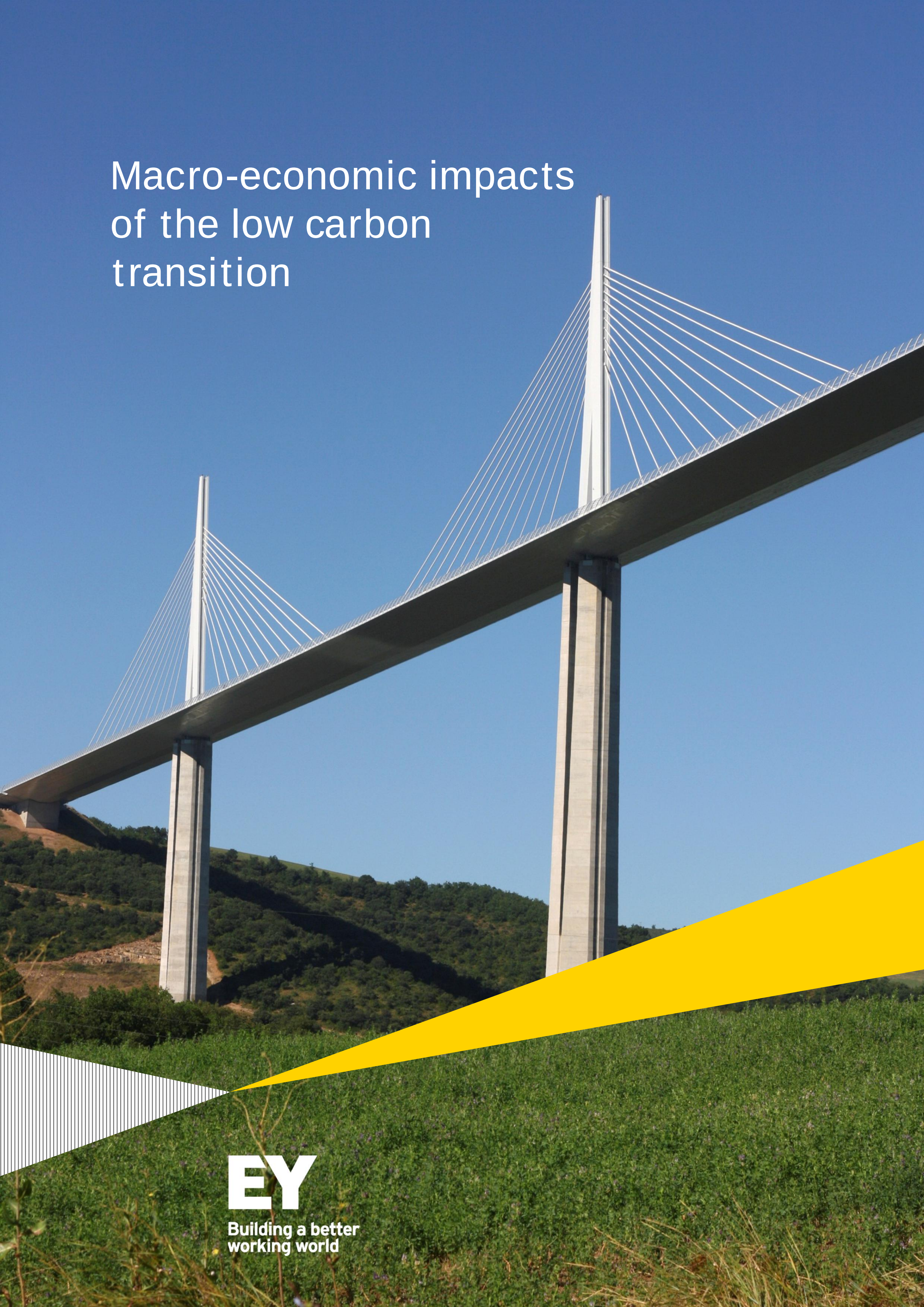
Macro-economic impacts of the low carbon transition



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Acronyms

BAU	Business-As-Usual
BPIE	Buildings Performance Institute Europe
CAPEX	Capital Expenditure
CCS	Carbon Capture and Storage
CPI	Current Policies Initiative
EC	European Commission
ECF	European Climate Foundation
EE	Energy Efficiency
EIA	Environmental Investigation Agency
EII	Energy-Intensive Industry
ETS	Emissions Trading System
EU	European Union
GDP	Gross Domestic Product
GHG	Greenhouse Gases
IEA	International Energy Agency
KfW	Kreditanstalt für Wiederaufbau (Reconstruction Credit Institute)
ktoe	thousand tonnes of oil equivalent
kW	Kilowatt
kWp	Kilowatt peak
kWh	Kilowatt hour
LCOE	Levelised Cost Of Energy
Mmbtu	One million British thermal units
Mtoe	Million tonnes of oil equivalent
MWh	Megawatt hour
nZEB	Nearly Zero-Energy Buildings
PV	Photovoltaic
RES	Renewable Energy Sources
Tcm	Thousand cubic metres
US	United States

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Executive summary

In its 2011 *Roadmap for moving to a competitive low carbon economy in 2050*, the European Commission (EC) established its plan for achieving 80% carbon emission reductions by 2050 compared to 1990 levels. The Roadmap set out the contribution expected from each economic sector, in comparison with a Business-as-Usual (BAU) scenario which, by means of the current policy framework, would be expected to achieve a 40% reduction by 2050. In January 2014 the Commission published a new Impact Assessment and associated documents focussing on the 2030 timeframe, reflecting an updated reference scenario published in December 2013.

The present study compiles the findings of recent expert research on macroeconomic impacts of the low-carbon transition in the European Union (EU). Many actors representing the targeted economic sectors (power, transport, buildings, and industry) have responded to the EC's findings, transposing them into their own sector-specific roadmaps and decarbonisation scenarios. This body of work has nurtured the debate on the impact of the transition on key macroeconomic features: the EU's energy import dependency, investment costs, energy costs, industrial competitiveness, GDP and employment. The analyses are often produced with milestones in 2020, 2030 and 2050, thus projecting the time horizon by when investments made in the short run would possibly generate returns.

This executive summary outlines the key findings of the study, and synthesises the arguments put forward in the reviewed body of literature. The full study is intended for readers interested in the detailed arguments, the sources from which they are drawn, and the extent to which some sources may differ.

Continuing with BAU will bring major economic challenges

Irrespective of the choices made by the EU regarding decarbonisation, it will face major economic challenges over the coming years. In particular:

- An aging energy infrastructure: according to the EC (2011), under a BAU scenario, average energy infrastructure investments across all sectors of the economy would increase from around € 800 billion per annum over the period 2010-2020 to € 1000 billion per annum over the period 2040-2050. The updated reference scenario prepared by the European Commission (2013) estimates similar investment needs, with average annual investments amounting to € 816 billion over the period 2011 to 2030, illustrating that in any case the EU will have to mobilise significant amounts to maintain its energy infrastructure.
- Evolution of energy demand, fossil fuel production and energy prices: according to the EC, while energy demand in the EU is expected to stabilise under BAU, fossil fuel production in Europe would halve over the period 2010-2050, increasing the EU's dependency on imports from third countries. Under the BAU scenario drawn by the Commission, Europe's import dependency would go up to 56.5% in 2050 compared to 52.6% in 2010. Regarding oil specifically, under BAU Europe's dependency on imports would increase from 74% in 2010 to 84% by 2030, and almost 90% by 2050 – even though import volumes would stagnate. Regarding natural gas, under BAU Europe's dependency on imports would increase from 64% in 2010 to over 70% by 2030, and almost 80% by 2050. With fossil fuel import prices set to rise, the total energy import bill of the EU is projected to rise by about 80% from 2010 to 2050, reaching around €600 billion (in 2010 euros) in 2050. For electricity, the average, pre-tax price is projected to increase by 40% between 2005 and 2030, though it would stabilise thereafter. The updated reference scenario dating from 2013 provides a slightly different picture, since it supposes that the EU is now embarked on a more ambitious decarbonisation trajectory, with the expected implementation of most recent policies (Energy Efficiency Directive, national policies). Consequently, power generation costs

increase more significantly than in the previous BAU scenario until 2020, because of higher capital costs (e.g. ENTSO-E provisions, RES 2020 investments). However, beyond 2020, prices are expected to stabilise, and even slightly decrease by 2050, as fuel cost savings materialise.

- Challenges of sustaining the growth of the transport sector: the transport sector has been persistently dependent on oil for years. 96% of energy used in transportation in the EU-27 today is fossil fuel. Although final energy demand in the transport sector is expected to stabilise by 2050 under BAU, this dependency rate would only be reduced to 90%. A study by Cambridge Econometrics finds that even with Europe maintaining domestic extraction rates on fossil fuel, the annual cost of oil imports to supply the transport sector would rise to € 590 billion by 2030 and further still to € 705 billion by 2050 based on price increases alone, compared to € 350 billion in 2012. Without reductions in the demand for oil, imports are also likely to increase in volume as domestic production depletes Europe's oil reserves. Europe thus faces a serious challenge to increase technological and system efficiency to reduce its oil dependency.
- A need to upgrade the current building stock: buildings account for 40% of total energy consumption in the European Union. With energy costs set to keep rising, there is a strong interest in maximising the energy efficiency of the building stock, and great potential to achieve this: Fraunhofer estimates saving potential of around 60% by 2030. Yet average demolition rates are currently only 0.1% per year. The greater part of the saving potential will therefore have to be realised in the existing building stock, whose average annual renovation rate is currently only 1% according to the Buildings Performance Institute Europe (BPIE).
- Challenges to the competitiveness of industry: despite the economic crisis, most European industrial sectors have managed to maintain or even enhance their competitive advantage since 2007. Regardless of past performance, however, most sectors will face increasingly strong competition on their key competitiveness drivers (labour productivity, labour cost, skills, capital formation, innovation, regulatory framework) over the coming years. Energy prices will play a secondary role, though they will remain an important driver for energy-intensive industries. Regardless of climate policy choices made, these industries will find it in their interests to continue to pursue energy efficiency gains as part of their competitiveness strategy, and will meanwhile face increasing cost competition on drivers other than energy prices.

These challenges illustrate that BAU differs from a mere "comfortable" continuation of the current situation, and will present difficult economic challenges. The question investigated by this report is whether decarbonisation could propose a path which is more desirable than BAU. The key macroeconomic value proposition of decarbonisation consists of increasing current investments in energy efficiency, alternative energy generation and grid infrastructure, to eventually achieve savings on fuel costs – and potentially generate employment - resulting altogether in a profitable equation. The body of literature reviewed in this study brings estimates on three key parameters of this equation, namely import dependency (and the EU external fuel bill), investment costs and energy costs. It also examines the effects on industrial competitiveness, GDP and employment, and a range of co-benefits.

Import dependency

Projections from the International Energy Agency (IEA) show Europe's energy demand as stabilising up to 2050, whilst overall energy production is expected to reduce significantly. This will be due in particular to a significant decrease in fossil fuel production, as presented in the European Commission's reference scenario to 2050. As stated earlier, these elements are likely to lead to a rise of the EU's energy import dependency and its external fuel bill.

Decarbonisation scenarios analysed by the European Commission would also see an increase in Europe's fuel bill compared to today, but to a much lower extent than under BAU. The Commission's *Energy Roadmap 2050* predicts that in 2050, compared to BAU the EU could save between € 518 billion and € 550 billion annually by taking a strong decarbonisation pathway. This can be achieved through a combination of energy efficiency and the promotion of a diverse portfolio of low-carbon generation technologies across Europe, including wind, solar, hydro, geothermal, biomass and other promising options.

In all decarbonisation scenarios, electricity would have to play a much greater role than now, contributing significantly to the decarbonisation of transport and heating/cooling of buildings, and almost doubling its share in final energy demand in 2050. In order to achieve this, the energy system would have to undergo substantial structural changes and achieve a significant level of decarbonisation by as early as 2030.

Reducing Europe's fossil fuel import dependency would result in reduced exposure to fossil fuel price spikes and their potentially adverse economic consequences. The reduction of the overall fossil fuel bill would also benefit consumers directly, in particular regarding fuel savings related to personal transport (reduction in transport fuel bill of up to € 180 billion per year in 2050 according to Cambridge Econometrics) and energy savings in buildings that lead to lower energy bills for households (up to € 474 billion savings over the next 40 years according to BPIE). This can have further positive effects for the European economy when consumers spend their increased disposable income that results from energy savings in other products or services, potentially more likely than fossil fuels to have been produced within the EU.

Energy prices and costs

Regarding energy prices, the European Commission's Impact Assessment (2014) indicates that energy prices would increase rather significantly in the next decades, under both BAU and decarbonisation scenarios. Though there are uncertainties surrounding model projections over the long-term, there is at this stage little indication that there would be significant energy price increase or decrease resulting from decarbonisation as compared to BAU.

Energy prices are the result of energy subsidies and taxes applied by governments, as well as the cost of energy production and sale. European Commission modelling predicts that under decarbonisation, electricity costs (as with overall energy costs) increase slightly higher than under BAU in the 2030 horizon, but that in the longer term they would follow a more desirable course than under BAU.

Alternative energy generation is also a fast-moving industry, and is increasingly cost-competitive compared to conventional generation. Fixed and variable expenses are embodied into the Levelised Cost of Energy (LCOE) which expresses the cost of different energy sources on a € / kWh basis. Recent research from Fraunhofer, using LCOE analysis, has shown empirically that investment costs for onshore wind, offshore wind and especially solar PV tend to fall even below the most recent assumptions from the European Commission. Solar PV has already achieved cost reductions in Germany which were predicted to occur only by 2035 in the European Commission's model. A study by the Lawrence Berkeley National Laboratory in the US also highlights how the right framework conditions (including a supportive policy framework and easy access to finance) can significantly lower the costs of alternative energy deployment.

The EC has partly acknowledged the fact that these costs have fallen faster than anticipated, by using reduced cost assumptions in its most recent scenarios. Further indication that the advantages of the decarbonisation route may be greater than expected is estimations of "indirect" cost savings. According to a study by Ecofys, energy efficiency measures could, in a short-term 2020 horizon, limit the increase (or even reduce) energy and electricity prices through indirect mechanisms: decrease of fossil fuel prices through lower demand, reduction of electricity spot prices by reducing tension on expensive peak-load generators, and a reduction of investments required in heavy energy infrastructure.

Regarding subsidies, it is worth noting that conventional energy sources (fossil fuels and nuclear) have historically accumulated subsidies which far exceed those received by alternative energy sources at this point in time. As a point of comparison, Green Budget Germany has estimated that coal has received € 418 billion in subsidies in Germany over the period 1972-2012, while nuclear energy has received € 213 billion. During the same period, renewables have received € 67 billion.

Some EU countries have succeeded in achieving greater energy efficiency and financing alternative energy deployment through taxation measures. A study by PwC empirically demonstrates that in some EU Member States such as Denmark and Germany, these taxes have represented a significant portion of electricity price rises. However they have generally not increased the overall tax burden, and have remained a minor part of total taxation. The EC's updated reference scenario dating from 2013 indicates that taxes and levies will represent an increasing percentage of electricity costs over time.

Investment costs

Between today and 2050, a wide-scale replacement of infrastructure and capital goods in Europe will have to be implemented, both in the energy system and throughout the economy as a whole. Regarding investments in the energy system, the Commission's Energy Roadmap 2050 estimates that total energy system costs (including fuel, electricity, capital costs, investment in equipment, energy efficient products) would represent slightly less than 14.6% percent of European GDP in 2050 in the case of BAU, which represents an increase of about 20% compared to today's level (approx. 12%).

Investment levels in decarbonisation scenarios do not differ substantially from this figure. All decarbonisation scenarios established by the Commission model a transition from an energy system based on high fuel and operational costs, to a system based on higher capital investment (CAPEX) and decreased fuel costs. Overall, total energy system costs related to GDP under decarbonisation remain close to BAU.

Power sector

Grid investments are prerequisites to decarbonisation, costs for which are fully recovered in electricity prices. Cumulative grid investment costs alone could range from € 1.5 trillion to € 2.2 trillion cumulated between 2011 and 2050 in decarbonisation scenarios, with a significant part of this due to investment to support renewable energy development.

As presented by Fraunhofer, renewables have been following an accelerated cost reduction trajectory for the last few years and CAPEX needs for Renewable Energy Sources (RES) are likely to be lower than modelled in the Commission's Roadmaps. Indeed, the January 2014 impact assessment estimates investment needs in decarbonisation scenarios as being in the range of € 854-909 billion in the period 2011-2030, and € 1188-1333 billion in the period 2031-2050. This represents a greater divergence between BAU and decarbonisation scenarios in the period 2031-2050 than in the 2011 work, indicating that estimates of the costs of decarbonisation have been revised downwards.

Furthermore, an integrated European approach could reduce transmission and generation costs related to the development of renewables. A study by Booz & Co has estimated that net savings of about € 16-30 billion a year could be achieved through cross-European planning of investments, the range reflecting cost uncertainty of PV capacity.

Transport sector

While deeper cuts can and will need to be achieved in other sectors of the economy, a reduction of at least 60% of GHG emissions by 2050 compared to 1990 will be required from the transport sector. According to the EC, average annual investments in transport would strongly increase under BAU, from less than € 700 billion in 2011 to more than € 800 billion by 2050. The increase is even greater in decarbonisation scenarios, amounting to € 1100 billion on average in 2050. However, fuel bills are expected to be much lower in decarbonisation scenarios than under BAU, decreasing to less than € 300 billion per year over the period 2040-2050 in the case of global action (vs. € 473 billion per year on 2011-2020), compared to € 728 billion under BAU over the same period.

