Examples of upskilling include skills in the assembly and installation of parts for industrial operators and industry electricians to work as wind turbine operators (Cedefop, 2010b), as well as training on solar PV for electricians and roofers to work as solar PV installers and designers (ibid.).

Another potential threat to a sufficiently large and skilled workforce comes from ageing. The trend of an ageing workforce is observed in the power sector, with workers aged 50 and over representing at least 40% of the workforce in one third of the companies surveyed by Poupard and Tarren (2011). A relatively old workforce carries the risk of not finding skilled labour market entrants to replace them when they retire.

Summary

As the employment level increases in both decarbonisation scenarios, the employment structure of the energy sector may shift to more highly qualified workers, particularly due to the relatively high level of qualification required in RES. This means that the energy sector will provide not only more jobs in the context of the new SET, but also better qualified ones.

3.2.4 *Regional implications*

Employment effects may not be homogenous throughout the EU due to regional characteristics of the energy system. The following paragraphs describe potential employment effects in three regions: central and eastern Europe, northern Europe and southern Europe. The analysis is based on the case studies on Poland, Sweden and Spain (see Annex 1), and is lead by the assumption that over time, EU economies will converge, leading labour productivity of energy technologies to converge as well. Convergence of productivity is discussed in NEUJOBS WP8 (D8.3) on "Regional disparities, ageing and territorial aspects of employment".

Central and eastern Europe is characterised by generally high shares of fossil fuels, especially solid fuels, in both the energy mix and the power mix. Table 17 summarises the shares of these fuels in gross inland consumption and in power generation in 2011.

Table 17. Share of fossil and solid fuels in gross inland consumption and in power generation in selected EU member states from central and eastern Europe, 2011 (%)

	Share in gross inland consumption		*Share in power generation*	
	Fossil fuels	*Solid fuels*	*Fossil fuels*	*Solid fuels*
Poland	91	53	92	85
Czech Republic	79	42	59	54
Romania	79	23	55	40
Bulgaria	75	42	58	54
EU27	**75**	**17**	**50**	**26**
Hungary	74	11	48	18
Slovakia	68	21	28	13
Slovenia	67	21	36	33

Source: European Commission (2013a).

Poland, the Czech Republic and Bulgaria show high shares of solid fuels in their energy mix. The case study on Poland (see Annex 1) suggests that the higher the share of fossil fuels in primary energy supply, the higher the number of jobs that will be lost in a decarbonisation scenario.

Similarly, a slowdown in the construction of new fossil-fired capacity in the power sector may result in job losses (in CIM), potentially affecting countries with relatively high shares of fossil fuels in power generation, such as Poland, the Czech Republic, Bulgaria and Romania. However, this may affect less those countries where lower shares of solid fuels in power generation are compensated by substantial shares of nuclear power (for example, Hungary, Slovakia and Slovenia have shares of between 39% and 54% of nuclear power in their power mix).

Besides the future evolution of fossil fuels and nuclear power, the extent to which employment in the energy sector in central and eastern Europe may increase will also depend on the future deployment of RES capacity.

With much higher shares of RES, the situation in northern Europe is quite different from that in central and eastern Europe. The share of RES in the primary energy mix and power mix is above the EU27-average in all Nordic countries.

Table 18 summarises these shares for Denmark, Finland, Norway and Sweden.

Table 18. Share of RES in gross inland consumption and in power generation in northern European countries, 2011 (%)

	Share in gross final energy consumption	*Share in power generation*
Norway	65	100
Sweden	45	60
Finland	32	29
Denmark	23	36
EU27	**13**	**21**

Source: Eurostat, 2013b.

The case study on Sweden (see Annex 1) shows that a high share of RES in the electricity mix is beneficial to employment levels, and that even a full phase out of (already comparatively low levels of) fossil fuels can have a positive net effect on employment. This suggests that in northern Europe, there may be the potential for job creation by further increasing the share of RES in the energy mix. With currently (for Nordic countries) modest shares of RES in final energy consumption, that potential may be largest in Denmark and Finland. In Norway, which already generates all of its electricity from RES, future potential for job creation is less clear.

Similarly to northern Europe, southern European countries also have relatively high shares of RES in their electricity mix when compared with the EU average (with the exception of Greece). However, in the south the share of gas is also relatively high, as shown in Table 19.

Table 19. Share of RES and gas in power generation in selected southern European countries, 2011 (%)

	Share of RES in power generation	*Share of gas in power generation*
Portugal	47	28
Spain	30	29
Italy	28	50
Greece	14	23
EU27	**21**	**22**

Source: European Commission, 2013a.

The case study on Spain (see Annex 1) shows that the fast deployment of RES may create jobs, especially if accompanied by a simultaneous deployment of gas-fired capacity. As shown in Table 19, the respective shares of RES and gas in the power mix of Portugal and Italy suggest potentially similar employment results to those of Spain.

However, despite natural resources favourable to RES development (e.g. solar radiation), southern European countries might not realise their RES potential due to financial constraints resulting from the economic crisis. The case study on Spain suggests that such a development may translate into fewer jobs as well.

3.2.5 *The potential role of exports*

Many EU member states are among the global leaders in terms of investments in RES technologies and installed capacities. This is particularly true for Germany, Spain and Italy (REN21, 2013). Technical expertise and global leadership can lead to additional demand for low carbon technologies from third countries, boosting exports of EU technology. In general, existing studies tend to agree on the growing global market and consequent growing export (and job) opportunities for green technologies, but there is no consensus on how to quantify this market.

It is worth pointing out two caveats when estimating export values of RES technologies. First, there are uncertainties in the quantification of import and export values of these technologies. This is due to the fact that trade balance statistics do not account for technologies but for components (Groba and Kemfert, 2011). Moreover, it is not possible to distinguish between pre-products and end products. As the main components for each technology are known, it is possible to estimate the import and export values for those components that are needed for a certain green technology.

However, in some cases a clear assignment is not possible and thus the values may be overestimated. In the case of exports there is also the opposite effect, however, as exports are typically underrepresented in global trade statistics,[66] including the commonly used UN Comtrade[67] database (Groba and Kemfert, 2011). The second caveat is that the set of low-carbon technologies is not well defined.[68] For the purpose of their analysis, Gehrke and Schasse (2013a) include technologies for the use of renewable energy sources as well as energy efficiency technologies, but also combined cycle gas turbines because of their (relatively) low specific emissions when producing electricity. In contrast, Groba and Kemfert (2011) only assess import and export values of renewable energy technologies. It is evident that the inclusion or exclusion of certain technology groups greatly affects the outcome of the analysis.

In general, data availability for the EU as a whole is scarce. However, there have been a number of studies focusing on Germany. According to Gehrke and Schasse (2013a), low-carbon technology components had an export value of €20 billion in 2011. In the same year, the import value of such components amounted to €14.5 billion. These values correspond to a share of 2% of the import/export value of industrial goods in general. In 2002, this share was 1.5%. Accounting for half of the exports and two thirds of the imports of low-carbon technologies, goods for the use of renewable energy sources – e.g. wind and hydro turbines, solar cells, solar modules, mirrors, power inverters, (heat) pumps, etc. – dominate the trade statistics,. Components for energy efficiency technologies and turbines for low emission heat or electricity generation constitute the remaining trading volume of low-carbon goods.

On the global level, Germany is the second-largest exporting country of green technologies, with a share of 15% of the total trading volume (Büchele et al., 2012). The world's leading supplier is China. In the last decade, China's importance has been growing significantly, especially in the field of solar energy. Their share of the global export value for low-carbon technologies increased from 4.5% in 2002 to 20.1% in 2011 (Gehrke and Schasse, 2013a). This increase was partly fuelled by the rising demand for solar cells in Germany, which was not covered by domestic German production. Nevertheless, in the same period the value of German green technology exports was constantly above the corresponding import value thanks to a rapidly growing global market.

The future development of exports of low-carbon technologies is characterised by an even higher degree of uncertainty. Capros (2014) points out that in a scenario where the EU takes early action and the rest of the world joins decarbonisation efforts after 2030, the EU can achieve cost advantages as a first mover allowing it to lead global markets at least for a limited time. However, this advantage would diminish over time due to the worldwide diffusion of technologies. Main winners of European low-carbon exports would be electric vehicles, while CCS and RES technologies are also important. In such a scenario, EU exports may increase by 1.4% cumulatively compared with the reference scenario (Capros, 2014).

Existing studies show that there are and will continue to be export (and therefore job creation) opportunities for first-moving countries that provide green technologies. However, a quantification of the employment effect is beyond the scope of this paper,

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[66] It is generally easier to collect data for imports than for exports, as the imports may be subject to custom charges.

[67] World Integrated Trade Solution: wits.worldbank.org/wits/

[68] A comprehensive methodological overview is provided in Gehrke and Schasse (2013b).

as we focus on power generation but do not cover the supply chain of generation (e.g. the supply of materials for power plants). Moreover, a quantification of export values is subject to great uncertainty due to the aforementioned reasons, even *ex post*, resulting in further uncertainties regarding the job creation effect.