According to a study by Cambridge Econometrics, decarbonisation scenarios for the transport sector that rely on conventional technologies add € 22-45 billion to the yearly capital cost of the car and van fleet in 2030. However this is more than offset by avoided yearly spending on fuel worth € 59-80 billion in 2030. This makes the total cost of running and renewing the EU car and van fleet in 2030 about € 36 billion lower than if the fleet were to continue running on today's technology. Although technology costs are likely to rise after 2030 to meet increased fuel efficiency requirements in decarbonisation scenarios, additional capital costs continue to be more than offset by the fuel savings. It should also be factored in that regardless of the chosen path regarding the carbon transition, no major change in transport would be possible without the support of an adequate network and more rational use of the infrastructure. According to the EC, the cost of EU infrastructure development to match the demand for transport has been estimated at over € 1.5 trillion cumulated from 2010 to 2030. The completion of the Trans-European Transport Networks (TEN-T) would additionally require about € 550 billion until 2020.

Buildings sector

Meanwhile, Europe's greatest energy savings potential lies in buildings. Technology is already available to cut existing consumption of buildings by half or three quarters, and to halve the energy consumption of typical appliances. According to the EC, BAU would see a yearly investment in buildings renovation of € 52 billion over the period 2010-2050. On the other hand, the EC's decarbonisation scenario would entail average annual investments over the period 2011-2050 of € 130 billion, i.e. about € 80 billion higher than under BAU. This greater investment effort would generate reductions in fuel and electricity expenses of around € 70-105 billion over the period to 2050.

The scale of decarbonisation's greater economic potential compared to BAU is further confirmed by BPIE's research, which estimates considerably higher net savings than the EC. According to the study *Europe's Buildings Under the Microscope*, BAU would generate cumulated net savings to consumers amounting to € 23 billion over the period 2010-2050, whereas the most ambitious decarbonisation scenarios would lead to much higher cumulated net savings of € 381-474 billion over the same period.

Industrial competitiveness

With the "servo-industrial" economy accounting for close to half of EU's GDP, the ambition of the European Commission is to maintain a strong industrial base in the decades to come. Most industrial sectors would be little affected by decarbonisation and its potential effects on energy and carbon prices; their priority will be to enhance their key global competitiveness drivers (labour productivity, labour costs, skills, capital formation, technology and innovation).

Decarbonisation would mostly affect energy-intensive industries (EII), notably steel, cement, aluminium, chemicals, pulp & paper, which account for the bulk of carbon emissions by EU industry. These industries contribute about 3.5% of EU employment and will have an important role to play in the industrial landscape of the future. At the same time they are particularly exposed to international competition, often with little possibility to differentiate their products on drivers other than production costs, which are particularly sensitive to energy costs and will thus face challenges over the coming years considering that, whether under BAU or decarbonisation, energy costs are set to rise.

The European Commission has estimated that a € 10 billion yearly investment until 2030 would be necessary to develop and deploy breakthrough technologies which would allow these sectors to reduce their energy use and to decarbonise process-wise. If the rest of the world does not undertake climate action to an extent comparable to Europe, the Commission's roadmap intends to shelter EIIs against international competition and the rise of carbon prices, with a system of continued free allocation of carbon credits, to be periodically reviewed.

EII Associations have responded to the Commission's 80% carbon reduction target with a commitment to continue pursuing energy efficiency, which also forms part of their global competitiveness strategy. Some of them (aluminium, pulp & paper) have expressed optimism regarding the prospect of reaching the reduction target in an economically viable way, while others (steel, cement, chemicals) state the need for major technological breakthrough, such as CCS, to be available by 2030 for deployment until 2050.

An important contribution to the technical part of the debate was made by CE Delft, which has assessed the technical and economic feasibility of breakthrough technology deployment in the cement, paper, and steel industries. The study concluded that breakthrough technologies in these sectors would be reaching market maturity in 2030 or before, enabling reductions of 80% or more.

Beyond the question of whether decarbonisation is technically feasible, all five EII Associations have identified this route as an opportunity for expanding their future business by providing new products to all economic sectors (power, building, transport, industry) and supporting them in reaching their decarbonisation targets. For instance, the steel industry sees an opportunity in further weight reduction of vehicles and building of wind power equipment, while the chemical industry would have a strong role to play in the energy efficiency of buildings (e.g. insulation, lighting, smart windows). The pulp & paper industry has gone the farthest in investigating the opportunity. The Two Team Project has identified eight breakthrough technologies to be supported immediately, with the promise of significantly contributing towards the industry's objective of increasing added value by 50% by 2050 and gaining strong competitive advantage in the global market, while reaching its carbon reduction target.

GDP and Employment

The impacts of decarbonisation on employment appear to be modest, but positive compared to BAU. The 2014 Impact Assessment covering the period 2020 to 2030 projects that compared to the reference scenario, a decarbonisation scenario with a 40% GHG reduction by 2030 would create an estimated 0.7 million additional jobs and that a decarbonisation scenario with a 40% GHG reduction, ambitious EE policies and a 30% RES target would generate 1.25 million additional jobs in 2030.

According to Cambridge Econometrics, between 660,000 and 1.1 million net additional jobs could be generated by 2030 in the transport sector. In 2050, this rises to between 1.9 million and 2.3 million additional jobs, taking into account the jobs lost during the transition. Most new jobs would be created outside the automotive value chain, in sectors such as services and construction, which benefit from the shift in spending away from the fossil fuel value chain and towards domestically-produced goods and services.

Regarding the building sector, while continuing with BAU would create less than 200,000 net jobs over the next 40 years, accelerated renovation scenarios would generate between 500,000 and 1 million jobs according to BPIE. Employment and economic impact stimulated by investing in a more sustainable building stock can be seen across a wide range of players in the value chain, from manufacturing and installation through to provision of professional services such as financing and project management. New jobs would also be stimulated by the need for products, components and material used or installed in better-performance building.

Regarding the power sector, estimates of the employment impact of decarbonisation are also generally net positive. For instance, the *EmployRES* report, funded by the European Commission, assesses that achieving a 20% share of renewables in final consumption could provide a net effect of about 410,000 additional jobs by 2020 and up to 656,000 additional jobs by 2030. The 2014 Impact Assessment anticipates that underlying structural changes would have a relatively small positive or negative impact on overall employment, depending on the assessment methodology, but significant shifts in employment among or within sectors is expected.

As for GDP, impacts of decarbonisation are limited: the impact on economic growth of achieving a 40% GHG reduction target, with or without additional EE policies or RES targets is limited, with impacts by 2030 expected to be less than 1% of GDP (in either direction). Projected impacts in the latest Impact Assessment for the period 2020 to 2030 for a scenario with a 40% GHG reduction compared to the reference scenario are estimated at a loss of between 0.1% to 0.45% of GDP, assuming a single target for GHG reduction and in function of the approach to carbon pricing in the non-ETS sectors and the use of auctioning revenues under the ETS. Scenarios with a 40% GHG reduction to be achieved partly through more ambitious explicit EE policies result in 0.46% to 0.55% GDP increases in 2030 as compared to the EC's reference scenario. A GDP increase of 0.53% is projected in the case of a 45% GHG target with complementary efficiency and renewables efforts. Long-range forecasts are difficult, but as with employment, avoided spending on fossil fuels would also enable a reallocation of these monetary benefits within the EU economy and stimulated GDP growth.

Co-Benefits

A number of additional benefits can be identified as being associated with the decarbonisation path, often referred to as 'co-benefits'. These especially include savings on health costs arising from reduced air pollution, which are estimated to be €38 billion a year by 2050 in the Commission's *Roadmap for moving to a competitive low carbon economy in 2050*. This order of magnitude is confirmed by other studies, such as one produced jointly by the Health and Environment Alliance (HEAL) and Health Care Without Harm Europe (HCWH E). However, a soon to be published report by CE Delft suggests that air pollution-related benefits from decarbonisation may be underestimated, as they do not take into account increased welfare; by taking into account assumed income growth of 1.5%, air quality benefits would increase by a factor of 1.27.

Further benefits would include savings on air pollution control, whose costs could decrease by € 50 billion a year by 2050 under decarbonisation, according to the EC; reduction of climate change adaptation costs, which would amount to € 250 billion per year by 2050 under BAU according to the EC; and reduction of fuel poverty. CE Delft has also provided an estimation of the avoided damage costs for CO_2, with calculated benefits ranging from € 10.2 billion to € 48.6 billion in 2030 for scenarios with a 40% GHG emissions reduction and from € 16.4 billion to € 74.3 billion for a scenario with a 45% GHG emissions reduction.

These co-benefits are to be added to the central value proposition of decarbonisation, namely that fuel savings generated in the power, transport, and building sectors justify the extra investments necessary for achieving them. Besides reducing its external fossil fuel bill, these investments will enhance Europe's energy security and help it to become less vulnerable to energy price spikes. This proposition also holds for most of the industry sector, though uncertainty remains for energy-intensive industries on the extent of climate action in other industrialised regions of the world, the scale of business opportunities arising from decarbonisation, and the future availability of breakthrough technologies.

1 Mapping Business-As-Usual vs. decarbonisation scenarios in a global context

Regardless of the choices Europe makes regarding decarbonisation, European industry and consumers will face important energy-related challenges over the coming decades. This chapter briefly outlines these challenges, and describes the political context of Europe's choices over whether and how to decarbonise. It then sets out in more detail the key Business-as-usual (BAU) and decarbonisation scenarios from the European Commission's Roadmap modelling exercises, which form the starting point for the examination of various economic parameters in chapter 2 of the report.

1.1 Europe faces major energy-related challenges, regardless of the choices it makes about decarbonisation

Irrespective of concerns over climate change, Europe faces a number of energy-related challenges over the coming decades. These concern mainly:

- The evolution of global fossil fuel prices, energy demand and fossil fuel production

  The EU faces major challenges, in a global context of increasing energy demand and political instability, and a domestic context of declining fossil fuel production, to improve its energy security and protect its economy from fossil fuel price spikes and uncertainty.

  In its *Energy Roadmap 2050*, the European Commission models the evolution of world prices of fossil fuels by 2050. The estimates are close to figures produced by other institutions (International Energy Agency, US Energy Information Administration), and foresee a steady rise of the prices of oil (+49% in 2050, in constant USD of 2008, compared to 2010), gas (+85%), and coal (+48%) under a BAU scenario. The European Commission's latest reference scenario, dating from December 2013, indicates a similar trend, with gas prices increasing by 68% from 2010 to 2025 and oil prices increasing by 45% over the same period[1].

  European final energy demand under BAU is expected to be relatively stable up to 2050 (decreasing by less than 5% compared to 2010). Specifically, it is estimated to decrease by 0.2% from 2010 to 2020, by 0.1% from 2020 to 2030 and then to increase by 0.1% over the period 2030 to 2050. This contrasts with global demand, which would increase significantly - by one third by 2035 according to the IEA's estimates[2], as the centre of gravity of energy demand switches to emerging and developing economies.

  Regarding electricity, in the European Commission's 2013 reference scenario, demand will grow by less than 0.5% per year over the period until 2020 (when energy efficiency policies would be in the process of being implemented),. After 2020, without further specific energy efficiency policies, the electricity demand growth rate would increase to nearly 1% per year[3].

  Meanwhile, total energy production is expected to decrease significantly in Europe (by more than 50% in 2050 compared to 2010), due particularly to an important decrease in fossil fuel production, as illustrated in the figure below.

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1 European Commission, Energy prices and costs report, 2014

2 IEA, World Energy Outlook, 2013

3 European Commission, EU Energy, Transport and GHG emissions – Trends to 2050, 2013

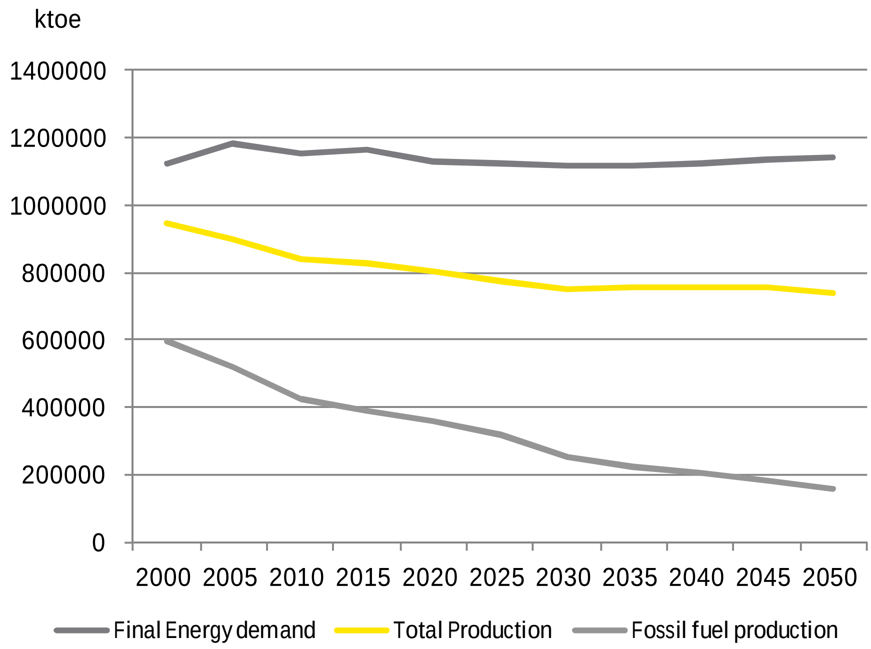

Figure 1: Final energy demand, total energy production and fossil fuel production in the EU under BAU, 2000-2050.
Source: European Commission, PRIMES model, 2013

Europe's dependence on energy imports is therefore set to continue under BAU. The EU-27's dependency has increased significantly within the past 30 years. In the 1980s, less than 40% of Europe's gross energy consumption relied upon imports, whereas by 2010 it had reached 52.5%, with the highest dependency rates for fossil fuels (84.1% for crude oil and 62.4% for natural gas)[4]. Given the evolution of energy demand and fossil fuel production, Europe's total import dependency under BAU would rise to 55% in 2030 and 56.5% in 2050[5].

Such long-term forecasts should be subject to caution, as uncertainty remains on future trends for energy demand and domestic production. However, recent experience suggests that the EU's current pathway is indeed one of increasing energy dependency and a rising external fossil fuel bill. According to the European Commission, the EU's trade deficit in energy products with non-EU countries reached € 421 billion (3.3% of EU GDP) in 2012. This deficit has increased nearly three-fold since 2004.

- The cost of renewing, upgrading and expanding Europe's energy infrastructure

Whether under BAU or decarbonisation, renewing Europe's ageing energy system is a challenge that will be associated with significant investment costs in the coming decades. According to the European Commission's Roadmap published in 2011, average energy-related investments in all sectors[6] of the economy would need to increase from around € 800 billion per annum in the period 2010-2020 to around € 1000 billion per annum in the period 2040-2050. Cumulatively, over the 2010-2050 period the annual investment would amount to € 929 billion on average[7]. Investment needs in the power sector would be particularly substantial. Capital expenditure needs for power generation would reach about € 2000 billion over the period 2011-2050, with € 1300 billion of additional investment in the transmission and distribution grid.

The new reference scenario and impact assessment prepared by the European Commission, dating from 16 December 2013 and 22 January 2014 respectively, provides estimates in the same range in terms of

[4] Eurostat

[5] European Commission, EU Energy, Transport and GHG emissions – Trends to 2050, 2013

[6] According to the European Commission, for all sectors except transport and the power sector, the investments relate to the energy part of the investment, not the capital good as a whole. For transport and power the investment is related to the whole capital good. Transport as such represents by far the largest part of investments.

[7] European Commission, A roadmap for moving to a competitive low carbon economy in 2050 – Impact assessment, 2011

needed investment. In the new reference scenario, over the period 2011 to 2030, average annual investments amount to € 816 billion. Under decarbonisation scenarios, investment requirements range between € 833 billion and € 909 billion, illustrating that in any case the EU will have to mobilise significant amounts to maintain its energy infrastructure[8].

► Challenges of sustaining the growth of the transport sector

According to the study by Cambridge Econometrics *Fuelling Europe's Future*[9], even with Europe maintaining domestic extraction rates on fossil fuel, price increases alone would cause the cost of imports to rise to €590 billion by 2030 and further still to €705 billion by 2050, compared to €350 billion in 2012 (in 2010 prices). Without reductions in the demand for oil, imports are also likely to increase in volume as domestic production depletes Europe's known oil reserves. Europe thus faces a challenge to increase both technological and system efficiency to reduce its oil dependency.

► A need to upgrade the current building stock

Buildings account for 40% of total energy consumption in the European Union, with more than half from the residential sector[10]. With energy costs and fuel poverty rates set to keep rising, there is a strong interest in maximising the energy efficiency of the building stock, and substantial potential to do so. It is legislated in the Energy Performance of Buildings Directive (EPBD) that, as of 31 December 2020, all new buildings in the EU will have to consume 'nearly zero' energy and the energy will be 'to a very large extent' from renewable sources. This will represent an important step forward, but with current average demolition rates of only 0.1%, the greater part of the saving potential will have to be realised in the existing building stock, whose average annual renovation rate is currently only 1% according to the Buildings Performance Institute Europe (BPIE).