3.2.6 *Fiscal implications*

There are various measures governments can take to support the penetration of RES in the energy/power system, including tax reductions, public investments, capital subsidies, investment or production tax credits and energy production payments (IRENA, 2013). However, as shown above, government intervention to increase the share of renewables in the context of decarbonising the EU energy system will not only create new, comparably higher-skilled jobs, but will also lead to the destruction of jobs related to fossil fuels. There will thus increasingly be further fiscal implications related to the energy transition. These will include costs for measures aimed at matching changing employment demand and supply patterns, both in quantitative and in qualitative terms. In quantitative terms, the creation of new jobs and the destruction of others will affect income tax revenues as well as social security spending. Since this paper suggests a net increase in employment levels in decarbonisation scenarios, a positive effect on both income tax revenues (i.e. an increase) and social security spending (i.e. a decrease) can generally be expected. In qualitative terms, however, the skills transition might entail additional spending to match the new skills demand with a corresponding supply. Examples of such costs include costs of education and (re)training. Structural and frictional unemployment related to the skills transition may additionally entail increases in social security spending (i.e. unemployment benefits), although potentially only for a limited period of time. Finally, some workers may enter early retirement, raising spending on pensions.

The EU budget can address skill shortages through training and technical assistance programmes and support to SMEs (e.g. COSME policy, cohesion policy for SME creation, technical assistance, etc.), but by how much remains unclear. The programmes, if well designed, can have a substantial impact. Technical assistance investments can lead to the leverage of considerable sums for large-scale projects, promoting employment and further skill development. In the area of energy for example, technical assistance programmes such as the ELENA programme have attracted investment funds 40 times higher than the EU budget assistance.

To summarise, the transition to a low-carbon energy sector will have both positive and negative effects on public budgets. On the one hand, increasing employment levels may positively impact public budgets by increasing income tax revenues and decreasing social security spending. The skills transition, on the other hand, may require more public spending in terms of education and (re)training, as well as (temporary) unemployment benefits. In the long term, however, (global) efforts to fight climate change are likely to have positive fiscal effects by reducing costs for adaptation and from loss and damages related to dangerous climate change in the future (Stern, 2006).

4. Summary and conclusions

This paper established a methodology for analysing employment impacts of changes in the composition of the primary (fossil) fuel mix and the electricity mix that are projected to occur in the context of a new socio-ecological transition away from fossil fuels. The methodology is based on employment factors. It allows for calculating employment impacts by multiplying (future) energy units (in ktoe for primary fuels and MW for the power sector) by technology-specific employment factors. These employment factors are equivalent to labour intensity ratios expressed in jobs per ktoe or jobs per MW. They are calculated on the basis of current energy sector figures and then used to calculate the number of jobs linked to the projected future volumes of primary energy and levels of installed electric capacity in the years 2020, 2030 and 2050. Projections are based on the reference scenario and two decarbonisation scenarios (Diversified Supply Technologies and High-RES) of the European Commission's *Energy Roadmap 2050*.

This methodology is applied to primary energy activities linked to fossil fuels as well as to the power sector. For activities linked to primary energy carriers, only fossil fuels are considered because RES such as wind, solar and hydro power do not require combustibles. Therefore, there is no fuel that needs to be extracted and/or processed. Regarding biomass and nuclear, no separate job figures are available for primary activities. As regards the power sector, a distinction is made between jobs in the construction, installation and manufacturing (CIM) of new electric capacity and jobs in the operation and maintenance (O&M) of existing and projected electric capacity.

While there will be many effects of the decarbonisation of the energy system on the labour market (direct, indirect and induced), this study focuses only on direct employment for reasons of data availability and the difficulties associated with assigning indirect or induced jobs to specific technologies.

Apart from changes in the quantity of direct jobs associated with the energy transition, this report also analyses how required qualification levels may change. This is done by applying the current distribution of low, medium and highly qualified jobs in various energy technologies to the changed mix of primary (fossil) fuels and of power sources in the future.

Figures underlying the calculations are based on a variety of sources, but the lack of detailed data on the level of individual technologies is a serious issue. Based on available figures and own calculations, estimations of the current employment level in the EU are derived. Since available figures are subject to variance, a lower range and an upper range of current employment, employment factors and consequently of future employment levels are established. Another drawback of this methodology is the fact that constant employment factors are used for the calculations of future employment levels. Disregarding any potential future reductions in labour intensity, this is done due to a lack of reliable information on how labour intensities might develop in the future for different energy technologies. In essence, this means that future employment figures may be overestimated, but by how much is uncertain. However, this overestimation may be counterbalanced by potentially positive impacts on employment resulting from increasingly decentralised electricity generation in the future, which have not been taken into account in this paper. An additional element of uncertainty regarding this methodology is introduced by the scenarios about the future development of the EU energy system. Scenarios are not forecasts of the future, but rather present a range of possible developments. These visions of the future energy system are highly dependent on a number of assumptions being made about an uncertain future. However, in the context of WP11 of the NEUJOBS project, they are required to identify potential future developments in the energy sector, which can be used to analyse related employment impacts.

Even when taking all these shortcomings into account, the employment factor based methodology still allows for identifying patterns regarding employment in a progressively decarbonising EU energy sector. The starting point is an energy sector largely dominated by fossil fuels, both in primary sources as well as in the power sector. The total number of direct jobs provided by the EU energy sector in 2011 is estimated at between 1.5 million (DG Energy) and 2.2 million (Eurostat, LFS), representing a share of 0.7-1% of the total employed workforce in that year. Electric power generation, transmission and distribution is by far the largest employer, providing for roughly 55-60% of all direct jobs in the energy sector. The extraction of primary fossil energy employs less than a quarter of all direct jobs, while other oil and gas activities (including oil refining, manufacture and distribution of gas) provide less than 20%.

As regards current qualification levels, it can be generalised that some 10% of the labour force employed in the energy sector in 2012 were low qualified, around 50-60% were medium qualified and around 40% were highly qualified. Qualification levels in the RES sector are similar to the overall energy sector, albeit possibly with a slightly higher share of highly qualified workers. However, there is a pronounced difference between qualifications required in the RES sector and in coal and lignite mining activities, where the share of highly qualified labour is considerably below the average of the entire energy sector.

Based on this stocktaking of the current energy sector, the calculation of employment factors for different energy technologies and the projections of the two decarbonisation scenarios, future employment levels are calculated for 2020, 2030 and 2050. According to our calculations and taking into account all uncertainties involved, total employment in the EU energy sector could increase from between 1.5 and 2.2 million in 2011 to between 2.3 and 2.8 million in 2020, between 2.4 and 3.1 million in 2030, and to between 3.5 and 5.4 million in 2050, depending on the scenario and on the applied employment factors (i.e. the low or high range). The results indicate that job losses in primary (fossil) fuels are more than outweighed by job creation in RES activities in the power sector.

The results also show that more jobs are created in the High-RES scenario than in any other scenario. In this scenario, there are up to 800,000 more jobs in 2020, 1.3 million more jobs by 2030 and 3.7 million more jobs by 2050 (all compared with 2011). Comparing the results for the High-RES scenario with the Reference scenario shows that up to 500,000 additional jobs may be created in the context of a decarbonisation by 2030 and possibly even up to 2.3 million additional jobs by 2050. In the DST scenario, there may be 100,000 more jobs by 2030 compared with the Reference scenario, and 600,000 additional jobs by 2050.

The results show that decarbonisation in the context of a new SET can lead to substantial employment creation, particularly in the long term. While the results of the two decarbonisation scenarios are similar to the Reference scenario until 2020, differences begin to materialise by 2030, and in particular by 2050. However, as noted before, results for 2050 are subject to high uncertainty due to the linear approach (i.e. constant employment factors) in calculating job projections. It should also be noted that the employment factor methodology implies that the more costly RES are, the more jobs will be created. This is especially the case where non-depreciated fossil installations are replaced by low-carbon energy sources, thus accelerating the energy transition but also raising related costs.

As the employment level increases in both decarbonisation scenarios, the employment structure of the energy sector may shift to more highly qualified workers, particularly due to the relatively high level of qualification required in RES. This means that the energy sector will provide not only more jobs in the context of the new SET, but also better qualified ones.

The transition to a low-carbon energy sector will have both positive and negative effects on public budgets. On the one hand, increasing employment levels may positively impact public budgets by increasing income tax revenues and decreasing social security spending. The skills transition, on the other hand, may require more public spending in terms of education and (re)training as well as (temporary) unemployment benefits as structural and frictional unemployment increases. In the long term, however, (global) efforts to fight climate change are likely to have positive fiscal effects by reducing costs for adaptation and from loss and damages related to dangerous climate change in the future.

These results will be taken forward in the third deliverable of NEUJOBS WP11 (D11.3), which will derive specific policy conclusions and recommendations in order to provide guidance for policy-makers as employment patterns change in the context of the energy transition.

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Annexes

Annex 1: Case studies

The purpose of the case studies is to show that the methodology used for EU-wide employment effects can also be applied on the member-state level to identify potential regional differences. The focus of the case studies is on Poland, Sweden and Spain, but depending on data availability, the methodology can be applied to any member state and third country.

Poland has been selected because of its primary energy mix largely dominated by fossil fuels, and its power generation mix largely dependent on coal. Poland also has a different structure of final energy use from western Europe, with a relatively low demand for electricity due to a high use of hard coal for heating purposes (Bukowksi et al., 2013). Sweden has a very different outlook, with already high shares of RES in its primary and electricity mixes, and an objective of zero net GHG emissions in 2050. Spain has been selected mainly for its fast growth of RES as primary energy source in the past and for its geographical location in the south of Europe.

1.1 Methodology

Each case study analyses the current energy balance of the country, as well as the employment linked to it. They address both employment level and structure. Energy sector data and figures are taken from national energy strategies for 2020, 2030, and 2050 (if available).