► Global trends regarding the competitiveness of European industry

Industrial competitiveness is understood in this study as the ability to capture global market shares. The Revealed Comparative Advantage (RCA) index compares the share of each EU sector's exports in the EU's total manufacturing exports with the share of the same sector's exports in the total manufacturing exports of a group of reference countries. Despite the recent economic crisis, Europe has generally managed to maintain or even enhance its RCA in most industrial sectors since 2007, though some have been on a downward trend.

Regardless of whether the EU engages in a deep decarbonisation route, it will continue to face major industrial challenges, and will need to foster its key competitiveness drivers: labour productivity, labour cost, human capital & skills, investment & capital formation, and technology & innovation. Details on specific trends and challenges to be met for each driver are discussed in section 2.4.2. Future evolution of industrial competitiveness will continue relying on these drivers, especially in sectors requiring high skills and innovation such as pharmaceuticals, or sectors requiring strong capital formation, such as paper.

Energy cost is a relatively minor driver of industrial competitiveness, though it would continue playing an important role in a few specific energy-intensive industries (steel, cement, aluminium, chemicals, pulp & paper), especially for products that are intensely traded on international markets. These industries have achieved high energy efficiency gains as part of their competitiveness strategy, and will continue doing so irrespective of the chosen path regarding decarbonisation. The question would be how to transform decarbonisation into an opportunity rather than a constraint, in such a way that these industries can create demand for new products within the EU and abroad, and adopt breakthrough decarbonisation technologies in parallel. Besides, the overall competitiveness of European industries may increasingly rely on the ability to capture global market shares in low carbon industries. This issue will be further discussed in a separate report.

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8 European Commission, Executive Summary of the Impact Assessment for A policy framework for climate and energy in the period 2020 up to 2030, 2014

9 ECF, Fuelling Europe's Future: How auto innovation leads to EU jobs, 2013

10 E3G, The macroeconomic benefits of energy efficiency – The case for public action, 2012

- Challenges related to climate change adaptation and costs

  Future climate change costs are uncertain, and existing cost-benefit analyses have to rely on many assumptions. As of today, limited empirical data exist on costs of adaptation strategies at EU or European country level. In the 2006 Stern review, valuating in particular impacts on water resources, food production, health and the environment, it was estimated that overall costs of climate change could range from around 5% to more than 20% of global GDP per year.

1.2 Purpose of this study

In February 2011 the European Council reconfirmed the EU objective of reducing greenhouse gas emissions by 80-95% by 2050 compared to 1990, in line with the reduction efforts required of all developed countries as their contribution to keeping atmospheric greenhouse gas concentrations below the level deemed to give a decent chance of avoiding 2° C global average temperature increase[11]. The EU is committed towards delivering long-term low carbon development strategies, and several Member States have already made steps towards this transition, or are in the process of doing so.

The European Commission has published several communications that depict possible action over the next decades in order to reach its emissions reduction target, among which the *Roadmap for moving to a competitive low carbon economy in 2050* (2011) and the *Energy Roadmap 2050* (2011) constitute essential pieces. These roadmaps outline milestones which show how the EU can stay on track for reaching its long-term objective, which policy challenges it will face and which investments are needed, and which opportunities exist in different sectors of the economy. On January 22nd 2014 the Commission published a new Communication entitled *A policy framework for climate and energy in the period from 2020 to 2030*, which provides a revised set of policy options and opportunities for the mid-term timeframe.

However, some national governments, members of the European Parliament, the European Commission and Council continue to express concerns that decarbonisation risks being too expensive to finance from stretched national budgets, would cause unmanageable energy price rises and damage the competitiveness of European industries, leading to its relocation outside the EU.

The present report aims at responding to these concerns by comparing BAU scenario with decarbonisation scenarios on a number of key parameters, based on existing research. The purpose of the analysis conducted throughout this report is to be as balanced as possible, exposing macroeconomic impacts of decarbonisation on the basis of an extensive literature review.

1.3 Distinguishing BAU and decarbonisation scenarios

1.3.1 Structure of this study

Each section of the study will follow a similar structure that corresponds to three main sections:

- First, BAU as defined by the European Commission, will be presented over the period 2011-2050;
- Secondly, a description of the impacts that were assessed in the Commission Roadmaps in decarbonisation scenarios is set out;
- Thirdly, a set of evidence from other literature is presented as well as the extent to which it may deviate from the Commission's roadmaps.

[11] Gupta, S., et al., "Chapter 13: Policies, instruments, and co-operative arrangements", Box 13.7 The range of the difference between emissions in 1990 and emission allowances in 2020/2050 for various GHG concentration levels for Annex I and non-Annex I countries as a group , in IPCC AR4 WG3 2007

Within this structure, two threads arise along the report:

- BAU differs from a mere "comfortable" continuation of the current situation, and would have macroeconomic impacts which are not benign. Even a small net positive effect under decarbonisation, as may be the case with electricity prices and employment, is still an improvement compared to what would happen under BAU.
- While the Commission's roadmaps to 2050 depict overall positive economic impacts of decarbonisation, on balance the trends and findings from additional literature review lead to the conclusion that the roadmaps' assumptions and findings may in some cases be rather conservative. For instance, this is the case regarding the cost of renewable energy sources, which has decreased in the past few years beyond certain expectations. The sources reviewed also forecast greater net benefits than the ones predicted by the Commission regarding the decarbonisation of the transport and building sectors on a range of parameters (import dependency, GDP, employment, etc.).

1.3.2 Presentation of BAU and decarbonisation scenarios established by the European Commission

Through its two major roadmaps published in 2011 – *A roadmap for moving to a competitive low carbon economy in 2050* and *Energy roadmap 2050* – and its latest impact assessment accompanying the communication *A policy framework for climate and energy in the period from 2020 to 2030* (2014), the European Commission has established several decarbonisation scenarios for the EU, which rely on different assumptions regarding Europe's energy mix, global fossil fuel price developments, rate of technological innovation, evolution of the ETS and carbon prices, etc.

Scenarios from the EC's *Roadmap for moving to a competitive low carbon economy in 2050*[12]

The low carbon roadmap published by the Commission in 2011 investigates what would be required for the EU to achieve large emissions reductions, in line with the 2ºC objective, under different decarbonisation scenarios. These scenarios differ from one to another on key parameters and include carbon prices as a cost-effective policy driver.

Using the global POLES model, the EC analysed the interaction of global climate action and fossil fuel prices under 3 scenarios:

- Global Baseline: no additional climate action is undertaken globally up to 2050.
- Global Action: global emissions would be halved by 2050 compared to 1990 due to global action.
- Fragmented Action: the EU takes a decarbonisation path but other countries only comply with the lower end of the Copenhagen Accord pledges until 2020 and undertake no additional efforts after 2020.

This sets the context in which the scenarios projected at EU level play out.

The scenarios, modelled using the PRIMES model, are:

- A reference scenario consisting of the implementation and continuation of existing policies (i.e. the Climate and Energy Package up to 2020). This scenario, modelled in 2009, does not take into account the *Energy Efficiency Plan* and subsequent *Energy Efficiency Directive*, nor the *Energy Taxation Directive* that were published afterwards. An updated version of this reference scenario was published by the European Commission in December 2013. The present report refers to this new reference scenario in some cases, although in many cases it still refers to the version used in the Commission's Roadmap. Overall, the new scenario would not have any significant impact on the conclusions set out in this report. Key changes to the reference scenario and the new proposed decarbonisation scenarios are summarised further below.
- Several decarbonisation scenarios based on an emissions reduction of 80% in the EU by 2050 compared to 1990, except for one fragmented action scenario where additional measures are taken to protect the international competitiveness of Europe's energy intensive industries.

12 European Commission, A roadmap for moving to a competitive low carbon economy in 2050, 2011

- Decarbonisation scenarios vary according to fossil fuel energy prices:
  - Scenarios with low energy prices staying relatively stable (oil prices in real terms in 2050 at around 70$ $_{2008}$/barrel), likely to occur with Global Action.
  - Scenarios with oil prices gradually doubling (increasing to 127$ $_{2008}$/barrel in 2050), as in the reference scenario, likely to occur with Fragmented Action.
  - Scenarios with a temporary oil shock or continued high energy prices from 2030 onwards (doubling to 212$ $_{2008}$/barrel in 2030), for which a real risk remains with Fragmented Action.
- Decarbonisation scenarios are differentiated according to assumptions on technological developments:
  - Effective technology scenarios represent successful enabling of energy efficiency and low carbon technologies.
  - 'Delayed CCS' and 'delayed electrification scenarios' assess sensitivities regarding the availability of certain technology pathways.
  - A sensitivity analysis on delayed climate action assumes no new and additional climate policies beyond the current Climate and Energy package are initiated before 2030. This scenario assesses the feasibility of achieving deep decarbonisation levels in 2050 under these conditions in all scenarios and analyses the economic impact of such a delay.

On the basis of these scenarios, the European Commission estimates that BAU would lead to 40% emission reduction by 2050, whereas decarbonisation scenarios would enable an 80% reduction of emissions by 2050, as illustrated in the figure below.

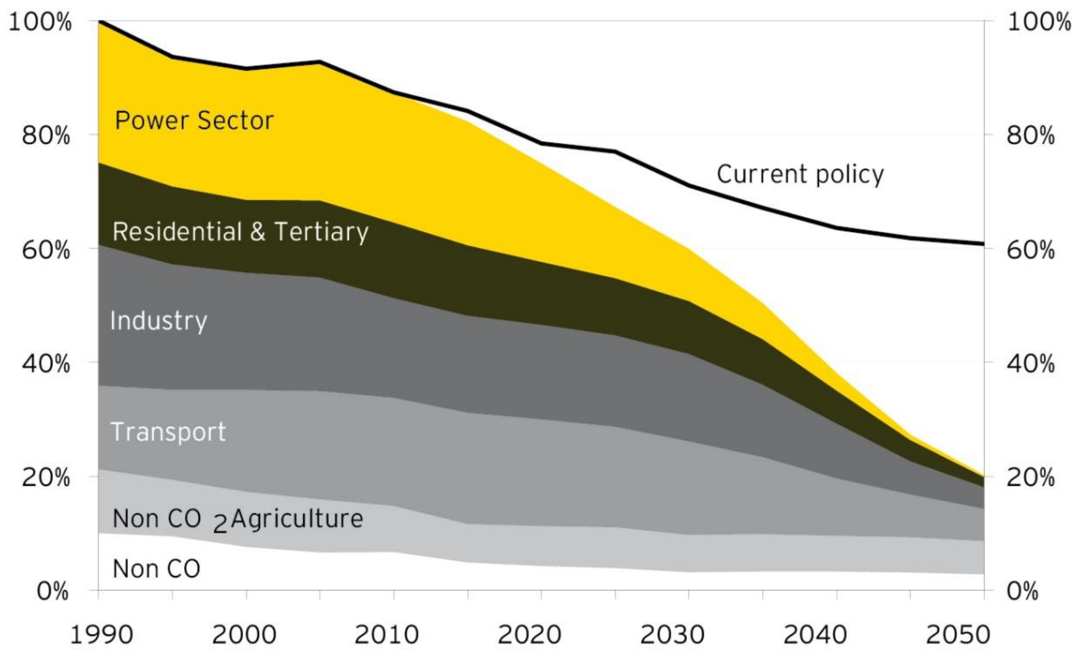

Figure 2: BAU vs. decarbonisation scenario to 2050.

Source: European Commission, A roadmap for moving to a competitive low carbon economy in 2050, 2011

New decarbonisation scenarios are presented in the Impact Assessment published by the European Commission on 22 January 2014; however, they focus on the period 2020 to 2030.[13] As the main focus of this study is the outlook to 2050, this study focuses primarily on the decarbonisation scenarios summarised above from the *Roadmap for moving to a competitive low carbon economy in 2050*. Reference is made to the most recent 2020-2030 decarbonisation scenarios throughout the report where relevant.

13 European Commission, Impact Assessment accompanying the Communication A policy framework for climate and energy in the period from 2020 up to 2030, 2014

The European Commission's Roadmap only models emission reductions of 80%. However, the EU has committed to achieving a GHG reduction of between 80-95% by 2050. This 80-95% objective derives from the level of reductions recommended by the IPCC to developed countries in order to keep atmospheric GHG concentrations below 450ppm. This is the atmospheric concentration level cited by the International Energy Agency as giving a 50% chance of staying within the internationally agreed target to limit atmospheric warming below 2°C. The Commission has therefore focused on the lowest end of this range. Developing scientific evidence on climate change indicates that this higher end may well become the more relevant 2050 reduction target for the EU and other developed countries.

Scenarios from the EC's *Energy Roadmap 2050*[14]

The European Commission's *Energy Roadmap 2050* completes the Low Carbon Roadmap, providing additional material regarding decarbonisation of the power sector. It models two current trend scenarios and five scenarios for decarbonisation of the power sector, which it describes concisely and qualitatively as described below. All scenarios analysed in the *Energy Roadmap* assume that similar efforts regarding decarbonisation are made by industrialised countries as a group.

Current trend scenarios:

- Reference scenario: This scenario includes current trends and long-term projections on economic development (GDP growth 1.7% pa), as well as policies adopted by March 2010, including the 2020 targets for RES share and GHG reductions and the Emissions Trading Scheme (ETS) Directive. Several sensitivity variants, with lower and higher GDP growth rates and lower and higher energy import prices, were included in the analysis.
- Current Policy Initiatives (CPI): This scenario remains a form of reference scenario, updated with recently adopted measures (in particular after the Fukushima events), and proposed as part of the Energy 2020 strategy. It also includes proposed actions from the *Energy Efficiency Plan*[15] and the *Energy Taxation Directive*. In both reference scenario and CPI, final energy demand slightly rises until 2030 (less than 5% compared to 2010) and is assumed to stabilise after 2030.

Decarbonisation scenarios:

- High Energy Efficiency: political commitment to high energy savings (e.g. more stringent minimum requirements for appliances and new buildings, high renovation rates of existing buildings, etc.); energy demand decreases by 41% by 2050 as compared to 2005.
- Diversified supply technologies: no technology is preferred; all energy sources can compete on a market basis with no specific support measures.
- High Renewable energy sources (RES): strong support measures for RES leading to a high share of RES in gross final energy consumption (75% in 2050) and a share of RES in electricity consumption reaching 97%.
- Delayed CCS: similar to 'Diversified supply technologies' scenario but assuming that CCS is delayed, leading to higher shares for nuclear energy, with decarbonisation driven by carbon prices rather than technology push.
- Low nuclear: similar to Diversified supply technologies scenario but assuming that no new nuclear reactor is being built, resulting in a higher penetration of CCS (around 32% in power generation).

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14 European Commission, Energy Roadmap 2050, 2011

15 Since the Commission's Roadmap was published, many of the measures mentioned in the *Energy Efficiency Plan* have been adopted in the frame of the Energy Efficiency Directive that was adopted in 2012

Scenarios from the EC's *Impact Assessment for A policy framework for climate and energy in the period 2020 up to 2030*[16]

The new reference scenario prepared in December 2013 is in line with the previous reference scenario laid out in *A roadmap for moving to a competitive low carbon economy in 2050* as well as the *Energy roadmap 2050.* The key points of the new reference scenario are summarised below:

- Full implementation of already adopted policies, including the achievement of renewable energy and GHG reduction targets for 2020 and the implementation of the Energy Efficiency Directive (leading to strong reductions up to 2020, decreasing afterwards);

The existing linear reduction of the cap in the ETS remains unchanged and continues beyond 2020. For 2030, this new reference scenario leads to the following results:

- EU GHG reduction of 32% below 1990 levels;
- Renewable energy share of 24% of final energy consumption;
- Primary energy savings of 21% as compared to the baseline for 2030 (as projected by PRIMES 2007 baseline).

The analysis prepared for the impact assessment on variants of the reference scenario and decarbonisation scenarios focus on the period 2020 to 2030, in order to address the current lack of objectives of a definite policy framework for climate and energy in a 2030 perspective. Due to the limited timeframe of the latest decarbonisation scenarios, the scenarios to 2050, as detailed in *A roadmap for moving to a competitive low carbon economy in 2050,* remain the main decarbonisation options considered throughout this study.

The key parameters considered in the different scenarios in the impact assessment are summarised below.

Options for combining headline targets:

- A sole GHG target, including elements of supporting renewables and energy efficiency policies;
- A GHG target combined with explicit (additional to the reference scenario) energy efficiency measures and elements of supporting renewables policies;
- A GHG target combined with a pre-set renewables target and explicit additional energy efficiency measures.

For each of which sub-options are considered, where applicable:

- GHG targets of between 35 and 45 % (reductions compared to 1990 GHG emissions levels);
- Pre-set RES targets of 30 and 35% (or no pre-set target) as a share of gross final energy consumption;
- Different level of ambition (moderate, ambitious and very ambitious) for energy efficiency policies (additional to those already present in the reference scenario).

Scenarios were modelled with either the same conditions as in the reference scenario or with enabling conditions, with assumptions on energy infrastructure development, R&D and innovation, decarbonisation of transport, and public acceptance, for which market coordination of certain technologies will be prerequisites.

Primary energy consumption modelled in the 2013 reference scenario varies only slightly from the 2011 reference scenario, by -2.5% in 2020, -1.3% in 2030 and -1.2% in 2050.

Scenarios from the two European Commission Roadmaps are used as starting points throughout this study to describe the estimated macroeconomic effects of BAU and decarbonisation. Where relevant, reference is made to the revised reference scenario published by the Commission in December 2013 and to the recent impact assessment on decarbonisation over the period 2020-2030. The EC's analysis is then compared to other evidence from the existing literature, which may confirm or challenge the EC's findings.

Other sources may use slightly different scenarios from those used by the EC. The purpose of this study, however, is not to analyse in detail variations between models and their assumptions, but rather to show on which points, and to what extent, expert research has reinforced, complemented or challenged the EC's baseline.

[16] European Commission, Executive Summary of the Impact Assessment for A policy framework for climate and energy in the period 2020 up to 2030, 2014

1.3.3 Actions to be undertaken in a decarbonisation pathway compared to BAU

The Commission has explored pathways for key sectors in its *Roadmap for moving to a competitive low carbon economy in 2050*. The table below presents the range of reduction needed to each sector by 2030 and 2050 according to the different decarbonisation scenarios that were analysed in the Roadmap, in order to reach an 80% reduction target compared to 1990.

GHG reductions compared to 1990	2005	2030	2050
Total	-7%	-40 to -44%	-79 to -82%
Sectors			
Power (CO_2)	-7%	-54 to -68%	-93 to -99%
Industry (CO_2)	-20%	-34 to -40%	-83 to -87%
Transport (incl. CO_2 aviation, excl. maritime)	+30%	+20 to -9%	-54 to -67%
Residential and services (CO_2)	-12%	-37 to -53%	-88 to -91%
Agriculture (non-CO_2)	-20%	-36 to -37%	-42 to -49%
Other non-CO_2 emissions	-30%	-72 to -73%	-70 to -78%

Table 1: GHG emission reduction targets by sector.

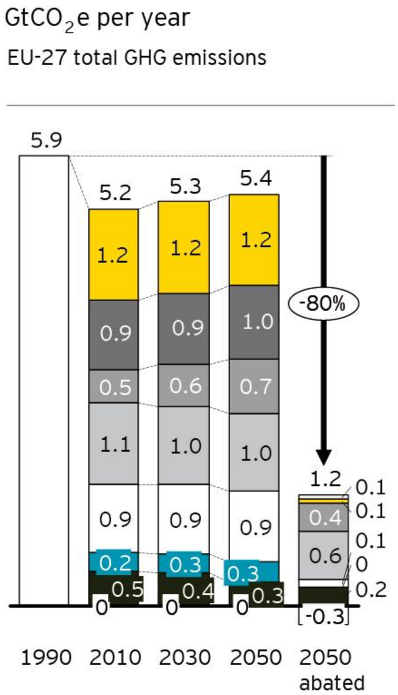
Source: European Commission, A roadmap for moving to a competitive low carbon economy in 2050, 2011

The challenge of decarbonisation is thus significant for Europe. In its *Roadmap 2050*[17], the European Climate Foundation reviews the extent of changes needed to reach the objectives set by the EU in terms of GHG emissions reductions, and that are common to most decarbonisation scenarios. Reaching the 80% emissions reduction target by 2050 would require stretched targets across all sectors of the economy and active choices to put Europe on a decarbonisation pathway.

- All sectors would have to go beyond already expected improvements, e.g. regarding development of energy efficiency or renewable energy sources, to reach the maximum reductions that would lead to a 80 to 95% emissions reduction.
- Further penetration of certain measures would be required between 2030 and 2050 in the transport and buildings sectors beyond the McKinsey Global GHG Abatement Cost Curve (see Figure 3). Further CCS and energy efficiency deployment would also be needed in industry.
- The power sector would have to be decarbonised by at least 95% by implementing carbon free technologies. A reduction of less than 90% in the power sector would make the 80% target effectively unreachable.
- Decarbonisation of the power sector would need to accommodate the electrification that has to be implemented, to the extent possible, by 2050 in main energy demand sectors, i.e. transport, industry and buildings.

17 ECF, Roadmap 2050: A practical guide to a prosperous, low-carbon Europe, 2011

The figure below highlights a plausible combination of abatement levels across sectors, which achieves the stipulated 80% target. Although these figures differ from the EC's Roadmaps for certain sectors, it illustrates Europe's challenges on the road to decarbonisation.



Sector	Total abatement	Abatement within sector[1, 2]	Abatement from fuel shift
Power	95% to 100%	> 95%	
Road transport	95%	20%	75% (electric vehicles, biofuels and fuel cells)
Air & Sea transport	50%	30%	20% (biofuels)
Industry	40%	35% (efficiency, CCS[3])	5% (heat pumps)
Buildings	95%	45% (efficiency)	50% (heat pumps)
Waste	100%	100%	
Agriculture	20%	20%	
Forestry	-0.25 GtCO2e	Carbon sinks	

Total abatement = Abatement within sector + Abatement from fuel shift

1 Abatement estimates within sector up to 2030 based on the McKinsey Global GHG Abatement Cost Curve
2 Large efficiency improvements are already included in the baseline based on the IEA WEO 2009 (up to 2030), especially for industry
3 CCS applied to 50% of large industry (cement, chemistry, iron and steel, petroleum and gas); not applied to other smaller industries
SOURCE: McKinsey Global GHG Abatement Cost Curve; IEA WEO 2009; US EPA; EEA; Team analysis

Figure 3: 80% decarbonisation overall means nearly full decarbonisation in power, road transport and buildings.

Source: ECF, Roadmap 2050 – A practical guide to a prosperous, low-carbon Europe, 2011

2 Impact of BAU vs. decarbonisation trajectories on key economic parameters

2.1 Energy import dependency

2.1.1 Under BAU, Europe would face a continued increase in its energy dependency and import bill

Almost all EU-27 Member States rely on energy imports to satisfy demand (see figure below). According to IEA projections in the World Energy Outlook 2013, this import dependency for both oil and gas is projected to increase substantially over the coming years under a BAU trajectory, with negative impacts on nations' trade balances.

According to the European Commission, the EU has a significant trade deficit in energy products in relation to non-EU countries, which reached € 421 billion (3.3% of EU GDP) in 2012. This deficit has increased nearly three-fold over recent years: in 2004 it was € 150 billion (in current prices). The European Commission notes that the situation induces macroeconomic vulnerability, especially due to inflationary pressures originating from energy price shocks[18].

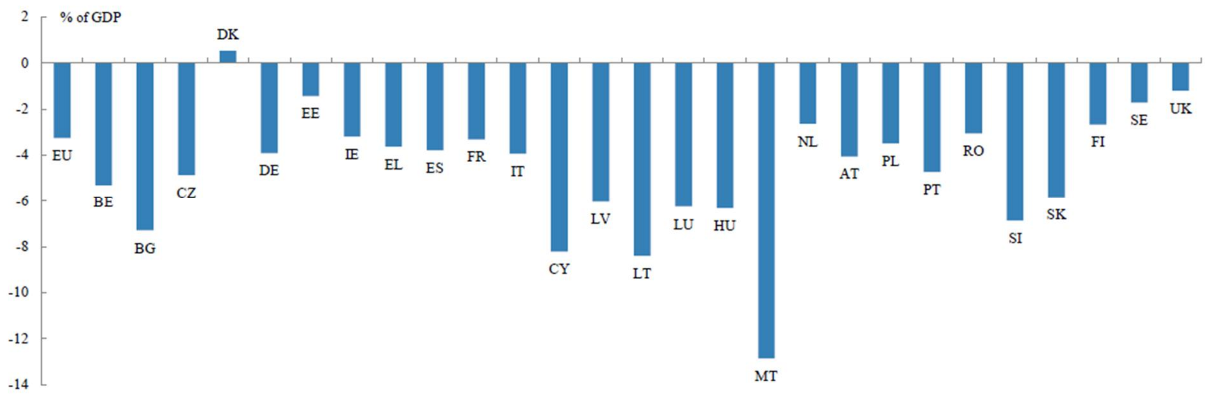


Figure 4: EU Member States trade balance in energy products as % of GDP, 2012.
Source: European Commission, Energy Economic Developments in Europe, 2014

Final energy demand under BAU is expected to remain relatively stable up to 2050 in Europe (decreasing by a little under 5% compared to 2010), in contrast to a significant increase in energy demand globally, as the centre of gravity of energy demand switches to the emerging and developing economies[19]. On the other hand, total energy *production* is expected to decrease significantly within Europe, by more than 50% in 2050 compared to 2010, due notably to a significant decrease in indigenous fossil fuel production, as illustrated in the figure below[20].

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[18] European Commission, Energy Economic Developments in Europe, 2014
[19] IEA, World Energy Outlook, 2013
[20] European Commission, PRIMES model, 2013

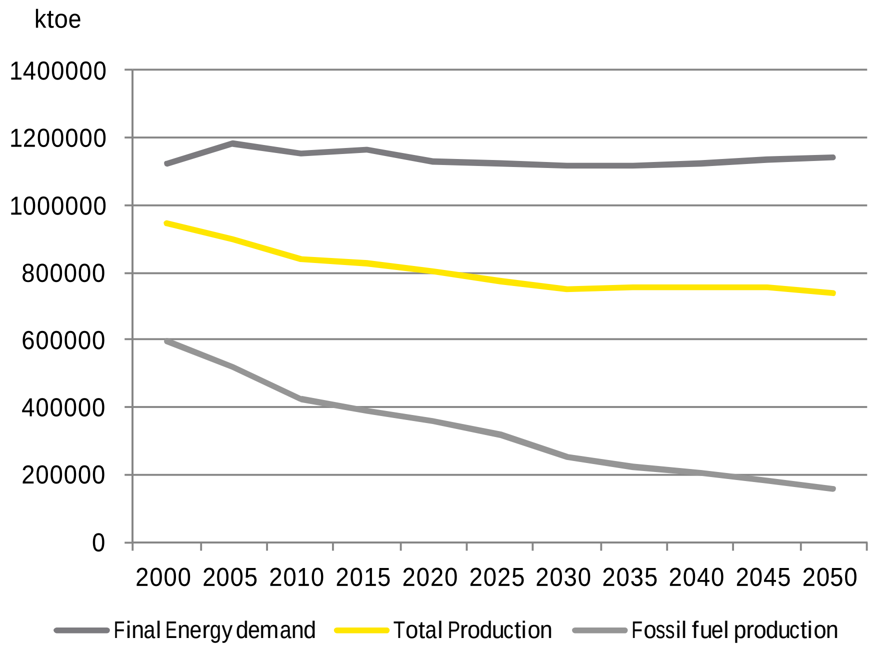

Figure 5: Final energy demand, total energy production and fossil fuel production in the EU under BAU, 2000-2050.
Source: European Commission, EU Energy, Transport and GHG emissions – Trends to 2050, 2013

The EU-27 dependence on energy imports has increased significantly over the past 30 years, due to a combination of rising energy demand and decreasing indigenous fossil resources. In the 1980s, less than 40% of Europe's gross energy consumption relied upon imports. By 2010 this had gone up to 52.6%, with the highest dependency rates for crude oil (84.1%) and natural gas (62.4%)[21].

Policies that have been, and will be implemented through the 2020 package are expected to curb the trend of continuously increasing gross energy demand and lead to a slightly decreasing overall use of energy resources. Specifically, the European Commission estimates that reaching the 20% energy savings target by 2020[22] could reduce EU-27 oil imports by the equivalent of 2.6 billion barrels a year compared to 2010, and potentially save up to €193 billion a year[23] by 2020. This absolute decrease in net primary energy demand is linked to a significant reduction in energy intensity of GDP in the Commission's reference scenario which will continue to have effect by 2050: intensity should be reduced by more than 50% in 2050 compared to 2005[24]. However, the absolute decrease in demand by both 2020 and 2050 would only be modest, and – due to falling domestic production - Europe's energy import dependency is therefore set to keep increasing until 2050. The total fossil fuel import bill of the EU is projected to rise in constant prices by around 80% from 2010 to 2050, reaching around € 600 billion (in 2010 euros) in 2050[25].

Energy import dependency – BAU	2010	2020	2030	2050
EU-27 import dependency (in %)	52.6	53.0	55.0	56.5

Table 2: EU27 energy import dependency under BAU.
Source: European Commission, EU Energy, Transport and GHG emissions – Trends to 2050, 2013

21 Eurostat
22 At present, the EU is not on track to meet this target. Progress will be reviewed in June 2014.
23 http://ec.europa.eu/commission_2010-2014/president/news/archives/2013/05/pdf/energy_en.pdf
24 European Commission, A roadmap for moving to a competitive low carbon economy in 2050 – Impact assessment, 2011
25 European Commission, EU Energy, Transport and GHG Emissions, Trends to 2050, 2013

Regarding oil specifically, under BAU Europe's dependency on imports would increase from 74% in 2010 to 84% by 2030, and almost 90% by 2050 – even though import volumes would stagnate. In the meantime, oil prices are expected to increase from $ 70/barrel in 2010 to $ 138 /barrel in 2050. These assumptions result in almost a doubling of the oil import bill in the EU by 2050. Regarding natural gas, under BAU Europe's dependency on imports would increase from 64% in 2010 to over 70% by 2030, and almost 80% by 2050[26]. This same trend holds true in the 2013 update of the EC's reference scenario.

These projections over the long run must be used with caution, as numerous uncertainties remain, in particular regarding the future evolution of global fossil fuel prices and the potential of domestic shale gas production, discussed later in this section. However, the reviewed literature does not challenge the EC's forecast that recent marked trends of declining domestic fossil fuel production and increasing import bills are set to continue under BAU.

Besides increased trade deficits, Europe's slowly-increasing dependence on imports under BAU would maintain or increase its vulnerability to the volatility in fossil fuel prices. A spike in oil and gas prices has historically been the spark that has sometimes led to a recession. The table below presents cumulative GDP gain or loss over the eight quarters following each spike on a selection of countries during the four major oil shocks that happened in the past decades.

	1973	1979	1999	2002
Canada	-8.3	-1.0	-1.5	3.2
Germany	-9.6	-3.5	1.3	-2.5
France	-7.6	-4.4	0.6	1.2
UK	-16.4	-9.2	0.4	2.5
Italy	-8.6	0.4	3.0	-2.0
Japan	-16.1	-4.4	7.6	3.3
US	-13.3	-11.8	-3.7	7.1
G7	-12.6	-7.7	-0.2	3.9
Euro-12	-9.1	-2.9	1.0	-0.4
OECD	-11.2	-6.5	0.1	4.1

Table 3: Oil shock episodes – Cumulative GDP change.

Source: Olivier J. Blanchard, Jordi Gali, The Macroeconomic effects of oil shocks: Why are the 2000s so different from the 1970s?, 2007

While the table above appears to indicate that the effects of oil price shocks have become smaller over time, it must be noted that shocks in 1999 and 2002 were of smaller magnitudes than previous ones. It is also noteworthy that they have damaged European GDP to a larger extent than in the rest of the world, illustrating Europe's apparently persisting vulnerability to fossil fuel price volatility. The data must however be interpreted with caution, as many factors other than oil shocks may have contributed to the observed macroeconomic effects. Assessing current and future vulnerability (or resilience) of the EU's economy to oil shocks would require further research.

26 European Commission, EU Energy, Transport and GHG Emissions, Trends to 2050, 2013

2.1.2 Decarbonisation of the power sector would enhance Europe's energy security

The European Commission has established several decarbonisation scenarios that all lead to a significant decrease of the EU's energy import dependency

The European Commission has established five decarbonisation scenarios for the power sector in its *Energy Roadmap 2050*. These scenarios all rely on different pathways for Europe's energy production and consumption (intensive energy efficiency measures, diversified supply technologies, high RES, delayed CCS and low nuclear) and are compared to a Reference scenario and a Current Policy Initiatives (CPI) scenario. It appears that in all of these decarbonisation scenarios, Europe's energy import dependency would significantly decrease from 2030 onwards, and its external fossil fuel bill would decrease below current levels by 2050.

Compared with current levels, all decarbonisation scenarios increase their fuel bill until 2030, but to lower levels than in the Reference and CPI scenarios. Financial savings and reduced import dependency are most striking in 2050. Indeed, compared with the CPI scenario, by 2050 the EU could save between € 518 and 550 billion (in 2009 euros) per annum by taking a strong decarbonisation pathway[27]. Over the 2010-2050 period, the average annual fuel cost decrease under decarbonisation compared to BAU is between € 175 and € 320 billion[28], depending on whether fragmented or global action is taken, and assuming that technology development is not delayed compared with currently accepted technology cases.

This upper bound estimate of € 320 billion annual savings stems from the pursuit of global decarbonisation efforts, with fossil fuel import prices expected to be much lower than under BAU. In addition, fossil fuel import volumes would also be lower due to energy efficiency and penetration of RES in the EU. These combined effects reduce the expenditure for each fossil fuel and therefore the total external fuel bill of the EU. The decrease of the fuel bill from 2005 in the decarbonisation scenarios is highest in the High RES scenario, where renewable energy replaces most fossil fuels and Europe's import dependency falls to 35.1%, as presented in the table below.