Future employment calculations are based on the same methodology used above, i.e. by multiplying energy units by employment factors. For the case studies, national employment factors are compared with EU employment factors. However, projections for future employment are calculated with the EU factors for two reasons:

- Over time, differences between member states are expected to even out. As economies converge, labour productivity for technologies should also converge. Convergence of productivity is discussed in NEUJOBS WP8 (D8.3) on Regional disparities, ageing and territorial aspects of employment.
- National factors cannot be defined for all technologies, due to a lack of data (mainly in terms of job figures per technology in individual countries).

1.2 Poland

Among all EU member states, Poland relies most heavily on coal for power generation. Roughly 85% of electricity produced in Poland is generated through solid fuel combustion (see Table 20). To effectively reduce its GHG emissions, Poland will need to clean up its power sector. Therefore, scrutinising the effects of decarbonisation of such a coal-dependent power sector is of great importance for this study.

1.2.1 Energy balance

In 2011, total power production in Poland reached 163.4 TWh (PAIiIZ, 2013). Poland derives about 85% of this power supply (138 TWh) through the combustion of solid fuels.[69] Therefore, and as illustrated by Table 20, when compared with the EU average (26%), Poland is heavily reliant on coal for electricity production. Generating 7.6 TWh

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[69] Including hard coal (53%) and lignite (32%) (Egenhofer et al., 2013).

of power, biomass was the second largest source of electricity and its contribution to the total energy production was one percentage point above the EU average. As opposed to the EU (22%), Poland barely uses gas for electric generation (4%). While wind holds a mere 2% of total power production, it is worth noting that between 2010 and 2011, power generation from wind installations doubled, increasing from 1.6 TWh to 3.2 TWh (ARE, 2012). Other sources of power supply include oil products (3%) and hydro (1%). Whereas nuclear makes up the bulk of the EU's generating portfolio (28%), there are no nuclear power plants operating in Poland.

Table 20. Power generation by sources in Poland and in the EU-27 (2011 data)

	Poland		*EU-27*	
Fuel type	*Power production (in TWh)*	*Share of total production*	*Power production (in TWh)*	*Share of total production*
Nuclear	0	0%	906.8	28%
Solid fuels	139.8	85%	848.7	26%
Gases	5.8	4%	726.5	22%
Oil products	4.7	3%	73.6	2%
Hydro	2.3	1%	335.2	10%
Wind	3.2	2%	179.0	5%
Biomass	7.6	5%	132.6	4%
Solar	n. a.	n. a.	46.3	1%
Geothermal	n. a.	n. a.	5.9	0.2%
Ocean	n. a.	n. a.	0.5	0.02%
Total	163.4	100%	3,279.6	100%

Sources: ARE (2012); Eurostat (2013b).

1.2.2 The energy strategy of Poland

At present, the Polish energy policy is based on a document entitled *Energy Policy of Poland until 2030* (Ministry of Economy, 2009a) and the objectives of the Climate and Energy Package. In the context of the 20-20-20 targets, differentiated national targets for the share of RES in final energy consumption have been introduced. Poland is committed to increasing its power production from RES to 15% by the year 2020.

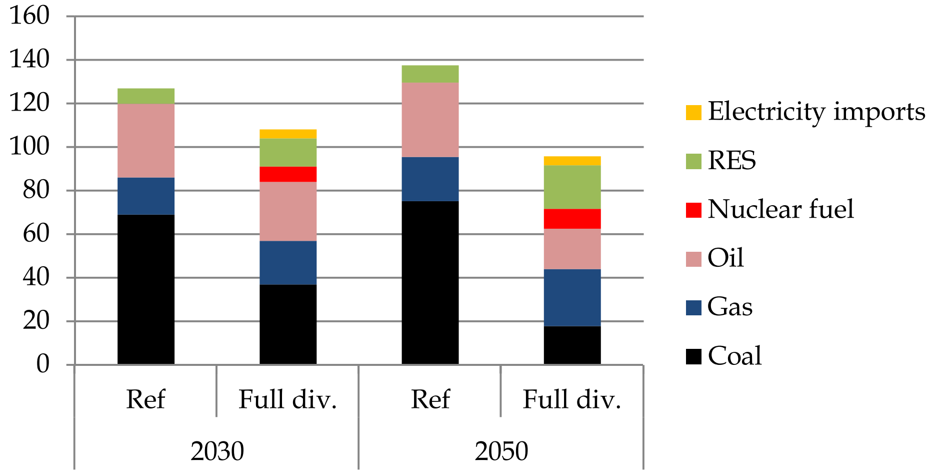
Prepared by the Polish Ministry of Economy, the *Energy Policy of Poland until 2030* was presented in 2009. The document includes a set of non-binding targets for 2020 and 2030. The main objectives of the strategy are to improve energy security, enhance energy efficiency, promote the use of RES and introduce nuclear energy to the power generation portfolio (Ministry of Economy, 2009a). The strategy is completed by an appendix that provides projections for the future demand for energy (Ministry of Economy, 2009b).

The Polish Ministry of Economy is currently working on a new energy strategy, and the 2009 strategy will thus soon be replaced (Hinc, 2013). Therefore, long-range projections presented in this section are based on a non-official roadmap outlining the pathways to a low-carbon economy in Poland. Entitled *2050.pl: the journey to the low-emission future* (Bukowski et al., 2013), the roadmap compares a set of modernisation scenarios to a reference scenario. In this case study, the European Climate Foundation (ECF) Full diversification variant[70] is compared with the ECF Reference scenario.

Primary fuels

As shown by Figure 14, the composition of the primary energy mix varies among scenarios. In the ECF Reference scenario, fuel consumption is dominated by coal. In 2030, demand for coal amounts to 69 Mtoe. By 2050, this rises to 75 Mtoe, accounting for 54% of the primary energy mix. Note that between 2030 and 2050, the primary energy supply increases from 127 Mtoe to 138 Mtoe. In the ECF Full diversification scenario, primary energy consumption shrinks from 107 Mtoe in 2030 to 96 Mtoe in 2050. In comparison to the Reference scenario, coal plays a more limited role, yet remains the main energy carrier in 2030. It loses importance in the 2040s and by 2050, coal contributes roughly 19% to the primary energy supply. RES hold a 21% share of the primary energy mix. Note that natural gas becomes the main energy carrier in that year (27%, or 26 Mtoe).

Figure 14. Primary energy mix in Poland in 2030 and 2050 (Mtoe)



Source: Bukowski et al. (2013).

Power sector

In the 2009 strategy, final demand for electricity is projected to grow by 55% between 2006 and 2030. To meet that demand, installed capacity increases from 35 GW in 2006 to 51 GW in 2030. Thereafter, solid fuels continue to dominate the power sector in Poland in the ECF Reference scenario (see Figure 15). Between 2030 and 2050, total installed capacity of coal-fired power plants increases from 37 GW to 50 GW. In 2050, coal-fired installations account for 80% of the total installed capacity in Poland. In the ECF Full diversification scenario, the total installed capacity grows from 66 GW in 2030 to 107 GW in 2050, i.e. +38% (see Figure 15). By 2050, coal-fired blocks represent a mere 7% of the totalled installed capacity in Poland. All forms of RES[71] make up the bulk of installed generation capacity (58%). Nevertheless, the role of RES is less important than in both EU decarbonisation scenarios.

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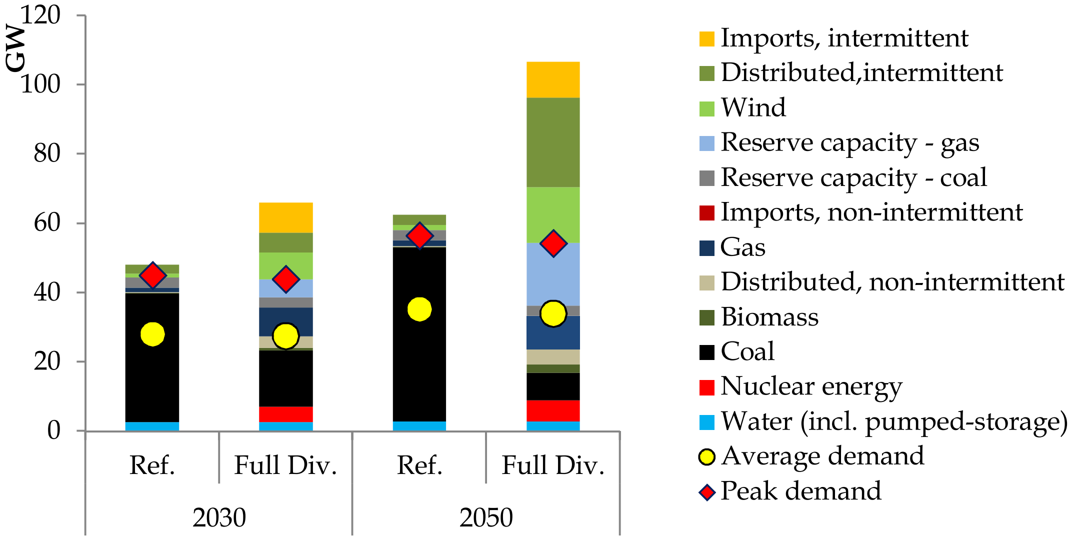
[70] This scenario relies on all technological options: fossil fuels, nuclear energy, RES, distributed generation, and imports.

[71] Including imports.

Figure 15. Structure of installed capacity in 2030 and 2050 in Poland (GW)



Source: Bukowski et al. (2013).

1.2.3 Employment in the current Polish energy supply sector

Table 21 provides figures for employment levels[72] and structure[73] in the energy sector in Poland in 2011.[74] To allow for a comparison, EU figures for the employment structure are also given. Overall, employment in extractive industries is concentrated in coal and lignite mining. The bulk of employment in oil and gas depends on imported volumes, i.e. it is in oil refining and marketing, and in gas transmission and distribution. Finally, most employment in RES is in biomass, which includes jobs in collecting and processing feedstock.

In terms of qualification levels (see Table 21, right part), energy activities in Poland are rather homogenous, with a majority of workers being medium qualified (61% to 78%), except for oil and gas extraction (47%). Highly qualified workers make up 27-35% of the workforce in each sector, except in coal mining (14%). Compared with the EU, activities related to oil and gas extraction as well as to electricity have a lower qualification level in Poland, i.e. there is a higher share of medium skilled and highly skilled jobs for these activities in the EU. The employment structure of other activities is comparable to EU figures. The crucial difference between Poland and the EU average is the significant role of jobs in mining.

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[72] Source: Eurostat (2013d). SBS is used instead of LFS, because LFS does not provide the required data.

[73] Source: Cedefop (2013).

[74] Number of jobs as reported by Eurostat and based on NACE Rev. 2 classification. Data on qualification levels as reported by Cedefop (2013) and based on NACE Rev. 1.1 classification. This results in differences in the definitions of activities in the left column of Table 21. For details on job numbers based on NACE Rev. 2, see Table 5 in Section 3.1.1.2, and for details on qualification levels based on NACE Rev. 1.1, see Table 7 in Section 3.1.2.2.

Table 21. Direct employment and structure of qualification levels in the energy sector in Poland and in the EU27 in 2011

Activity	*Number of jobs*	*Low qualified (%)*		*Medium qualified (%)*		*Highly qualified (%)*	
	Poland (PL)	*PL*	*EU*	*PL*	*EU*	*PL*	*EU*
Mining of coal and lignite	122,061-186,000[75]	8	10	78	75	14	15
Oil and gas extraction	6,500[76]	21	11	47	47	32	42
Manufacture of coke and refined petroleum products	13,724	n. a.	8	61	55	35	37
Electricity[77]	93,200	4	8	69	55	27	37
Manufacture of gas and distribution through mains	11,406	4	7	69	60	27	33

Sources: Cedefop, 2013; Eurostat, 2013d.

Based on the data provided in Table 20 and Table 21, employment factors (equivalent to labour intensities) for Poland are calculated. Table 22 shows these figures both for Poland and the EU.

Table 22. Labour intensity of primary energy activities in the EU27 and in Poland in 2011

	EU	*Poland*		
	Employment factor (jobs/ktoe)	*Employment factor (jobs/ktoe)*	*Direct jobs*	*Energy (ktoe)*
Mining of coal and lignite [B05]	1.37 – 2.06	2.19 – 3.34	122,061 – 186,000	55,760
Oil and gas extraction	0.49 – 0.81	1.33	6,500[78]	4,900
Oil refining [C19.2]	0.20 – 0.33	0.35	9,399	26,510
Gas other [D35.2]	0.37 – 0.53	0.85	11,406	13,490

Sources: Eurostat, 2013c and 2013d.

The comparison of Polish employment factors for primary fuels with the EU average factors reveals a less productive primary energy sector in Poland. This means that more people are needed per unit of energy produced. For instance, Poland's solid fuels industry remains more manual than that of other EU member states.[79] The relatively low productivity of oil and gas extraction may be explained by the same reason.

It is worth mentioning that the mining sector in Poland has been subject to structural changes since 1989, aimed at improving its productivity. Around 330,000 jobs have been lost in the process (IEA, 2011b). Given the depletion of domestic coal and lignite

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[75] In line with the figure of 128,000 direct jobs in 2012 by Euracoal (2013).

[76] Source: estimation by Cedefop (2013).

[77] Qualification levels also include activities in steam and hot water supply.

[78] Estimation by Cedefop (2013).

[79] Based on an interview with Euracoal.

resources (ibid.) and further desired improvements in productivity, employment in the sector continues to decline.[80]

For the power sector, the lack of data prevents a comparison of employment factors for Poland with EU factors. To assess the employment level and structure of the future Polish energy sector, EU employment factors have been used, thus assuming convergence at the EU level.

1.2.4 Employment in the future Polish energy supply sector

Primary fuels

Table 23 shows the projections for future employment in primary fuels based on the scenarios presented in the previous section. There is a significant decline in employment of nearly 20% from 2011 to 2020 in all scenarios. This is mainly related to the use of EU employment factors, which are lower than the Polish employment factors (see Table 22).[81] The underlying assumption is that the labour intensity of similar activities will converge in Europe over time.

From 2011 to 2030, the employment related to primary fuels decreases significantly in the ECF Full diversification scenario (-33%) and less significantly both in the ECF Reference scenario (-17%) and in the 2009 strategy scenario (-13%). Overall, this development is not surprising given that fossil fuels continue to play a significant role in the primary energy mix in those two scenarios. Significant differences between the various scenarios begin to materialise after 2020 because the targets for the year 2020 have already been set. The bulk of the job losses are attributable to the decrease in domestic coal production.

Table 23. Direct employment in primary fuel activities in Poland in 2011, 2020, 2030 and 2050

	2011	*2020*			*2030*			*2050*	
		2009 strat.	*ECF Ref*	*ECF full div.*	*2009 strat.*	*ECF Ref*	*ECF full div.*	*ECF Ref*	*ECF full div.*
Solid fuels [B05]	122,000 – 186,000	90,619	92,700	94,760	95,625	92,700	72,100	78,280	30,900
Oil and gas extraction	n. a.	n. a.	4,050	3,240	n. a.	4,860	4,860	5,670	6,480
Oil refining [C19.2]	9,399	9,042	10,230	9,240	10,263	11,220	8,910	11,220	6,270
Gas other [D35.2]	11,406	7,685	7,950	6,890	9,116	9,010	10,600	10,600	13,780

Source: own calculations, based on Bukowksi et al. (2013); Ministry of Economy (2009b).

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[80] The productivity of coal and lignite mining in Poland is still relatively low. For instance, in 2010, there were 981 jobs per million tons of coal and lignite produced in Poland, against 224 in Germany (based on Eurocoal (2011)).

[81] Moreover, projections do not include the number of jobs linked to imported volumes of coal. They may thus be further underestimated.

In terms of qualifications, there is little change in the reference scenario, since employment levels remain stable per activity. However, the Full diversification scenario has an adverse impact on medium qualified workers, since it may primarily cause job losses in coal mining (78% of medium qualified workers).

Power sector[82]

In the 2009 strategy, employment in the power sector decreases by roughly 35% from 2011 to 2030. This is mainly due to a decrease in CIM jobs in solids-fired power generation, while the O&M employment base remains stable. The creation of 11,000 jobs in nuclear power and around 20,000 jobs in RES-E between 2020 and 2030 is not enough to offset the decrease in employment in fossil fuel related activities.

The ECF scenarios do not allow for a distinction between CIM and O&M jobs, because the newly installed capacities are not disclosed in the reports. Therefore, no in-depth calculations can be conducted for these scenarios. For 2050, the difference between the installed capacity in 2050 and in 2030 can be used to estimate the newly installed capacity. In the following, results for 2050 are discussed.

By 2050, there are 73,000 jobs in the power sector in the Reference scenario, against 141,000 in the Full diversification scenario. Similar to the EU, this is due to the difference in RES installed capacity, which results in 9,000 people employed in RES in the Reference scenario, against 94,000 in the Full diversification scenario.

The increase of the employment level in the power sector in the Full diversification scenario is not expected to have a strong impact on the employment structure. Although the decrease in coal-based power generation affects mainly medium qualified workers, the increase in jobs in gas and in RES create jobs mainly for medium skilled, and only to a lesser extent for highly skilled workers.

1.2.5 Conclusions

Compared with the EU, employment in primary fuels in Poland decreases more in the decarbonisation scenario than in the reference scenario. This is especially the case for employment in solid fuels. Similar to the results for the EU, the difference between a low-carbon and a business-as-usual pathway becomes more visible over time.

In contrast to the EU, employment in the power sector in Poland is projected to decrease by 2030. This is due to the decreasing amount of new installations of coal-based capacity which has a larger impact on Poland than on the EU, given the much larger share of solid fuels in the Polish power generation mix (85% versus 26% for the EU). By 2050, there are almost twice as many jobs in the power sector in Poland in the decarbonisation scenario than in the reference scenario. This is in line with the results for the Reference and the High-RES scenario for the EU.

Overall, for the total energy sector, the difference between a business-as-usual pathway and a low-emission pathway in Poland is not high in terms of jobs. By 2030, diversification of the energy sector might have a negative impact on employment in Poland (30,000 fewer jobs compared with the Reference scenario). By 2050, however,

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[82] Methodological notes: (1) The upper range of EU employment factors is used for fossil fuels given the high labour intensity in Poland. (2) For the category “distributed intermittent” in the ECF roadmap, the employment factor used is the average of the EU factors for solar PV, small hydro, and biogas (the three sources that are detailed in the 2009 strategy). (3) Projections for new installed capacity come from a monitoring report of the Ministry of Economy on the security of electricity supply in 2011-2012 (Ministerstwo Gospodarki (2013)).

the impact on employment may be positive, with close to 40,000 additional jobs in the Full diversification scenario.

Table 24. Direct employment in the energy sector in Poland in 2050

	2050	
	Reference	*Full diversification*
Primary fuels	105,770	57,430
Power sector	73,019	140,741
Total	180,507	218,241

Source: own calculations.

The core difference in the long term between the Reference and the Full diversification scenario is that in the Reference scenario, the bulk of employment is in primary fuels, whereas in the Full diversification scenario, the bulk of employment is in the power sector. Results are shown in Table 24.