Energy import dependency (%) – Decarbonisation scenarios	2030	2050
1. Reference	55.0	56.5
1 bis. Current Policy Initiatives	57.5	58.0
2. Energy Efficiency	56.1	39.7
3. Diversified supply technologies	55.2	39.7
4. High RES	55.3	35.1
5. Delayed CCS	54.9	38.8
6. Low nuclear	57.5	45.1

Table 4: EU-27 energy import dependency under decarbonisation scenarios.

Source: European Commission, Energy roadmap 2050 – Impact assessment, 2011

As shown in Table 4, under decarbonisation import dependency remains close to reference scenario levels until 2030, but falls to less than 40% in 2050. The revised EC decarbonisation impact assessment, dating from January 2014, remained in line with the 2011 estimate[29]. This would logically result in reduced exposure to fossil fuel price volatility. Energy price spikes would result in a similar absolute increase in fuel expenses when they occur in the case of either decarbonisation or BAU. However, the price increase in the case of decarbonisation would pertain to a significantly lower volume of fossil fuels than under BAU.

27 European Commission, Energy roadmap 2050 – Impact assessment, 2011

28 European Commission, A roadmap for moving to a competitive low carbon economy in 2050 – Impact assessment, 2011

29 European Commission, Impact Assessment - A policy framework for climate and energy in the period from 2020 up to 2030, 2014

Furthermore, in all European Commission decarbonisation scenarios, electricity would have to play a much greater role than now, contributing importantly to the decarbonisation of transport and the heating and cooling of buildings. Its share in final energy demand would almost double to 36-39% in 2050, and would have to contribute to the decarbonisation of transport and heating/cooling of buildings. In order to achieve this target, the power generation system would have to undergo structural changes and achieve a significant level of decarbonisation by as early as 2030 (57-65% in 2030 and 96-99% in 2050) [30].

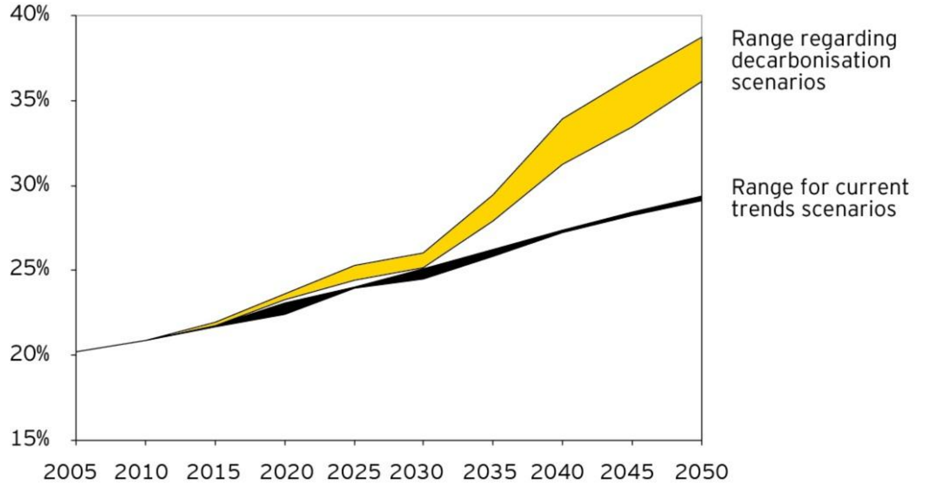

Figure 6: Share of electricity in current trend VS decarbonisation scenarios (in % of final energy demand). *Source: European Commission, Energy roadmap 2050, 2011*

Further studies confirm that energy efficiency, combined with a shift to indigenous renewable energy sources, would lead to a major decrease of EU import dependency and protect against the impacts of fossil fuel price spikes

Comprehensive investment in energy efficiency and the intensive use of renewable energy sources are seen as key elements in energy policy by many national governments. They reduce the dependence on fuel imports, reduce emissions from fossil fuel sources, and help to decouple energy costs from oil prices.

According to the ECF Roadmap[31], fuel sourced from non-OECD countries for power supply could decrease from 35% of total fossil fuels under BAU down to 7% of total fossil fuels in a pathway that relies on 80% renewable energy sources by 2050. Sufficient grid, demand response and back-up investments can ensure that the increased intermittency of the decarbonised power generation system delivers reliable power (see section 2.2).

A recent study by the Fraunhofer Institute[32] has found that significant investments to maximise Europe's energy efficiency potential could cut EU final energy demand by 33% between 2008 and 2030, and by 42% between 2008 and 2050 compared to BAU (PRIMES 2009 model used in the EC's *Energy Roadmap 2050*), thereby delivering primary energy savings equal to 118% of EU energy imports in 2008, financial savings of €500 billion annually, and emission cuts of 79% economy-wide compared to 1990 levels. Savings related to the use of renewable energy sources would be additional to this.

These figures are coherent with the Commission's estimates in the High Energy Efficiency decarbonisation scenario, where final energy demand declines by 40% between 2005 and 2050 compared to BAU, delivering financial savings of over € 500 billion annually.

30 European Commission, Energy roadmap 2050, 2011

31 ECF, Roadmap 2050 – A practical guide to a prosperous, low-carbon Europe, 2011

32 Fraunhofer Institute, Contribution of Energy Efficiency Measures to Climate Protection within the European Union until 2050, 2012

2.1.3 Fuel shift could enable decarbonisation in the transport, building and industry sectors and reduce Europe's dependence on energy imports

A shift towards low-carbon technologies would reduce Europe's transport sector fuel bill by €115-180 billion in 2050

The transport sector has been persistently dependent on oil for years. 96% of energy used in transportation in the EU-27 today is fossil fuel. Although final energy demand in the transport sector is expected to stabilise by 2050 under BAU, this dependency rate would only be reduced to 90%[33] in 2050 – even considering an increase in the use of biofuels and electricity compared to today – with renewable energy sources marginally exceeding the 10% target set for 2020 by the European Commission. CO_2 emissions from transport in 2050 would remain one third higher than their 1990 level under BAU, according to the EC's *White Paper on Transport*[34].

In the Commission's reference scenario, the share of road transport in total transport CO_2 emissions decreases from 84% in 2005 to 77% in 2050. In decarbonisation scenarios, thanks to increased fuel efficiency and fuel shift, this share decreases to 65% in 2050 (with the exception of delayed electrification - 76%). The share of aviation increases from 14% in 2005 to 20% in 2050 in reference scenarios, and by up to 31% in decarbonisation scenarios[35] (due to rising demand coupled with relatively fewer decarbonisation options for aviation other than modal shift). In all scenarios, the combined share of aviation and road transport represents more than 95% of CO_2 emissions from the transport sector. In the long term, as power generation becomes nearly carbon-free, the transport sector becomes the largest source of CO_2 emissions[36].

According to a recent study by Cambridge Econometrics *Fuelling Europe's Future*[37], even with Europe maintaining domestic extraction rates on fossil fuel, imports related to use in the transport sector would rise to € 590 billion per year by 2030 and € 705 billion per year by 2050 based on price increases alone, compared to € 350 billion in 2012 (in 2010 prices). Without reductions in the demand for oil, imports are also likely to increase in volume as domestic production depletes Europe's known oil reserves. Europe thus faces a challenge to increase both technological and system efficiency to reduce its oil dependency. In order to achieve this objective, transport would have to use less and cleaner energy, and better exploit existing infrastructure.

This transition is expected to involve a progressive shift towards a mix of low-carbon technologies as well as modal shift. Technological development relies on efficient Internal Combustion Engine (ICE) vehicles, Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs), Range-Extended Electric Vehicles (REEVs), Battery Electric Vehicles (BEVs) and Fuel Cell Electric Vehicles (FCEVs)[37]. A shift to a low-carbon transport sector would have immediate effects on Europe's fossil fuel import dependency.

Cambridge Econometrics has investigated several decarbonisation scenarios to 2050 for the transport sector. These scenarios represent various CO_2 efficiency levels in European new vehicles and technologies that are likely to improve efficiency, whereas the decarbonisation scenarios analysed by the Commission are set out in a more basic way, simply assuming a mix of low carbon technologies. The decarbonisation scenarios in the Cambridge Econometrics report are compared to two baselines:

- The REF scenario, which represents a future with no technology improvement beyond today's levels;
- Cambridge Econometrics' Current Policy Initiatives (CPI) scenario (treated as BAU in the present study), which assumes that the current EU policy debate leads to the confirmation and achievement of the proposed CO_2 target for cars of 95 g/km, and a target for vans of 147 g/km by 2020.

The CPI scenario and the "Tech 1" scenario in Cambridge Econometrics' report both ignore the penetration of advanced powertrains, focusing on what might be achieved using only conventional ICE and hybrid technology. The "Tech 2" and "Tech 3" scenarios include the deployment of advanced powertrains and accompanying infrastructure. High and low fossil-fuel price sensitivities were also considered in this analysis, enabling the

[33] In the revised reference scenario dating from December 2013, this dependency on fossil fuels for transport is expected to be slightly less; an estimated 89% in 2030 and 88% in 2050.

[34] European Commission, White Paper – Roadmap to a Single European Transport Area: Towards a competitive and resource efficient transport system, 2011

[35] European Commission, A roadmap for moving to a competitive low carbon economy in 2050 – Impact assessment, 2011

[36] European Commission, EU Energy, Transport and GHG Emissions : Trends to 2050, 2013

[37] Cambridge Econometrics, Fuelling Europe's Future: How auto innovation leads to EU jobs, 2013

robustness of the results to be tested against uncertainty surrounding future fossil-fuel prices[38]. It appears that in all cases, decarbonisation pathways are more advantageous than the BAU trajectory.

The sensitivity analysis shows reductions to the average annual fuel bill of car owners are expected to range from €269 - €379 per car for the Current Policy Initiatives scenario by 2030, and €355 - €738 per car by 2050. The corresponding savings for Tech 1 scenario are €367 - €517 per car by 2030, and €595 – €1,236 by 2050. Savings for the Tech 2 and Tech 3 scenarios are even greater, reaching as much as €1,461 by 2050 for the Tech 3 scenario. Savings thus appear to be much more significant in decarbonisation scenarios, in particular on a long term basis, as presented in the figure below, taking into account the IEA's central case fuel costs.

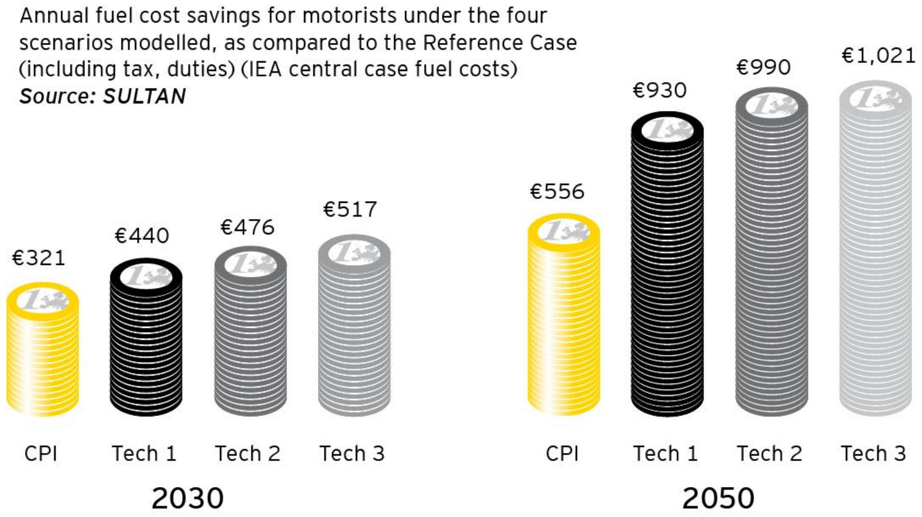

Figure 7: Annual fuel cost savings for motorists under decarbonisation scenarios, as compared to the Reference case (IEA central case fuel costs).
Source: Cambridge Econometrics, Fuelling Europe's Future, 2013

Depending on the decarbonisation scenario, the fuel bill of Europe's car and van fleet would be reduced by around € 58 billion to € 83 billion in 2030 (excluding taxes and duties) with a shift to low-carbon vehicles, and by € 115 billion to € 180 billion in 2050[39].

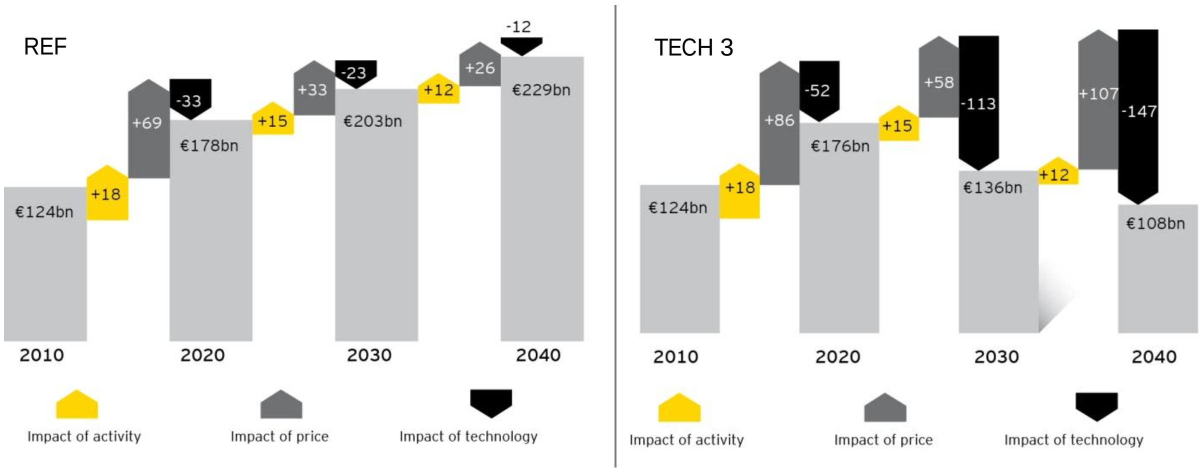

Figure 8: Evolution of EU fuel bill (cars only) in Reference scenario and in Tech 3 scenario (excluding taxes and duties).
Source: Cambridge Econometrics, Fuelling Europe's Future, 2013

38 An uncertainty range of +/- 25% in 2030 and +/- 50% in 2050 was used for modelling oil prices. The results are dependent on energy price assumptions, with the positive economic impacts becoming larger if prices are higher and smaller if prices are lower.

39 Cambridge Econometrics, Fuelling Europe's Future: How auto innovation leads to EU jobs, 2013

The sensitivity analysis also shows that these savings would be equivalent to reductions in the total fuel bill in the order of €39 - €65 billion in the CPI scenario, €54 - €89 billion in the Tech 1 scenario and up to €47 - €99 billion in the Tech 3 scenario.

The study by Cambridge Econometrics is one of very few to investigate the question of how the reduction in fossil fuel imports translates into alternative spending patterns. For instance, if oil savings are reinvested on EV batteries imported from Asia, the effect on the balance of trade would be neutral. If total imports decrease, the exchange rate would likely rise until the balance of trade is restored, meaning that domestic goods would be more difficult to sell abroad. Some of the initial positive economic impact could thus be lost due to this rebound effect[40]. The direct rebound effect was addressed in *Fuelling Europe's Future* by sensitivity analysis modelling a rebound effect of 30%, while the indirect rebound effect is incorporated within the macroeconomic model E3ME. The result was to reduce the positive impact on GDP by half. For the more ambitious decarbonisation scenarios, the direct rebound effect would have a low impact on the economy, since by 2050 the fuels consumed would be hydrogen and electricity produced in Europe.

Moreover, national governments are concerned by the loss of revenue from falling sales of oil. However, Cambridge Econometrics' modelling suggests that very small increases in VAT rates would be required in the short term to maintain government revenues, and in the longer term the stimulus to the economy generates enough income tax revenue, social security contributions and VAT receipts to outweigh the lost excise duty from falling oil sales[41].

As a complement to energy efficiency and electrification paths, the development of biofuels can contribute towards the reduction of import dependency in the transport sector

According to the International Council on Clean Transportation (ICCT), the European Union transport sector, along with the pulp & paper industry (cf. section 2.4.6) could enjoy further opportunities through EU's decarbonisation by mobilising and valuing its share of biomass wastes and residues available for re-use, estimated at over 220 million tonnes per year, currently and in 2030[42]. If that resource, considered as sustainable, were entirely dedicated to biofuel production, it could supply 37 Mtoe of road transport fuel in 2030, generate up to € 15 billion of additional annual revenues for the pulp & paper industry and the rural economy annually, and create up to 300,000 additional jobs by 2030.

It is clear that the business cases for use of these resources are highly location-specific, and it is unlikely that all 220 million tonnes of biomass wastes would be mobilised. Nevertheless, some of the business cases are close to being competitive with fossil fuels, according to analysis in the same project by the National Non-Food Crops Centre, making a large portion of the available volume potentially viable.

Comprehensive building renovation efforts could deliver net energy savings that could be up to 20 times higher than under BAU

Energy use in the residential and service sector comes from fuel and electricity consumption in buildings, households and offices, from heating, cooling and the use of household and office appliances. Opportunities to improve the energy performance of buildings include:

- Improving the thermal performance of the building fabric through insulation of walls, floors and roofs, and replacement and tightening of windows and doors;
- Improving the energy performance of heating, ventilation, air conditioning (HVAC) and lighting systems;
- Installation of renewable technologies such as photovoltaic panels, solar thermal collectors, biomass boilers, or heat pumps;
- Installation of building elements to manage solar heat gains[43].