Overall, by 2050, there are 21% more jobs in the energy sector in the decarbonisation scenario than in the Reference scenario for Poland. This places it between the DST scenario (+12%) and the High-RES scenario (+38%) when compared with the Reference scenario for the EU energy sector.

1.3 Sweden[83]

The second case study is on Sweden. In contrast to Poland, Sweden already had a very high share of RES in its energy mix in 2011 and aims to emit zero net GHG emissions by 2050. It has been selected not only to represent a country with a strong decarbonisation agenda, but also to represent a country from northern Europe.

1.3.1 Energy balance

Table 25 shows that Sweden's energy balance is dominated by low-carbon energy sources. The country produces hardly any fossil fuels domestically and only imports significant quantities of petroleum. Gross inland consumption is based on RES, nuclear and oil with almost equal shares. Coal and natural gas play a negligible role.

Table 25. Energy balance of Sweden in 2011

	Production (Mtoe)	*Imports (Mtoe)*	*Imports share in total supply*	*Share in gross inland consumption*	*Share in electricity mix*
Solid fuels	0.2	2.4	92%	5%	1%
Petroleum and products	0.1	15.9	99%	29.5%	0.5%
Gases	0.0	1.2	100%	2.5%	1.5%
Nuclear	15.6		0%	31.5%	40%
RES	15.7		0%	32%	56%

Source: European Commission, 2013a.

Sweden already has an almost carbon-free power sector, which relies almost exclusively on RES (56%, mainly large hydro power[84]) and nuclear power (40%).

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[83] With the assistance of Susanna Roth, Visiting Mistra Fellow at CEPS.

1.3.2 The energy strategy of Sweden

Sweden has national targets for RES for 2020, and a vision for zero net GHG emissions in 2050.

Targets for the year 2020

Under the EU "renewables directive" (2009/28/EC), Sweden is subject to a binding national target for the share of RES in gross final energy consumption of 49% by 2020. In addition, Sweden will need to provide at least a 10% share of RES in the transport sector by 2020. Based on the targets set by the renewables directive, Sweden in 2009 adopted a new energy and climate policy with the following targets for the year 2020:

- 40% reduction in greenhouse gases compared with 1990.
- At least 50% share of renewable energy in the energy mix.
- At least 10% share of renewable energy in the transport sector.
- 20% more efficient use of energy compared with 2008.

By 2010, Sweden had already reached a share of 47.8% RES in its energy mix, and 8% RES in the transport sector (Regeringskansliet, 2011, 2012).

In absolute terms, the national target for 2020 is to increase renewable electricity in the electricity certificate system by 25 TWh from 2002 to 2020, with a strong focus on wind power (both on- and off-shore). In 2011, an increase of 13.3 TWh had already been achieved (Swedish Energy Agency, 2012).

Long-term vision 2050

The Swedish government formulated in 2009 a vision for reaching zero net GHG emissions in 2050. It is currently developing a roadmap for how this objective could be realised. The Swedish Environmental Protection Agency and the Swedish Energy Agency (Energimyndigheten, 2012) have already published inputs for the roadmap on the electricity and heating sectors, including a scenario analysis. In addition, the IVL Swedish Environmental Research Institute modelled an RES scenario to analyse how a (close to) 100% share of RES in the energy mix could be reached by 2050 (Gustavsson et al., 2011). This RES scenario projects that total energy demand decreases from 400 TWh in 2010 to 270 TWh in 2050. The demand for electricity is also projected to decrease from 130 TWh in 2030 to 110 TWh in 2050.

This case study uses the RES scenario of Gustavsson et al. (2011) for the calculations on future employment in primary fuels and in the power sector. For the power sector, a comparison with the Reference scenario of Energimyndigheten (2012) is added.

Primary fuels

In the RES scenario of Gustavsson et al. (2011), gas and all related activities are completely phased out by 2040, while all oil-related activities come to an end by 2050. The only fossil fuel left in the energy mix is coal (mainly used in the steel industry), but with a very low contribution to the overall energy mix (less than 5%).

Power sector

The RES scenario published by Gustavsson et al. (2011) assumes that nuclear power is completely phased out by 2040 and that hydro power generation remains constant at 2010 levels until 2050. Strong increases are expected from wind and solar power, the latter in particular after 2040. The results are summarised in Figure 16.

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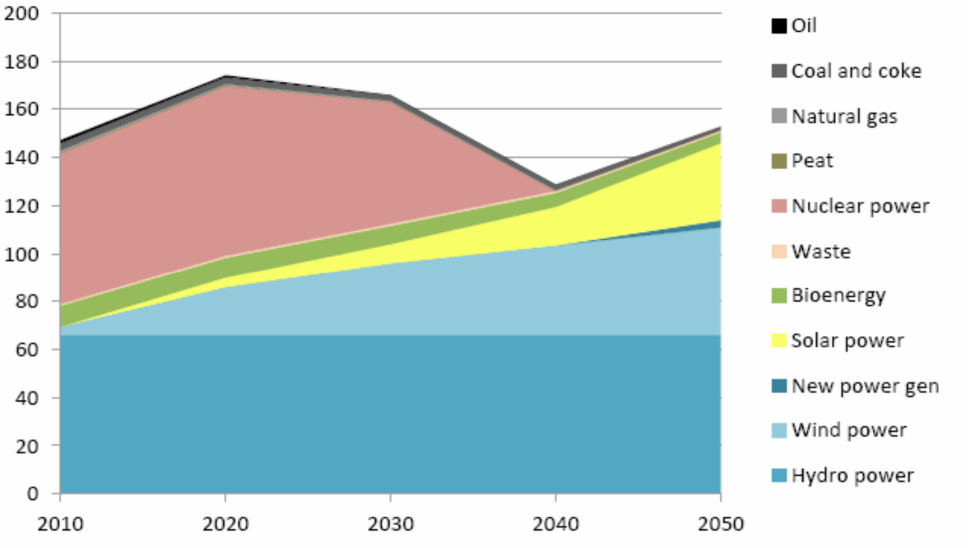
[84] Facilities of more than 10 MW of installed capacity.

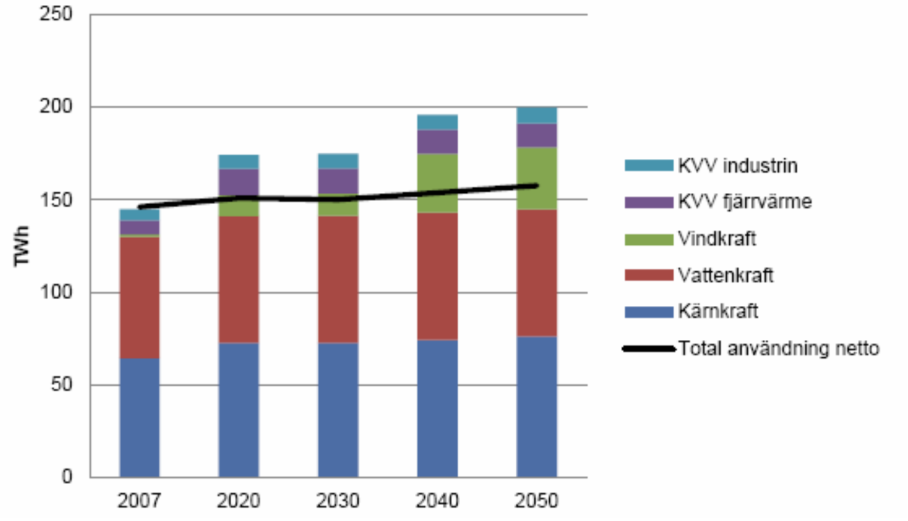
Figure 16. Power generation in Sweden by source, 2010-2050 (TWh)



Source: Gustavsson et al. (2011).

Comparisons can be made with the Reference scenario of Energimyndigheten (2012). This scenario is based on current policies and measures. It does not project the achievement of the target of zero net GHG emissions in 2050. Results from this Reference scenario are presented in Figure 17 and show an increase in power generation until 2050, mainly based on an expansion of wind power. Nuclear power generation increases slightly, while hydro power generation remains constant in the timeframe under consideration. The main differences with the RES scenario are that nuclear power is not phased out[85] and that there is no role foreseen for solar power. Oil- and gas-based power generation is phased out in both scenarios (oil in 2020 in the Reference scenario and in 2030 in the RES scenario; gas in 2030 in both scenarios).

Figure 17. Power generation in Sweden by source in the Reference scenario, 2007-2050 (TWh)



Source: Energimyndigheten (2012).[86]

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[85] The reference scenario nevertheless provides a variant with no new nuclear power, which leads to a capacity reduced by half in 2040 (compared with 2030) and a complete phase out by 2050.

[86] KVV industrin: CHP industry; KVV fjärrvärme: CHP district heating; Vindkraft: wind energy; Vattenkraft: hydropower; Kärnkraft: nuclear energy; Total användning netto: total net use.

1.3.3 Employment in the current Swedish energy supply sector

The energy balance presented in Table 25 implies that there are no jobs in Sweden associated with the production of fossil fuels; almost all jobs related to fossil fuels are in oil refining. In the power sector, RES and nuclear power provide the vast majority of jobs. Table 26 presents the number of direct jobs per energy activity as well as the associated distribution of qualification levels in 2011.[87]

Table 26. Direct employment and structure of qualification levels in the energy sector in Sweden in 2011

Activity	*Number of jobs*	*Low qualified*	*Medium qualified*	*Highly qualified*
Mining of coal and lignite	-	-	-	-
Oil and gas extraction	-	-	-	-
Manufacture of coke and refined petroleum products	2,300	12.7%	41.2%	46.1%
Electricity	21,998	11.5%	52.4%	36.1%
+ *biomass and waste*	*18,477*			
Gas other	303	-	-	-

Sources: Cedefop (2013); Eurostat (2013c, 2013d); Liébard (2012).

While Eurostat reports 22,000 jobs in the whole power sector in Sweden, Liébard (2012) reports a much higher figure of 32,000 jobs in RES-E related activities alone, of which 18,500 are in biomass and waste. The difference between the Eurostat figure for the total power sector and the figure for jobs in RES only may be explained by the importance of the biomass and waste sector in Sweden, for which employment in collecting fuel is not included in the Eurostat figure. As a matter of fact, Sweden was the EU's top consumer of wood pellets in 2011, and wood waste and black liquor made up for 83% of energy production through biomass (Liébard, 2012). Sweden is also the fifth-largest producer of energy from waste incineration in the EU, an energy source that is not included in Eurostat employment figure either. The inclusion of jobs in the supply of wood pellets and waste incineration thus explains the difference between the number of jobs in RES reported by Liébard (2012) and the number of jobs in the power sector reported by Eurostat. Employment in fuel supply for biomass and incineration of waste has not been added to the power sector for the EU as a whole (see Chapter 3) because it is less important at the EU level.

Starting with the Eurostat figure of 22,000 jobs in the power sector and based on the EU employment factor for nuclear power (see Section 3.1.1.2) and the total installed capacity of nuclear power in Sweden in 2011, we estimate that there are 8,900 jobs in nuclear power generation in Sweden in 2011. Since power generation in Sweden relies almost exclusively on RES and nuclear, the remaining 13,100 jobs in the power sector are assumed to be in RES. Adding to this figure the number of jobs in biomass and waste (18,500) gives a total number of 31,600 people working in RES-E related activities

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[87] Number of jobs as reported by Eurostat and based on NACE Rev. 2 classification. Data on qualification levels as reported by Cedefop (2013) and based on NACE Rev. 1.1 classification. This results in differences in the definitions of activities in the left column ofTable 26. For details on job numbers based on NACE Rev. 2, see Table 5 in section 3.1.1.2, and for details on qualification levels based on NACE Rev. 1.1, see Table 7 in section 3.1.2.2.

in the power sector. This number is in line with the figure of 32,000 jobs derived from Liébard (2012).

Based on Table 26, total employment in the Swedish energy sector amounts to 43,100 jobs, of which almost three-quarters work in RES-E related activities.

Levels of qualification in oil refining and the power sector in Sweden are similar to EU averages (see Section 3.1.2.2).

As shown in Table 27, Sweden is below the EU average for labour intensity of oil and gas downstream activities. This means that fewer workers are required per energy unit produced. This justifies the use of the low range of EU factors in calculations for future employment related to primary fuels in Sweden.

Table 27. Labour intensity of primary energy activities in the EU27 and in Sweden in 2011

	EU	*Sweden*		
Activity	*Jobs/ktoe*	*Jobs/ktoe*	*Direct jobs*	*ktoe*
Oil refining [C19.2]	0.20 – 0.33	n. a. – 0.14	n. a. – 2,300	15,970
Gas other [D35.2]	0.37 – 0.53	0.26 – n. a.	303 – n. a.	1,160

Sources: own calculations based on European Commission (2013a); Eurostat (2013c, 2013d).

Employment factors for RES show varying results compared with EU factors, with some lower, some similar, and some higher. Results are presented in Table 28.

Table 28. Labour intensity of RES-E technologies in the EU27 and in Sweden in 2011

	EU	*Sweden*		
	Jobs/MW	*Jobs/MW*	*Direct jobs*	*MW*
Biomass and waste	8.22	4.66	18,477	3,968
Small hydro	1.08	0.96	920	956
Solar PV	2.35	9.30	174	2,769
Wind	1.45	1.46	4,040	18,7

Sources: own calculations based on Liébard (2012), and European Commission (2013a). Direct jobs: based on Liébard (2012); MW: biomass and waste: European Commission (2013a); Small hydro, solar PV and wind: Liébard (2012).

While employment factors for wind and small hydro are similar to the EU averages, that for solar PV is considerably higher, while the factor for biomass and waste is substantially lower. The higher factor for solar PV may be explained by the relatively limited deployment of that technology in Sweden (only 18.7 MW of installed capacity in 2011). In contrast, biomass and waste is a mature industry in Sweden, with close to 4,000 MW of installed capacity in 2011 (European Commission, 2013a), possibly enabling labour productivity gains.

1.3.4 Employment in the future Swedish energy supply sector

Primary fuels

The RES scenario projects a complete phase out of fossil fuels in the primary energy supply by 2050. In terms of employment, the achievement of its 2050 target thus means that all jobs related to fossil fuels in Sweden will be lost. In 2011, most of these jobs (2,300) were in the manufacture of coke and refined petroleum products. The rest (300) were in the manufacture and distribution of gas. This means that in total, 2,600 jobs in primary activities will be lost.

Power sector

Available projections from both the RES scenario and the Reference scenario are in TWh. Since the methodology used in this report multiplies MW by employment factors, TWh are converted into MW with the use of capacity factors per technology in Nordic countries from IEA and Nordon (2013).

Table 29 shows projected employment in the power sector for the Reference scenario and the RES scenario. In the Reference scenario, employment is stable between 2010 and 2020 but then decreases until 2030. After 2030, it picks up again to reach 25% above 2010 levels by 2050. In the RES scenario, on the other hand, employment in the power sector increases substantially (+57%) between 2010 and 2020. In the following decade until 2030 some jobs are lost again, but employment increases rapidly between 2030 and 2050.

Table 29. Current and projected direct employment in 2020, 2030, and 2050 in the power sector in Sweden

	2011	*2020*	*2030*	*2050*
Reference scenario	43,100	43,338	35,851	53,816
RES scenario		67,737	61,985	119,395

Source: own calculations.

1.3.5 Conclusions

The Swedish decarbonisation scenario projects a full phase out of fossil fuels. Therefore, all 2,600 jobs in primary fuels are lost. This is in contrast to the EU, where fossil fuels are not fully phased out. Thus, until 2050, one third of the EU employment level of 2011 can be preserved in the decarbonisation scenarios.

In the power sector, the difference in the number of jobs created between the RES scenario and the reference scenario is proportionally higher for Sweden than for the EU (Reference vs. High-RES scenario) in all years considered (2020, 2030 and 2050). This is due to the proportionally higher difference in newly installed RES capacity between Sweden and the EU when comparing their RES/High-RES scenario to the corresponding reference scenario.

Taking all the limitations of this calculation into consideration (data availability, linearity, focus on direct jobs, etc.), there may be a case in Sweden where its decarbonisation strategy until 2050 leads to an increase in employment in its energy sector. The 2,600 jobs lost in activities related to fossil fuels are easily outweighed by increasing job numbers in the power sector. Compared with the Reference scenario, the RES scenario may lead to the creation of 24,000, 26,000 and 66,000 additional jobs in the power sector by 2020, 2030 and 2050, respectively. In fact, by 2050 there may be more than twice as many people employed in the Swedish power sector in the RES scenario compared with the Reference scenario. However, there may be a dent in employment numbers between 2020 and 2030 due to a decline in new additional installed capacity, which requires attention.

1.4 Spain

Spain experienced very fast growth of RES over the last decade, but with the background of the economic crisis, its strategy towards RES changed considerably. Currently, there is no energy strategy beyond 2020 and there is a moratorium on new renewable energy projects based on the suspension of financial incentives for investments in renewable energy. Given the high level of uncertainty, this case study only assesses developments until 2020.

1.4.1 Energy balance

RES primary production in Spain increased from 6.8 Mtoe in 2000 to 13.8 Mtoe in 2011 (Eurostat, 2013b), mainly driven by wind power. In fact, wind power generation increased from 4,727 GWh in 2000 to 42,433 GWh in 2011, and solar PV from 18 GWh in 2000 to 7,386 GWh in 2011 (Eurostat, 2013b). However, despite these developments, Spain continues to rely heavily on fossil fuels, with some 78% of gross inland consumption being dependent on oil, gas and coal. Oil and oil products alone cover almost half of gross inland consumption and are almost entirely imported. The share of low-carbon energy sources is higher in the electricity mix, half of which is based on RES and nuclear and the other half on fossil fuels and in particular gas. Table 30 shows the energy balance of Spain in 2011.

Table 30. Energy balance of Spain in 2011

	Production (Mtoe)	*Imports (Mtoe)*	*Imports share in total supply*	*Share in gross inland consumption*	*Share in electricity mix*
Solid fuels	2.6	8.7	77%	10%	15%
Petroleum and products	0.4	66.3	99%	45%	5%
Gases	0	29.4	100%	23%	29%
Nuclear	14.9		0%	12%	20%
RES	13.8	0.9	6.5%	11%	30%

Source: European Commission (2013a).

1.4.2 The energy strategy of Spain

Following the economic crisis, Spain enacted a law on Sustainable Economy in March 2011, aimed at supporting the economic recovery of the country with a sustainable growth model. The law defines the national targets of 20% of RES in gross final energy consumption and 10% of RES in the transport sector by 2020. In addition, different strategic documents are related to the law on Sustainable Economy:

- An indicative energy plan (Ministerio de Industria, Energía y Turismo, 2011), required by the law on Sustainable Economy to form the basis for a future binding energy framework. This plan until 2020 includes projections for future energy needs and the means to cover them.
- A *National Action Plan on Renewable Energies for 2011-2020*, which defines the Spanish strategy for RES. It is complemented by the *Renewable Energies Plan 2011-2020* (Ministerio de Industria, Turismo y Comercio, 2011), which provides concrete measures to implement the strategy.