[40] Linda Brinke, Sander de Bruyn, Literature review on employment effects of GHG reduction policies for transport, Delft, CE Delft, February 2012

[41] Cambridge Econometrics, Fuelling Europe's Future: How auto innovation leads to EU jobs, 2013

[42] ICCT, 2013, Availability of cellulosic residues and wastes in the EU

[43] BPIE, A guide to developing strategies for building energy renovation, 2013

Buildings account for 40% of total energy consumption in the European Union, with more than half of this coming from the residential sector[44]. The residential sector accounts for 70% of emissions from the built environment[45]. It is legislated in the Energy Performance of Buildings Directive (EPBD) that, as of 31 December 2020, all new buildings in the EU will have to consume 'nearly zero' energy and the energy will be 'to a very large extent' from renewable sources. This will represent an important step forward in terms of the efficiency of Europe's buildings, but by far the greater part of the saving potential will have to be realised in the existing building stock.

According to the Commission's BAU ('Reference') scenario, CO_2 emissions from the residential and services sectors are set to decrease by 33% in 2030 and by 45% in 2050 compared to 1990. In decarbonisation scenarios, emission cuts in the sector would amount to 37-53% in 2030 and about 90% in 2050 compared to 1990[46].

The Buildings Performance Institute Europe (BPIE) has estimated macroeconomic impacts of these different approaches by defining five decarbonisation scenarios for the building sectors with 2020, 2030 and 2050 horizons. These scenarios differ from BAU in terms of renovation types, renovation magnitude, and the pace at which investments are undertaken[47]. The BAU trajectory assumes the current average renovation rate of 1% to continue until 2050, which translates to the renovation of 40% of the existing stock. This is consistent with the Commission's BAU.

The figure below compares the present value of investment needed as well as energy cost savings in all scenarios. The difference between the two provides net savings for consumers over the lifetime of the buildings, and thus gives an indication of the possible reduction of Europe's energy import bill for the building sector.

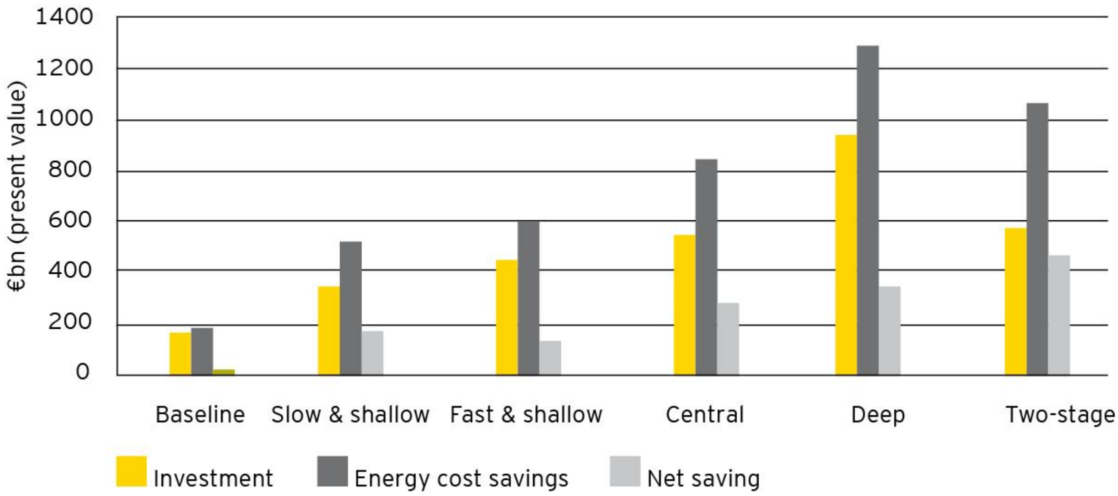

Figure 9: Lifetime financial impact of buildings renovation for consumers (present value) – Results to 2050.
Source: BPIE, Europe's Buildings Under the Microscope, 2011

It appears that under BAU, net savings to consumers from investments in building renovation would be limited, totalling €23 billion over the period 2010-2050. Regarding decarbonisation, BPIE finds that its so-called Two-Stage scenario strikes the best balance between three key factors of achievement of CO_2 reduction targets, investment needed and positive employment effects. This scenario would deliver €474 billion of cumulated net

44 E3G, The macroeconomic benefits of energy efficiency – The case for public action, 2012

45 European Commission, A Roadmap for moving to a competitive low carbon economy in 2050 – Impact Assessment, 2011

46 European Commission, A Roadmap for moving to a competitive low carbon economy in 2050 – Impact Assessment, 2011

47 The 'Deep' and 'Two-Stage' scenarios appear to be the most interesting ones. The Deep scenario assumes that by 2020, deep renovations become the dominant activity and remain so until 2050. nZEB (Nearly Zero Energy Buildings) renovations accelerate from 2020 onwards, such that they account for 30% of the total by 2050, by which time both minor and moderate each account for just 5% of the total. The Two-Stage scenario models the case where some properties undergo two rounds of renovations. Buildings that undergo minor or moderate renovation between 2011 and 2030 are thereby upgraded 20 years later, to deep and nZEB standards respectively. In both scenarios, an average renovation rate of 2.5% per year is assumed in order to achieve 100% renovation of the building stock in 2050.

savings in the period 2010-2050, which is 20 times more than the savings generated under BAU. Thus, although the investment required is significantly higher than under BAU, the Two-Stage scenario has positive outcome in terms of energy cost savings –i.e. the higher investment would give considerably higher returns.

It should be noted that some experts recommend a focus on the Deep scenario rather than the Two-Stage approach. The Deep scenario requires higher investment levels than the Two-Stage, but generates even higher energy savings and further positive employment effects. It also avoids certain concerns related to the phased approach:

- That it is unrealistic to expect buildings to undergo energy renovation twice between now and 2050. The risk of this is that only minor renovations would be done, with the rest of the energy savings potential thus being locked in for another 30-40 years;
- That the costs of deep renovation will not go down by as much after 2030 as the Two-Stage scenario assumes, as the 'slow' approach will not provide the learning curve that would be needed to bring costs down, and also considering that a large share of costs are associated with labour;
- That opting for the Two-Stage scenario would signal to decision-makers that 'BAU renovations' (which generally achieve between 10% and 35% savings) are acceptable until 2030.

The effect of shale gas on EU's energy mix and import dependency is highly uncertain

The United States' (US') recent 'unconventional gas revolution' provides an apparently striking example that shale gas can significantly impact US dependency on energy imports. According to the Energy Information Administration (EIA), projections of future gas supply and production from the US have shown significant adjustments from the beginning of shale gas extraction: while 2008 projections predicted an overall decrease in natural gas production in the US between 2008 and 2030, the trend was reversed by as soon as 2009[48]. The US is currently expected to become a net exporter of natural gas from 2016, according to the EIA's reference scenario[49] - i.e. its dependency is projected to be negative by this date.

In contrast to these forecasts, the Post Carbon Institute has conducted an analysis of shale gas production trends in the key extraction fields, showing an overall production decline for the top five US shale gas plays since 2012. The production from these top five plays constituted 81% of US shale gas production in the period 2006-2013. Similarly, according to the same study, 74% of tight oil production comes from two plays. The study finds that production is likely to peak by 2017, as 'sweet spots' become exhausted early on in field development, requiring drilling rates to continually escalate to maintain production levels, until the limit is reached[50]. Such opposition in expert opinions, in a US shale gas market which is relatively mature but still uncertain, illustrates the doubts surrounding forecasts for the coming decades.

Projections for the EU also vary widely. The IEA's 'New Policies' scenario foresees a declining European gas production by 2030[51], despite the fact that the EU's unconventional gas resources are believed to be substantial (albeit lower than in the US[52]). Estimates are subject to uncertainties at several levels, however. From a technical point of view, shale gas is assessed to provide a large majority of the recoverable energy potential from unconventional gas sources: shale gas recoverable volumes are estimated to be significantly larger than Coal Bed Methane or Tight gas[53]. However, a literature review of estimates highlights the level of uncertainty surrounding Europe's shale gas resources. While the IEA suggests that technically recoverable resources would amount to 13 Tcm[54], a difference of factor 4 is found between the lowest and the highest estimate among 8 other studies published between 2009 and 2012, ranging between 5 and 20 Tcm[55]. For comparison, the EU-28 natural gas consumption amounted to 0.5 Tcm in 2012[56].

48 EIA, 2009 Annual Energy Outlook, 2009

49 EIA, Annual Energy Outlook 2014

50 J. David Hughes, Global Sustainability Research Inc., Post Carbon Institute, 2013, The "Shale Revolution", Myths and Realities

51 IEA, World Energy Outlook 2013

52 EIA, Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States, 2013

53 IEA, World Energy Outlook, 2012

54 EIA, Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States, 2013

55 ICEPT, Unconventional Gas – A review of estimates, ICEPT Working Paper, 2012

56 Eurogas, Statistical Report 2013, 2013

Beyond the question of available shale gas resources, the Brookings Institute has offered one of the most comprehensive analyses of shale gas development in Europe. Their conclusion is that shale gas development is likely to remain limited, and far below US levels, in view of the many barriers to be lifted[57]:

- Unfavourable geological conditions (e.g. test drilling operations in Poland and Sweden);
- Lack of investment in infrastructure (e.g. in Poland, the EU country that is currently most politically favourable to shale gas extraction);
- Mineral rights laws that, in contrast to laws in the US, offer no incentives for local communities for acceptance of shale gas extraction;
- Widespread public opposition and national regulations banning shale gas exploitation.

From an economic point of view, the current literature covers mainly technically recoverable resources and lacks data on economically recoverable resources[58]. It has been estimated that European shale gas, less amenable to hydraulic fracturing extraction than the US shale gas, would be associated with a higher break-even point than in the US: above $10/mmbtu for EU shale gas[59], in contrast to a level of between $3/mmbtu and $7/mmbtu for US shale gas.

Besides the question of Europe's own domestic production of shale gas, another consideration is the effect of US shale gas production on wholesale gas prices. So far this has led to a significant decrease in gas prices from 2008[60]. Future US exports of low-cost gas (currently 2.5 times cheaper than European gas and 5 times cheaper than Japanese gas[61]) to either Europe or to Asia, could result in a decrease of gas market prices of -$0.60 by 2030[62], thereby fuelling Europe's increasing demand for gas – with likely impacts on Europe's reliance on gas at the expense of other energy sources[63]. Such figures are however also highly uncertain: for instance, Asche *et al.* modelled gas and oil prices following the gas boom, which indicated that although a gas boom is followed by price differences, a long-term equilibrium leads to equal prices[64]. This suggests that market projections must be read with caution. Further economic factors might also contribute to significant changes in market prices, including in particular the oil-gas price link which is currently strong in Europe. Substantial delinkage could favour decreases in gas prices[65].

Energy efficiency achievements might also become a key driver of change, as gas demand projections could be strongly affected by such improvements. For instance, residential and commercial natural gas consumption, currently amounting to 35-40% of Europe's natural gas consumption[66], is expected to remain almost constant for the next 20 years as a result of energy efficiency improvements[67]. The potential for energy savings in the household sector could reach 61% by 2030[68]. Such improvements, whether in the household sector or other sectors, suggest that gas demand, and therefore gas import dependency, is strongly linked with scientific and technical breakthroughs. Moreover, a limited number of public policy decisions might also have significant impacts: in the case of household consumption, about 80% of European natural gas consumption was concentrated in only six countries in 2012[69], implying that a single major energy efficiency plan for buildings could entail substantial reductions in household gas consumption in these countries.

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57 Tim Boersma, Brookings Institute, 2013, Four Questions on Shale Gas Development in Europe and the US

58 ICEPT, Unconventional Gas – A review of estimates, ICEPT Working Paper, 2012

59 Keffertputz R. (2010), *Shale Fever: Replicating the US gas revolution in the EU ?* CEPS Policy Brief n°210

60 KPMG, Shale Gas – A Global Perspective, 2011

61 IEA, World Energy Outlook 2013

62 Deloitte, Global Impacts of LNG exports from the United States, 2013

63 IEA, World Energy Outlook 2011

64 Asche F., Oglend A. & Osmunden P. (2012), *Gas versus oil prices: the impact of shale gas.* Energy Policy, 47, pp. 117-124

65 Gracceva F., Zeniewski P. (2013), *Exploring the uncertainty around potential shale gas development – A global energy system analysis on TIAM (TIMES Integrated Assessment Model).* Energy, 57, pp. 443-457

66 Eurogas, Statistical Report 2013, 2013

67 Eurogas, Long-term outlook for gas to 2035, 2013

68 Fraunhofer Institute for Systems and Innovation Research ISI, Contribution of Energy Efficiency Measures to Climate Protection within the European Union until 2050, 2012

69 Eurogas, Statistical Report 2013, 2013

Overall, both Europe's unexploited shale gas potential and the US future shale gas exports are characterized by uncertain features that do not allow confident prediction of their effects on the evolution of EU energy import dependency.

Taking account of this uncertainty and the number of variables, various detailed analyses of both US and EU potential shale gas extractions have been carried out. Models by the European Union Joint Research Centre (EU-JRC) and the International Energy Agency (IEA) have considered several scenarios, including "High Unconventional Gas" and "Low Unconventional Gas" scenarios, characterised by various economic features (GDP growth, production costs) and a wide range of potential shale gas resources (between 149 Tcm and 417 Tcm for the EU-JRC model[70], and between 30 Tcm and 208 Tcm for the IEA model[71]). Results suggest that Europe's gas import dependency in 2035 could amount to up to 72% in the EU-JRC "Low Unconventional Gas" scenario. Under the "High Unconventional Gas" scenario, it may fall to 57% (EU-JRC), or 59%. A similar model concurs and yields that Europe, although benefitting from shale gas extraction in terms of energy dependency, would not achieve a dependency decrease exceeding 10% by 2040[72].

The assessment that the contribution of shale gas to EU gas demand would remain limited was confirmed in the most recent institutional communication from the European Commission, published on 17 March 2014, stating that "*While the EU will not become self-sufficient in natural gas, natural gas production from shale formations could, at least partially, compensate the decline in the EU's conventional gas production and avoid an increase in the EU's reliance on gas imports. Indeed it would be, in a best case scenario, able to contribute almost half of the EU's total gas production and meet about around 10% of the EU gas demand by 2035*"[73].

At the same time the Commission published a Recommendation that intends to provide clarity and predictability for public authorities, market operators and citizens[74]. The Recommendation defines fracking and includes requirements for environmental and risk assessments, as well as ongoing monitoring; the Commission will undertake an assessment of the effectiveness of this approach in mid-2015. However, this Recommendation and its accompanying Communication and Impact Assessment are not anticipated to affect existing estimates on shale gas uptake in Europe and its impacts on energy import dependency.

This section has highlighted the degree to which energy imports underlie large trade deficits for most European countries. Under BAU, models in the reviewed literature concur that Europe's external fossil fuel bill would continue to rise under BAU. Investment in Europe's energy efficiency and RES potential, in particular in the power, transport and building sectors can be expected to improve the EU's energy security and significantly reduce its dependence on fossil fuel imports. Although the exact macroeconomic effects of future fossil fuel price shocks are uncertain, reducing Europe's import dependency through decarbonisation would build more resilience against energy price spikes. Meanwhile, although shale gas poses an uncertain new variable, it seems unlikely that Europe could solely rely on this recent development to reduce its energy import dependency.

70 EU-JRC, Unconventional Gas: Potential Energy Market Impacts in the European Union, 2012

71 IEA, World Energy Outlook 2011

72 Gracceva F., Zeniewski P. (2013), *Exploring the uncertainty around potential shale gas development – A global energy system analysis on TIAM (TIMES Integrated Assessment Model).* Energy, 57, pp. 443-457

73 European Commission, Communication on the exploration and production of hydrocarbons (such as shale gas) using high volume hydraulic fracturing in the EU, 17 March 2014

74 European Commission, Commission Recommendation on minimum principles for the exploration and production of hydrocarbons (such as shale gas) using high volume hydraulic fracturing, 2014

2.2 Investment costs

2.2.1 Renewing, upgrading and expanding Europe's energy infrastructure under BAU will require major annual investments up to 2050

Under a BAU trajectory, renewing, upgrading and expanding Europe's ageing energy system is a challenge that will be associated with significant investment costs in the coming decades.

The effects of carbon prices and changes in energy costs will be major drivers for the type and volume of investments that will be undertaken. According to the European Commission's reference scenario, average investments in all sectors of the economy[75] will increase from around € 800 billion per annum in the period 2010-2020 to around € 1000 billion per annum in the period 2040-2050, as presented in the table below. Over the 2010-2050 period, the average annual investment needs would amount to € 929 billion[76].

Average yearly investments (in billion €)	2011-20	2021-30	2031-40	2041-50	Average
Reference scenario (BAU)	816	916	969	1014	929

Table 5: EU-27 total average yearly energy investments in the EU under BAU.
Source: European Commission,
A roadmap for moving to a competitive low-carbon economy in 2050 – Impact assessment, 2011

The Impact Assessment revised in 2014 provides similar estimates, with an average annual investment of € 816 billion in the period 2011-2030 and € 949 billion in the period 2031-2050. These slightly lower estimates are partly due to the fact that energy-efficiency and renewable energy technologies have recently achieved faster cost reductions than anticipated in 2011.