As of today there is no Spanish energy strategy post-2020. In January 2012, the Spanish government decided on a moratorium on new renewable energy projects, by suspending financial incentives to investors in renewable energy. Together with other changes in the legislation on RES since the beginning of the economic crisis in 2008, the moratorium has left the Spanish renewable energy sector facing uncertainty about the future. The following projections and results therefore only focus on 2020.

Primary fuels

Projections for primary fuels come from the indicative energy plan up to 2020 (Ministerio de Industria, Energía y Turismo, 2011). This document contains three scenarios: a reference scenario, and two scenarios reflecting lower and higher energy demand than the reference case. The reference scenario is described as the most likely scenario and is thus used for the calculations in this case study. For primary fuels, the projections available are for primary energy consumption, i.e. the sum of production and imports.

The primary energy consumption increases from 132 Mtoe in 2010 to 143 Mtoe in 2020 (+8%). The share of fossil fuels decreases from 77% to 71% and the share of RES increases from 11% to 19.5%. Between 2010 and 2020 there will essentially be a shift away from fossil fuels towards more RES in the primary energy mix. In absolute terms, primary oil consumption decreases from 62,358 ktoe in 2010 to 51,980 ktoe in 2020, while the primary consumption of gas increases from 31,003 ktoe in 2010 to 39,237 ktoe in 2020. The primary consumption of coal increases slightly from 8,271 ktoe in 2010 to 10,058 ktoe in 2020.

Power sector

The Spanish Renewable Energies Plan 2011-2020 provides projections for installed capacity only for RES. Therefore, projections for installed capacity in fossil fuels and nuclear are taken from Eurelectric (2012). Up to 2020, the installed capacity in coal and gas slightly increases (from 39,855 MW to 42,259 MW), with an increase in gas-fired capacity compensating for a slight decrease in coal-fired capacity. Nuclear power is projected to remain stable from 2010 to 2020. The capacity in RES (biomass and waste, small hydro, solar PV and wind) is projected to increase by 73%, from 29,737 MW in 2011 to 51,535 MW in 2020.

1.4.3 Employment in the current Spanish energy supply sector

Table 31 presents figures for direct employment in the Spanish energy sector, as well as the distribution of qualification levels per energy activity in 2011.[88]

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[88] Number of jobs as reported by Eurostat and based on NACE Rev. 2 classification. Data on qualification levels as reported by Cedefop (2013) and based on NACE Rev. 1.1 classification. This results in differences in the definitions of activities in the left column of Table 26. For details on job numbers based on NACE Rev. 2, see Table 5 in Section 3.1.1.2, and for details on qualification levels based on NACE Rev. 1.1, see Table 7 in Section 3.1.2.2.

Table 31. Direct employment and structure of qualification levels in the energy sector in Spain in 2011

Activity	*Number of jobs*	*Low qualified*	*Medium qualified*	*Highly qualified*
Mining of coal and lignite	5,439	41%	15%	43%
Oil and gas extraction[89]	280			
Manufacture of coke and refined petroleum products	9,280	13%	15%	72%
Electricity[90] + *biomass and waste*	48,425 *20,891*	12%	22%	66%
Gas other	3,299		22%	66%

Sources: APPA (2011); Cedefop (2013); Eurostat (2013d).

The distribution of qualification levels in the Spanish energy sector diverges strongly from the EU figures presented in Table 7. On the one hand, the share of highly qualified workers is substantially higher in all energy activities in Spain than in the EU average (around 30 percentage points higher across all activities). On the other hand, the share of medium qualified workers is substantially lower (15-20% in Spain compared with 50-60% in the EU). Additionally, the proportion of low qualified jobs in coal mining is 31 percentage points higher than the EU average.

Labour intensity ratios for Spain (presented in Table 32) are in the range of the EU values for oil and gas extraction, and slightly lower for downstream activities like oil refining and manufacturing of gas and its distribution. These downstream activities are thus generally less labour intensive when compared with the EU average.

Table 32. Employment factors for primary fuels in the EU27 and in Spain in 2011 (jobs/ktoe)

	EU	*Spain*		
	Jobs/ktoe	*Jobs/ktoe*	*Direct jobs*	*ktoe*
Coal and lignite mining	1.37 – 2.06	2.05	5,439	2,650
Oil and gas extraction	0.49 – 0.81	0.65	280	430
Oil refining	0.20 – 0.33	0.14	9,280	66,700
Gas other	0.37 – 0.53	0.11	3,299	29,400

Source: own calculations based on European Commission (2013a); Eurostat (2013d).

Turning towards labour intensity of RES-E in the Spanish power sector, Table 33 shows that Spain is less labour intensive in activities related to small hydro power, wind power and (to a lesser extent) solar PV than the EU average. This may be due to the maturity of these technologies in Spain. Power produced from biomass and waste, on the other hand, is much more labour intensive in Spain when compared with the EU average.

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[89] Excluding support activities for extraction.

[90] The sum of jobs in electricity and biomass and waste totals 69,316. This includes 50,876 jobs in RES (APPA, 2011), for which the distribution of qualification levels is 50% low-to-medium qualified workers and 50% highly qualified workers (Jiménez Herrero and Leiva, 2010).

Table 33. Employment factors for RES-E technologies in the EU27 and in Spain in 2011 (jobs/MW)

	EU	*Spain*		
	Jobs/MW	*Jobs/MW*	*Direct jobs*	*MW*
Biomass and waste	8.22	26.55	20,891	787
Small hydro	1.08	0.55	1,056	1,930
Solar PV	2.35	2.30	10,013	4,345
Wind	1.45	0.73	15,813	21,547

Sources: APPA (2011); European Commission (2013a); Liébard (2012).

1.4.4 Employment in the future Spanish energy supply sector

Primary fuels

Overall, employment in fossil fuels increases from 18,018 jobs in 2011 to 30,353 jobs in 2020.[91] Almost all of the job gains occur in gas downstream activities. Such an increase is mainly due to the use of EU employment factors for the calculations, which for oil and gas are higher than the Spanish EU factors (see Table 32).

Power sector

For fossil-based and nuclear power generation, projections for 2020 are based on Eurelectric (2012). Projections for RES power generation are based on the *Renewable Energies Plan 2011-2020* (Ministerio de Industria, Turismo y Comercio, 2011).

Overall, employment in the power sector increases from a range of between 69,700 and 77,600 jobs in 2011 to a range of between 135,200 and 146,800 jobs in 2020. This is mainly due to increases in gas-fired capacity and in RES installed capacity (especially wind and solar energy).

Employment in RES is set to double from 50,000 jobs in 2011 to 103,500 jobs in 2020. By then, employment in RES represents a share of 70% to 77% of the employment in the power sector. The increase is especially large in wind energy, which increases from 15,800 to 51,600 jobs, and in solar energy, which increases from 10,000 to 35,400 jobs between 2011 and 2020.

The increase in gas-fired capacity results in a growth in the number of jobs from between 14,900 and 21,000 in 2011 to between 25,500 and 35,700 in 2020.

1.4.5 Conclusions

Employment in primary fuels in Spain is projected to increase in the decade until 2020, unlike in the EU. This would be accompanied by an increase of employment in the power sector, driven by an increase in RES capacity and, to a smaller extent, in gas-fired capacity, following EU trends. Table 34 summarises the results.

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[91] The same number of jobs in coal mining as in 2011 is assumed for 2020, due to a lack of data for calculating employment in coal in 2020.

Table 34. Current and projected direct employment in 2020 in the energy sector in Spain, lower range

	2011	*2020*
Primary fuels	18,018	30,353
Power sector	69,745	135,243
Total	87,763	165,596

Source: own calculations.

However, given the current uncertain regulatory framework for RES, the projections of the Renewable Energies Plan 2011-2020 can be put in doubt. It is likely that the actual installed capacity will be lower than projected, thus creating fewer jobs than the results of this case study suggest.

Moreover, a decrease in direct employment in the renewable energy sector has already been observed since the economic crisis, with a decrease from 75,000 jobs in RES in 2008 to 54,000 jobs in 2011 (APPA, 2011).

It is important to note that the results of the Spanish case study need to be taken with care because of the use of the EU employment factors for the calculations. Indeed, as the EU employment factors are overall higher than the Spanish employment factors (except for coal mining and biomass), the multiplication of future energy volumes and installed capacity by the EU factors leads to abnormally high results. This shows that the assumed convergence of EU economies may only come true in the long term, making short-term results of the case studies very sensitive to the choice of using national or EU employment factors. In the case of Spain, the increase of the employment level by 2020 in primary fuels results more from choosing EU employment factors than from changes in the energy mix.

1.5 Conclusions

The case study on Poland suggests that employment in primary fuels in countries that have a high share of coal in their energy mix may decrease under the measures taken to achieve climate objectives. Similarly, a slowdown in the construction of new fossil-fired capacity in the power sector may result in job losses. The extent to which employment in the total energy sector increases depends then on the deployment of RES capacity.

The case study on Sweden shows that even a full phase out of fossil fuels can have a positive net effect on the employment level.

The case study on Spain suggests that an aggressive RES deployment strategy is accompanied by a strong deployment of gas-fired power plants, thus increasing the overall employment level. However, despite the substantial RES potentials in Spain, these may not be realised due to financial constraints resulting from the economic crisis. This may translate into fewer jobs as well.

Annex 2: List of interviewees

European institutions and agencies:

- European Centre for the Development of Vocational Training (Cedefop)
- European Commission, DG Energy
- European Commission, Eurostat

Industry and professional associations:

- Eurogas, which represents the European gas wholesale, retail and distribution sectors
- European Association for Coal and Lignite (Euracoal)
- European Atomic Forum (Foratom)
- European Federation of Public Service Unions (EPSU)
- European Renewable Energy Council (EREC)
- Europia, which represents the oil refining and marketing industry in Europe
- International Association of Oil and Gas Producers (OGP)
- Observatoire des Energies Renouvelables (Observ'ER)
- Union of the Electricity Industry (Eurelectric)

International organisation:

- OECD

Research institutes and consultancies:

- Gesellschaft für Wirtschaftliche Strukturforschung mbH (GWS)
- Fraunhofer

Information obtained from interviews is used throughout the paper and generally assigned to the respective organisations but not to the experts interviewed. Much of the information obtained served to identify and clarify existing data in order to optimally integrate it into the paper. In some cases, data from interviews is used in calculations but is not directly reported in the document. In other cases, information was confidential.

Annex 3: Disaggregation of LFS data with SBS and DG Energy figures

SBS until 2009 and DG Energy estimates for 2011 cover a more detailed breakdown of energy activities than the LFS. On the basis of the proportions of each category in the detailed breakdown of SBS/DG Energy estimates, the LFS figures are broken down following the same classification. The result is a comparable breakdown of energy activities in DG Energy estimates and LFS data.

Available figures for direct jobs in the energy sector in SBS, DG Energy estimates and the LFS are reported in Table 35.

Table 35. Direct employment in the energy sector in the EU27

Activity	*SBS, 2009*	*DG Energy, 2011*	*LFS, 2011*
Mining of coal and lignite [B05]	256,500	229,401	345,000
Extraction of crude petroleum and natural gas [B06]	75,700	67,618	91,500
Extraction of crude petroleum [B06.1]	50,400		
Extraction of natural gas [B06.2]	25,300		
Extraction of peat [B08.92]	12,100	11,678	
Support activities for petroleum and natural gas extraction [B09.1]	39,600	45,553	
Manufacture of coke and refined petroleum products [C19]	133,200	127,355	210,700
Manufacture of coke oven products [C19.1]	9,900	8,915	
Manufacture of refined petroleum products [C19.2]	123,300	118,440	
Electricity, gas, steam and air conditioning supply [D35]	1,203,700	1,198,854	1,650,200
Electricity [D35.1]	885,500	888,358	
Gas [D35.2]	154,046[92]	150,796	
Total (B05, B06, B08.92, B09.1, C19, D35.1, D35.2)	1,556,646	1,520,759	

Sources: Eurostat (2013c, 2013d); European Commission (2013a).

SBS data provides a complete breakdown of energy activities in 2009. The share of employment of each energy activity in total employment in the energy sector can thus be calculated. These shares are used to breakdown DG Energy estimates and LFS data where necessary. On that basis, Table 36 gives a completed version of Table 35. Figures in italics are those derived from SBS and DG Energy proportions.

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[92] DG Energy estimate (European Commission, 2013a).

Table 36. Direct employment in the energy sector in the EU27

Activity	*SBS, 2009*	*DG Energy, 2011*	*LFS, 2011*
Mining of coal and lignite [B05]	256,500	229,401	345,000
Extraction of crude petroleum and natural gas [B06]	75,700	67,618	91,500
Extraction of crude petroleum [B06.1]	50,400	*45,304*	*61,305*
Extraction of natural gas [B06.2]	25,300	*22,314*	*30,195*
Other mining and quarrying [B08]	221,700		238,700
Extraction of peat [B08.92]	12,100	11,678	*11,920*
Mining support service activities [B09]	45,500		125,900
Support activities for petroleum and natural gas extraction [B09.1]	39,600	45,553	*95,439*
Manufacture of coke and refined petroleum products [C19]	133,200	127,355	210,700
Manufacture of coke oven products [C19.1]	9,900	8,915	*14,749*
Manufacture of refined petroleum products [C19.2]	123,300	118,440	*195,951*
Electricity, gas, steam and air conditioning supply [D35]	1,203,700	1,198,854	1,650,200
Electricity [D35.1]	885,500	888,358	*1,221,148*
Gas [D35.2]	154,046[93]	150,796	*214,526*
Total (B05, B06, B08.92, B09.1, C19, D35.1, D35.2)	1,556,646	1,520,759	2,190,233

Source: Author, based on Eurostat (2013c, 2013d); European Commission (2013a).

Annex 4: Employment in the power sector based on Eurelectric data

In its 2012 statistical report on the power sector, Eurelectric (2012) provides employment figures for eight member states. This study relates Eurelectric figures to the total employed workforce[94] in those eight countries. In all cases, the employment share of the power sector within total employment varies between 0.35% and 0.61%. The average share for the eight member states is 0.52%. The extrapolation of that average to the employed workforce in the EU27 results in about 1.1 million people working in the power sector.[95] This places it between estimates of DG Energy and LFS data reported in Table 36.

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[93] DG Energy estimate (European Commission, 2013a).

[94] 15 to 64 years old.

[95] 1,057,700 out of a population of 503,700,000 (Eurostat, October 2012).

Annex 5: Employment in RES

This study was confronted with a shortcoming of Eurostat in assessing the number of jobs in the renewable energy sector. In NACE, RES are included together with non-renewable energy sources in class D35.11 "Production of electricity", which cannot be broken down by technology. Data for activities in the renewable energy sector other than power generation, such as the manufacturing of components for plants, installation, transport of equipment, decommissioning, and R&D activities, are spread among various classes in NACE Rev. 2.

Eurostat is currently developing a data collection module, including a gap-filling exercise for employment data, for the environmental goods and services sector (EGSS), which covers RES.

As a consequence, data on employment in the renewable energy sector in this study comes from other sources. EurObserv'ER estimates employment in RES at 1,144,210 jobs in 2011. That figure is also conveyed by EREC. REN21 provides a similar estimation of 1,117,000 jobs in 2011. These figures include direct and indirect jobs.

The number of direct jobs within the total of direct and indirect jobs is calculated on the basis of multipliers of direct to indirect jobs. Multipliers are technology-specific and are taken from a study commissioned by IEA's *Implementing Agreement on Renewable Technology Deployment* (Nathani et al., 2012). That report provides direct and indirect job numbers separately for each renewable technology in nine different countries. The multipliers used in this study are averages of the multipliers of the six EU member states included in the nine countries. Table 37 summarises the number of direct jobs and the multipliers of direct to indirect jobs for RES in 2011.

Table 37. Direct employment in the renewable energy sector in the EU27 in 2011

	Direct jobs	*Direct to indirect jobs multiplier*	*Direct + indirect jobs*
RES, including:	577,581		1,186,460
Biogas	45,481	1.56	70,950
Biomass	181,556	0.51	274,150
Geothermal	34,430	0.49	51,300
Small hydropower	14,755	0.63	24,050
Solar PV	120,436	1.59	311,930
Solar thermal	27,659	0.76	48,680
Waste	16,774	0.55	26,000
Wind	136,490	0.98	270,250

Source: Author, based on Liébard (2012) and Nathani et al. (2012).

Results are in line with the estimation of 607,000 direct jobs in RES-E and RES-H in 2010 by Teske et al. (2012).

Annex 6: Employment in the nuclear sector

Eurostat NACE statistical classification includes employment in nuclear power generation in category D35.11 "Production of electricity". However, no breakdown of this overall employment figure is available for individual power sources such as nuclear power.

The European Atomic Forum (Foratom, 2010) provides an estimate of 125,000 direct jobs in the EU nuclear sector in 2010. Some national associations of the nuclear industry also provide employment figures, but they are not used in this study for various reasons: some do not cover employment in the full sector, but only in their member companies, some provide figures that are too high compared with other countries, and as such, are not considered reliable; and some asked for the source not to be quoted.

For these reasons, the figure used in this study for employment in nuclear power generation is the one from Foratom.

Annex 7: CIM and O&M employment factors in the power sector

For the power sector, a distinction is made between jobs in operation and maintenance (O&M) and jobs in construction, installation and manufacturing (CIM). The reason is that jobs in CIM do not last for the full lifetime of a power plant, in contrast to jobs in O&M.

O&M employment factors are expressed in jobs/MW. CIM employment factors are expressed in *job-years* per installed capacity, as the whole process of construction, installation, and manufacturing is usually not linked to a specific year. In order to have comparable employment factors for both CIM and O&M jobs, CIM job-years/MW are converted into CIM jobs/MW. This is done by dividing the job-years/MW by the technology-specific lifetime of an installation.

To derive separate employment factors for O&M and CIM from the factor of total jobs/MW, factors for CIM and O&M jobs per technology in the OECD are taken from Rutovitz and Harris (2012). In this paper, the share of each factor in the total employment factor in Rutovitz and Harris (2012) is used to break down the total factor in jobs/MW into O&M and CIM employment factors.

Table 38. Shares of CIM jobs and O&M jobs in total employment per technology in EU27 (%)

Technology	*Share of CIM jobs*	*Share of O&M jobs*
Coal	76	24
Gas	57	43
Nuclear	56	44
Small hydro	18	82
Wind	63	37
Solar PV	70	30
Biomass	27	73
Biogas[96]	25	75
Geothermal	47	53

Source: based on Rutovitz and Harris (2012).

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[96] Based on Liébard (2012).

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