The total energy system cost[77] would represent 14.6% percent of European GDP in 2050[78] (i.e. about € 3300 billion) in the case of BAU, compared to 12% today[79]. The revised EC reference scenario (2013) shows similar trends, with system costs in 2020 amounting to 15% of GDP, rising from 13% in 2010; beyond 2020 energy costs continue to increase in absolute terms but at a slower rate than GDP. In 2050, total systems costs as a percentage of GDP are expected to fall to 12.3%, a drop of about 2 percentage points compared to the numbers presented in the 2011 reference scenario[80].

Investment levels in decarbonisation scenarios do not differ substantially from these figures, as presented in the figure below. On average, investments in infrastructure and energy efficiency would be 1.9% higher under decarbonisation scenarios than under BAU (differences of CAPEX needs under both scenarios are detailed in section 2.2.2.), but would be offset by lower operating expenditure (OPEX) by 2050.

75 For all sectors except transport and the power sector, the investments relate to energy part of the investment, not the capital good as a whole. For transport and power the investment is related to the whole capital good. Transport as such represents by far the largest part of investments.

76 European Commission, Energy roadmap 2050 – Impact assessment, 2011

77 The sum of electricity costs, fuel purchases, energy equipment, transport equipment, direct efficiency investment, deducted ETS auctioning revenue, and non-energy related mitigation costs

78 GDP is assumed to be the same in all scenarios (BAU and decarbonisation). The EU's GDP is expected to almost double in 2050 compared to 2010.

79 European Commission, Energy roadmap 2050 – Impact assessment, 2011

80 European Commission, EU Energy, Transport and GHG Emissions : Trends to 2050, 2013

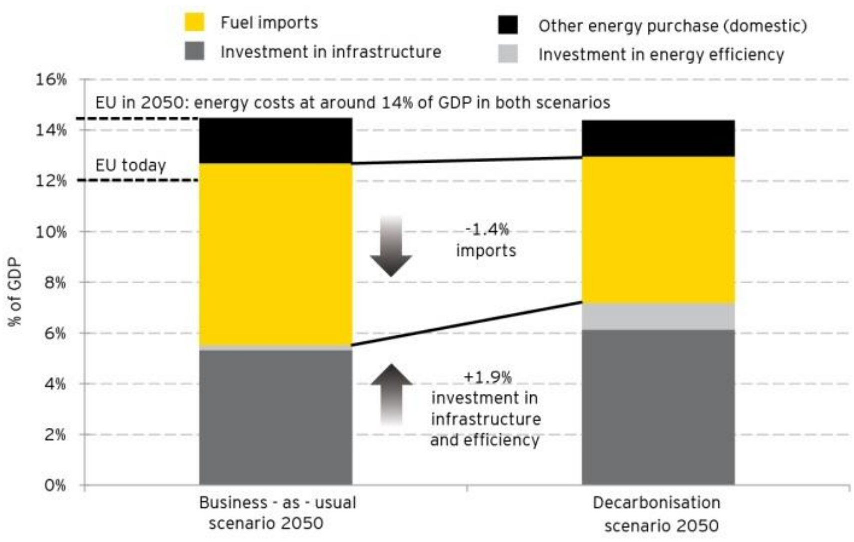

Figure 10: Shifts between energy cost components under decarbonisation VS BAU.
Source: European Commission, Energy priorities for Europe,
Presentation of J.M. Barroso to the European Council of 22 May 2013

2.2.2 The Commission's roadmap projects higher CAPEX in decarbonisation scenarios than under BAU

In decarbonisation scenarios of the 2011 EC Impact Assessment, capital expenditure (CAPEX) for all sectors increases by 30% compared to BAU, to an annual average of around € 1200 billion over the period 2010-2050. This corresponds to an increase of just over € 250 billion yearly investment compared with BAU[81]. Decarbonisation scenarios indeed require more sophisticated infrastructure (mainly electricity lines, smart grids and storage) than BAU.

Average yearly investments (in billion €)	2011-20	2021-30	2031-40	2041-50	Average
Effective technology scenario (decarbonisation scenario)	858	1040	1309	1592	1200

Table 6: EU-27 total average yearly energy investments in the EU under decarbonisation.
Source: European Commission,
A roadmap for moving to a competitive low-carbon economy in 2050 – Impact assessment, 2011

The Impact Assessment indicated that Europe could benefit from proceeding with faster-paced decarbonisation investments up to 2030. Delaying investments that will be eventually be required to reach the 2050 objectives would cause CAPEX to increase by around €100 billion per annum from 2030 to 2050 compared to immediate climate action, without decreasing the investment needs before 2030[81].

In the revised Impact Assessment dating from January 2014, annual investment needs in decarbonisation scenarios compatible with 2050 GHG objectives are in the range of € 854-909 billion in the period 2011-2030, and € 1188-1333 billion in the period 2031-2050. These numbers indicate that estimates have been revised down. The exact reason is not cited in the text, although a number of underlying hypotheses for the reference scenario have been updated (e.g. shale gas production, different uptake levels of renewable energies, recently adopted EU Directives and national policies, capital cost estimates).

81 European Commission, A roadmap for moving to a competitive low carbon economy in 2050 – Impact assessment, 2011

Though BAU and decarbonisation scenarios achieve similar results in terms of overall energy system costs, grid investment costs differ significantly due to the development of renewable energy sources under decarbonisation

All decarbonisation scenarios established by the Commission model a transition from an energy system based on high fuel and operational costs, to a system based on higher CAPEX and lower fuel costs. The transition is facilitated by the fact that large shares of current energy supply capacities will soon come to an end of their useful life and would need to be replaced.

The scenarios analysed by the Commission estimate that although there is a shift in the nature of the spending, the relative costs of transforming the energy system do not differ substantially between BAU and decarbonisation. The total energy system cost[82] would in any case remain slightly above 14%, as presented in the table below.

	Cumulative system costs related to GDP
Reference	14.37%
CPI	14.58%
High Energy Efficiency	14.56%
Diversified supply technologies	14.11%
High RES	14.42%
Delayed CCS	14.06%
Low nuclear	14.21%

Table 7: Cumulative energy system costs related to GDP 2011-2050.
Source: European Commission, Energy roadmap 2050 – Impact assessment, 2011

The Impact Assessment published in January 2014 has revised these forecasts. While they remain in line with the 2011 Impact Assessment for the period 2011-2030, the gap slightly widens between BAU and decarbonisation scenarios in the period 2031-2050. System costs in that period are on average 13% in the case of BAU, while they are around 15% in decarbonisation scenarios compatible with the 2050 GHG reduction objectives.

Between now and 2050, a wide-scale replacement of infrastructure and capital goods throughout the economy would be implemented. These investment needs are substantial, with returns expected over the long term: overall system costs are expected to increase to up to more than 15% of GDP in all scenarios in 2030 and decrease until 2050.

Investment in power generation capacity involves substantial CAPEX in all scenarios over the period 2011-2050. It would be most pronounced in the high RES scenario, amounting to over €3 trillion up to 2050, as illustrated in the figure below.

[82] The sum of electricity costs, fuel purchases, energy equipment, transport equipment, direct efficiency investment, deducted ETS auctioning revenue, and non-energy related mitigation costs

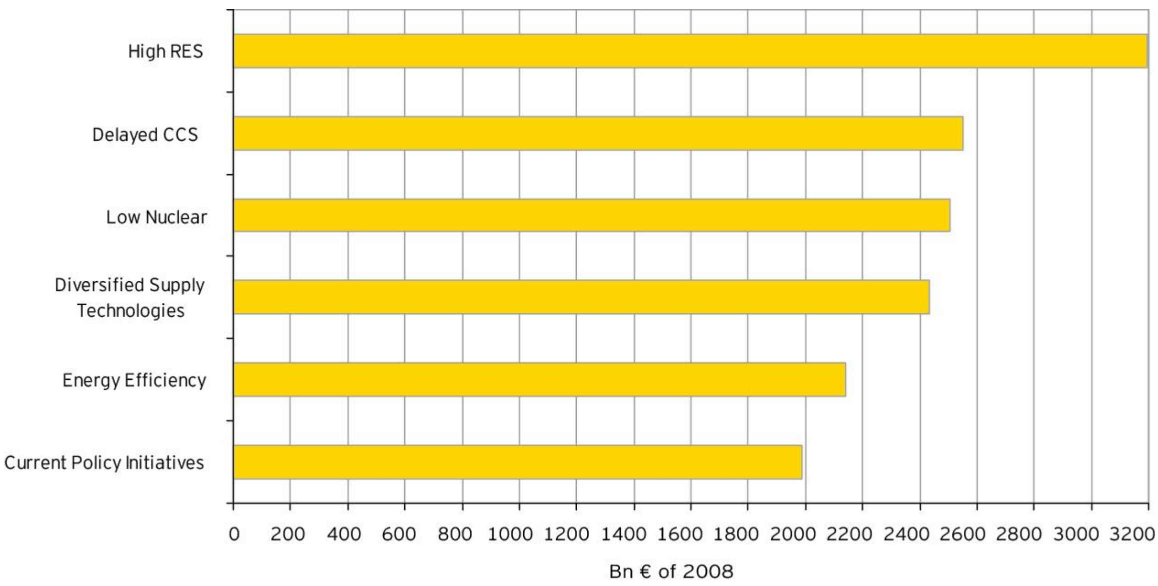

Figure 11: Cumulative investment expenditure in 2011-2050 for power generation (in € of 2008).
Source: European Commission, Energy roadmap 2050 – Impact assessment, 2011

The analysis conducted by the Commission assumes that grid investment costs are linear across the period 2011-2050. The model assumes that grid investments, which are prerequisites to the decarbonisation scenarios in this analysis, are undertaken and that costs are fully recovered in electricity prices. Grid investment costs alone could range from € 1.5 to 2.2 trillion cumulated between 2011 and 2050 in decarbonisation scenarios, with a significant part of this attributable to more substantial investments to support renewable energy development[83].

(in € billion 2005)	2011-20	2021-30	2031-50	Total 2011-50
Reference	292	316	662	1269
CPI	293	291	774	1357
High Energy Efficiency	305	352	861	1518
Diversified supply technologies	337	416	959	1712
High RES	336	536	1323	2195
Delayed CCS	336	420	961	1717
Low nuclear	339	425	1029	1793

Table 8: Grid investment costs (investments in transmission grid including interconnectors and investments in distribution grid including smart components).
Source: European Commission, Energy roadmap 2050 – Impact assessment, 2011

However, these figures can vary substantially over time and will depend on the evolution of RES costs and their scale development by 2050. Recent evidence suggests that CAPEX for RES is likely to be considerably lower than expected in the Energy Roadmap (see Section 2.2.3). This is at least partly reflected in the lower cost estimates used in the Commission's more recent work. Grid investment costs are also a strong argument for developing an integrated European approach: their level could be very different from the figures above if the EU engages on such an integrated pathway (see section 2.2.3.).

83 European Commission, Energy roadmap 2050 – Impact assessment, 2011

2.2.3 The capital costs for some renewables, particularly solar, have come down faster than expected - potentially lowering the overall system costs under decarbonisation trajectories to levels more similar to those under BAU

Cost reductions of renewable energy technologies have been faster than expected, resulting in a need to review CAPEX forecasts downwards

The deployment of RES in Europe contributes towards approximately 40% of the emissions reduction needed in the power sector between 2010 and 2020, and the EU would continue to lead globally in RES deployment up to 2020[84]. As deployment in the rest of the world increases, the European share of total worldwide installed capacity would gradually decrease and costs would be brought down. This would support EU demand, with the EU RES sector in return benefitting from deployment in the rest of the world.

Estimated cumulative CAPEX under BAU for energy generation, transmission and backup in ECF's study *Power Perspectives 2030*[84] amounts to € 628 billion from 2010 to 2020, and an additional amount of € 1,153 billion over the period from 2020 to 2030, bringing the total CAPEX between 2010 and 2030 to € 1,781 billion compared to approximately €1600 billion over 2010-2030 in the Commission's *Energy Roadmap 2050*'s CPI scenario. When comparing a high RES scenario (60% RES share in 2030) with BAU[85], the model predicts a 40% increase in overall CAPEX costs for 2020–2030, which is substantially offset by lower generation OPEX over that same period of € 177 billion per year versus € 212 billion per year under BAU (i.e. € 353 billion OPEX reduction compared to BAU over 10 years).

Some more recent studies suggest that investment cost estimates made in 2011 by the European Commission and ECF for renewable energy generation equipment, grids and storage, were overestimated. A recent analysis for Germany shows that on the distribution level, the total cost for grid expansion can be as low as € 3 billion: just 10% of earlier estimates [86]. Also, for instance, new storage capacity is found not to be needed in Germany before a share of 60%-80% of renewables is reached[87].

Estimates of system costs such as balancing requirements and back-up capacity resulting from the integration of large shares of renewables are also subject to uncertainty. The specific functionalities of some systems are already integrated in modern technologies, as for example in the case of PV where inverters can now provide reactive power provision or storage. In addition, balancing occurs at the level of an overall power system, and partly depends on the system's interconnection capacity and gate closure time – both factors which are unrelated to the share of renewables.

Besides these evolutions in understanding of system requirements, the costs of renewable energy technologies themselves have evolved over the last two years. Several renewable energy solutions have accelerated their cost reduction trajectory beyond expectations, thus making the renewable energy pathway more attractive for Europe. This cost reduction has been so significant that the cost level for PV that was expected for 2050 in the *ECF Roadmap 2050* has already been reached.

The most recent study illustrating this point was produced in November 2013 by Fraunhofer ISE: *Levelized Cost of Electricity, Renewable Energy Technologies*. The Levelised Cost Of Energy (LCOE) allows comparison of various generation technologies on a cost per kWh basis. It is the discounted lifetime cost per kWh of ownership and use of a generation asset. Calculations rely on certain assumptions and local project-specific parameters (e.g. load factors, capital and operating costs, effective tax rates), causing a degree of uncertainty and cost ranges which are sometimes large.

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84 European Climate Foundation, Power Perspectives 2030, 2011

85 The *On track case* scenario is considered as BAU in this study and assumes full implementation of the existing plans for the power sector up to 2020 and models a power system in line with the EC's emission reduction goals with a production mix with 50% renewable energy sources and 16% nuclear across Europe towards 2030.

86 RWTH Aachen, IFHT: Technologieoptionen für den Verteilungsnetzausbau in Deutschland – Marktanalyse und Bewertung; Schlussbericht – Aachen, 2013

87 VDE, Energiespeicher für die Energiewende Speicherungsbedarf und Auswirkungenauf das Übertragungsnetz für Szenarien bis 2050, Frankfurt, 2012

The main findings of the Fraunhofer study regarding Photovoltaic (PV) energy can be summarised as follows[88]:

- PV system prices have dropped significantly, supported by expansion of new PV module production capacity in 2010-2012.
- Prices for PV have a similar learning rate as other semiconductor goods: prices drop by ~15-20% with each doubling of installed capacity.
- PV power plants in Germany have thus reached an LCOE between € 78/MWh and € 142/MWh in the third quarter of 2013, depending on the type, location, and orientation of power plant, as well as other local factors.

In December 2013 the European Commission partly acknowledged these trends by updating the figures it had used in the *Energy Roadmap 2050* in its new reference scenario[89]:

- The current capital cost of large-scale PV was updated in the 2013 reference scenario to €2000/kW; despite this significant update compared to the earlier *Energy Roadmap 2050*, published in 2011, this figure remains much above the higher range currently observed in the Fraunhofer study.
- The capital cost level of €1000/kW, which is currently observed by Fraunhofer in some locations, would only be reached in 2035.

It should be noted that in making these updates the Commission used assumptions from early 2012 to make its forecasts, whereas the Fraunhofer study relies on observations from November 2013. As of November 2013, investment costs for small PV systems (up to 10 kWp, suitable for small residential installations) were in fact in the range €1300-1700/kW. For larger systems (up to 1000 kWp, used in large rooftop systems), the range was €1000-1700/kW. The range is even €1000-1400/kW for utility-scale systems (above 1000kWp). These costs have decreased by up to 25% compared to a previous study by Fraunhofer, produced a year and a half before, in May 2012. This illustrates the fact that in the fast-moving industry of renewable energy, particularly in solar PV, cost reduction has tended to go faster than expected.

These comparisons are illustrated in the table below:

Source	2013	2020	2030
Fraunhofer, Levelized Cost of Electricity, Renewable Energy Technologies, November 2013	€1000-1700/kW	€760-1140/kW	€570-850/kW
European Commission, EU Energy, Transport and GHG Emissions, Trends to 2050, 2013 (forecasts based on assumptions from early 2012)	€2000/kW	€1508/kW	€1085/kW
European Commission, Energy Roadmap 2050, 2011	€3700/kW	€2678/kW	€1663/kW

Table 9: Large-scale solar PV capital cost estimates and forecasts in different sources.
Sources cited in the table

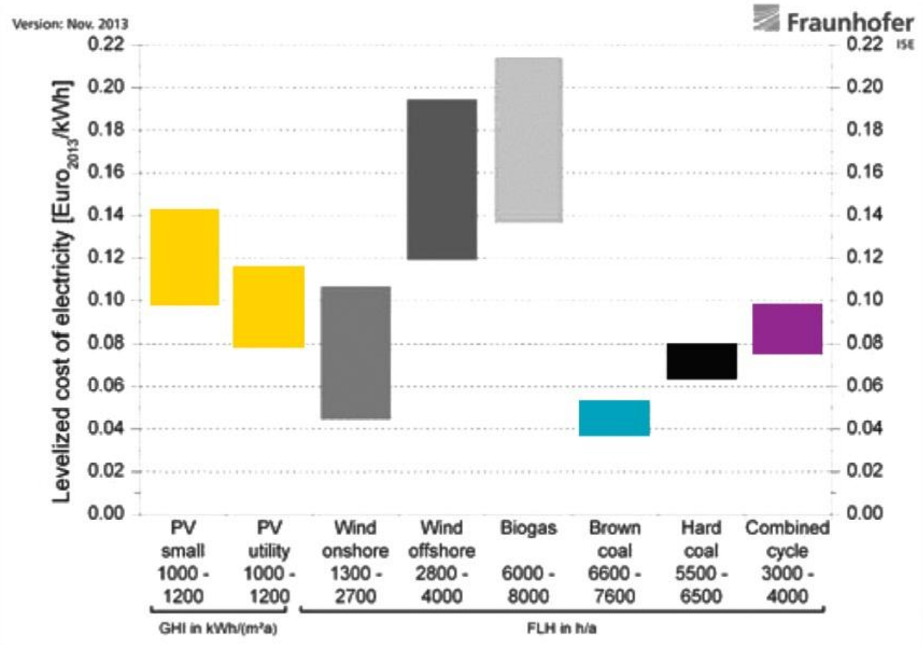
Similarly, the Fraunhofer study finds that wind power in favourable onshore locations in Germany sometimes shows lower costs than hard coal or CCGT. Currently the LCOE for onshore wind power (with CAPEX of €1000-1800/kW) are between €45/MWh and €107/MWh. Offshore wind remains less competitive, with an LCOE of €119/MWh to €194/MWh, because of more expensive installation as well as higher operating and financing costs (with CAPEX of €3400-4500/kW). LCOE for biogas, with CAPEX in the range of €3000-5000/kW, is between €135/MWh and €215/MWh depending on substrate costs and full load hours.

88 Fraunhofer, Levelized Cost of Electricity, Renewable Energy Technologies, 2013

89 European Commission, EU Energy, Transport and GHG Emissions, Trends to 2050, 2013

These figures for renewable energy sources are to be compared with the LCOE range for brown coal (€38-53/MWh), hard coal (€63-80/MWh), and CCGT (€75-98/MWh).

These findings are summarised in the figure below:



The value under the technology refers in the case of PV to the insolation global horizontal irradiation (GHI) in kWh/(m²a), for the other technologies it refers to the number of full load hours (FLH) for the power plant per year. Specific investments are taken into account with a minimum and maximum value for each technology.

Figure 12: LCOE of renewable energy technologies and conventional power plants at locations in Germany in 2013.
Source: Fraunhofer ISE, Levelized Cost of Electricity, Renewable Energy Technologies, 2013

Furthermore, the study by Fraunhofer provides updated cost reduction forecasts for the renewable energy technologies mentioned above. These can be summarised as follows in terms of LCOE cost evolution between now and 2030[90]:

- PV: reduction of over 30% mainly due to learning rates inducing greater installation efficiency and know-how, allowing this technology to compete with hard coal and CCGT from 2020, and brown coal by 2030.
- Onshore wind: further small reductions expected; increasing ability to compete with coal and CCGT due to expected price increase of fossil fuel power plants.
- Offshore wind: reduction of over 20%, allowing this technology to compete with hard coal and CCGT by 2030.
- Biogas: small further reductions expected.

[90] Fraunhofer, Levelized Cost of Electricity, Renewable Energy Technologies, 2013

These findings are summarised in the figure below:

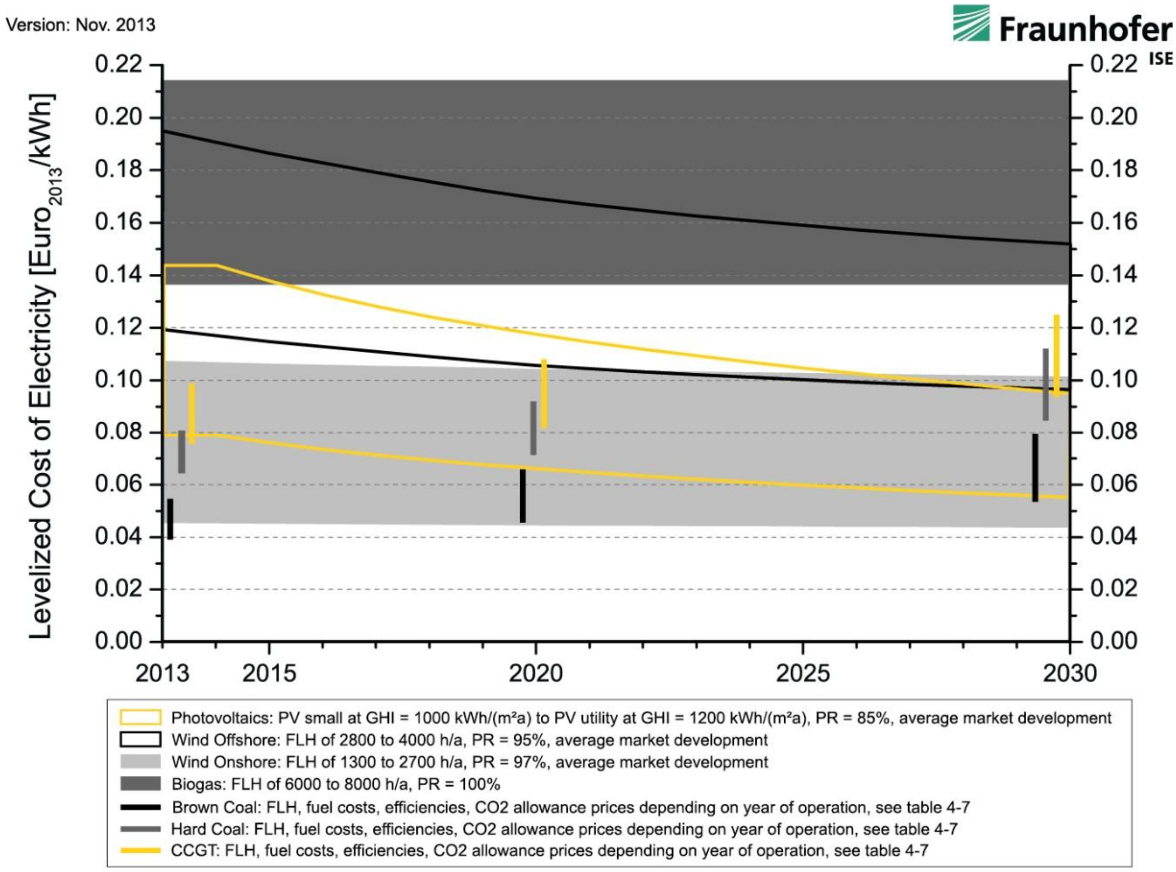


Figure 13: Learning-curve based predictions of the LCOE of renewable energy technologies and conventional power plants in Germany by 2030.

Source: Fraunhofer ISE, Levelized Cost of Electricity, Renewable Energy Technologies, 2013

Translating renewable energy cost reductions into lower energy costs in the long term

The fact that the capital cost achievements detailed above have not yet translated into lower electricity prices is explained by a number of reasons:

- RES and other low-carbon technologies are capital-intensive technologies, whose upfront investments need time for being recovered, and where lower capital costs do not immediately translate into lower electricity costs.
- Even though the share of renewables in the EU electric mix has increased from 15% in 2000 to 27% in 2013[91], the penetration rates of RES are not high enough to significantly impact retail electricity prices. This is especially true for the case of PV, which has recently seen significant capital cost reductions, but whose share in the electric mix remains minor.
- Besides RES generation costs, many other important factors determine electricity costs, including fossil fuel wholesale prices, exchange rates, infrastructure investment, supplier costs and margins, system costs, subsidies, and energy and climate change policies (see section 2.3).
- As confirmed by a number of expert institutions (IEA[92], PIK[93], Ecofys[94]), LCOE assessments would need to shift to a “System LCOE” approach in order to account for the integration costs of renewables for energy systems in transition.

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91 Enerdata, 2013

92 International Energy Agency, The Power of Transformation- Wind, Sun and the Economics of Flexible Power Systems, 2014

Translating RES technical and economic progress into actual electricity price reductions therefore requires analysis and action at policy and system level, given the key role of these parameters in the formation of electricity prices.

An integrated European approach could help to reduce generation costs related to the development of renewables

As stated in ECF's *Roadmap 2050*[95], a large increase in regional integration and interconnection of electricity markets is key to decarbonisation. It is also the way towards reliable and economically viable integration of localised energy production through balancing out variable generation over a large area, along with investments in smarter control of demand and decentralised supply. The development of regionally integrated approaches to planning and operation of grids and markets is required. Incorporating large shares of variable renewable energy production into the transmission system is technically feasible but a significant increase in transmission capacity is required as well as additional backup generation capacity (10-15% on top of the generation capacity, as estimated in 2010). This additional transmission capacity can level demand and supply profiles and allows sharing diverse energy resources across Europe.

As presented in the figure below, all decarbonisation scenarios modelled by ECF require significant additional transmission capacity and backup generating capacity. These requirements grow with increased penetration of intermittent renewable energy sources.

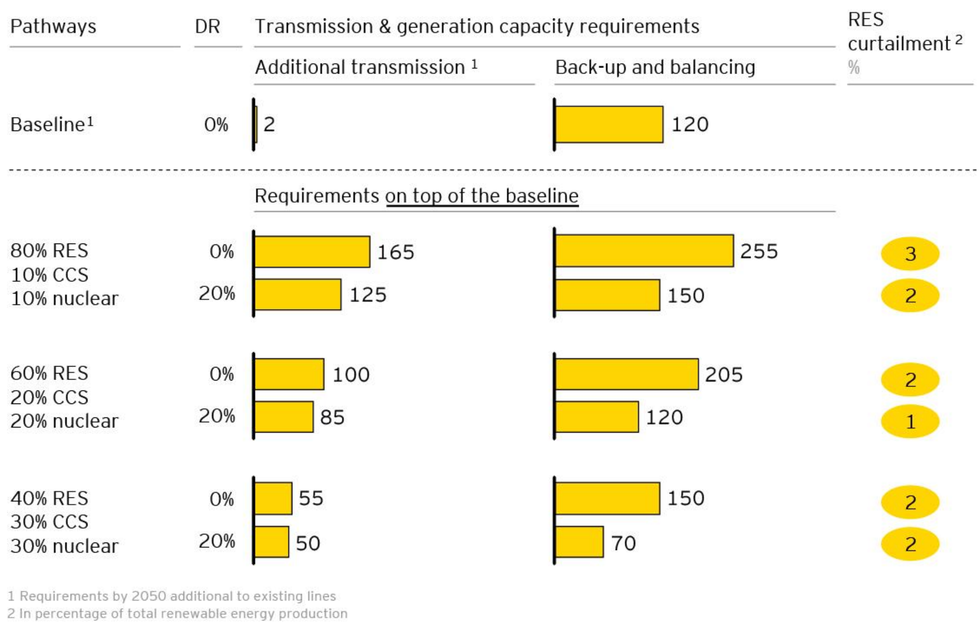

Figure 14: Transmission flows and back-up generation capacity requirements (2050, GW).
Source: ECF, Roadmap 2050, 2011

Without supply sharing, achieving decarbonisation and RES penetration targets becomes more challenging for individual regions. It would imply additional generation investments with higher levels of curtailment. Even for the level of decarbonisation on which Europe has engaged between now and 2020 (40% RES pathway), addressing the system integration issues on a country-by-country basis, rather than through an integrated European approach, would drive up costs. ECF estimates that reserve sharing across EU-27 would reduce total reserve requirements by approximately 40%.

A study by Booz & Company entitled *Benefits of an integrated European energy market*[96] underlines that full integration would require large investments, but not much higher than what would already be needed under

93 Potsdam Institute for Climate Impact Research, System LCOE: What are the costs of variable renewables?, 2013
94 Ecofys, Apples to Oranges - Comparing the costs of energy technologies, 2013
95 European Climate Foundation, Roadmap 2050 – On the road to a prosperous low carbon economy, 2011
96 Booz & Company, Benefits of an integrated European energy market, 2013

BAU. The ENTSO-E plan of a 40% increase in investments by 2020 is considered as fully adequate by Booz & Company. However, it is found that until 2030, 90% of economic benefits of European integration are achievable even if just half of the transmission capacity planned by ENTSO-E is built.

The figure below illustrates that net savings of about €16bn - €30bn a year (after netting out the effect of additional transmission costs and some generation cost savings, shown in the right hand bars in the chart) could be achieved compared to a less efficient, non-integrated deployment. The range reflects cost uncertainty of PV capacity. Additional transmission capacity is required to facilitate the relocation of renewable energy capacity, which can be financed with a small fraction of capital savings in generation capacity.

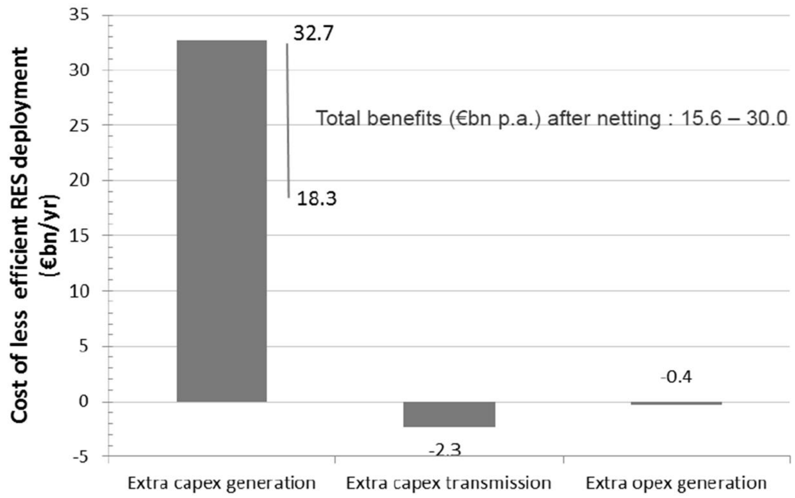

Figure 15: Economic benefits of European integration of electricity markets.
Source: Booz & Company, Benefits of an integrated European energy market, 2013

2.2.4 The transport and building sectors also require large but economically viable investments for decarbonisation

CAPEX for the transport sector is mostly passed on to consumers but is compensated by fuel savings within a few years

The European Commission's analysis[97] estimates that while deeper cuts can be achieved in other sectors of the economy, a reduction of at least 60% of GHG emissions by 2050 compared to 1990 is nevertheless required from the transport sector, which remains a significant and growing source of carbon emissions.

According to the Commission's *Low Carbon Roadmap*, average annual investments in transport would increase substantially under BAU, from less than € 700 billion in 2011 to more than € 800 billion by 2050. This increase is even more important in decarbonisation scenarios, amounting to € 1100 billion on average in 2050. However, fuel bills are expected to be much lower in decarbonisation scenarios than under BAU, decreasing to less than € 300 billion per year over the period 2040-2050 in the case of global action (vs. € 473 billion per year on 2011-2020), compared to € 728 billion under BAU over the same period.

Most studies make the assessment that improving vehicle fuel-efficiency would result in additional capital costs. Much is already known about vehicles that are being designed today for 2020, which will deliver most of the benefits by 2030. According to the study by Cambridge Econometrics *Fuelling Europe's Future*[98], at the EU level, decarbonisation scenarios that rely on conventional technologies add €22-45 billion to the yearly capital cost of the car and van fleet in 2030. However this is more than offset by avoided yearly spending on fuel worth € 59-80 billion in 2030. This makes the total cost of running and renewing the EU car and van fleet in 2030 about

[97] European Commission, White Paper – Roadmap to a Single European Transport Area: Towards a competitive and resource efficient transport system, 2011

[98] Cambridge Econometrics, Fuelling Europe's Future: How auto innovation leads to EU jobs, 2013

€36 billion lower than if the fleet were to continue running on today's technology. These additional capital costs would add € 1,100 - € 1,200 to the production cost of the average car in 2020.

Estimates made by Cambridge Econometrics are in the same range as two other studies on the subject:

- In its study for the European Commission impact assessment[99] on the 95g/km target, TNO, the Dutch Organisation for Applied Scientific Research, found central-case additional manufacturing costs of € 1,159 per vehicle on average, relative to the 130 g/km target in 2015.
- According to the International Council on Clean Transportation (ICCT)[100], the 95 g/km target would lead to less than € 1,000 of additional manufacturing costs per vehicle, compared to a 2010 vehicle.

After 2020, technology costs are likely to continue to rise in order to meet increased fuel-efficiency requirements in different decarbonisation scenarios presented in the study by Cambridge Econometrics. However, additional capital costs are more than offset by the fuel savings. Consumers select their vehicles on the basis of a wide range of factors, of which capital costs are just one element. In calculating the overall impact on motorists of improved vehicle efficiency, it is also useful to look at Total Cost of Ownership (TCO), which includes most other important factors in the overall running costs, such as fuel and maintenance costs.

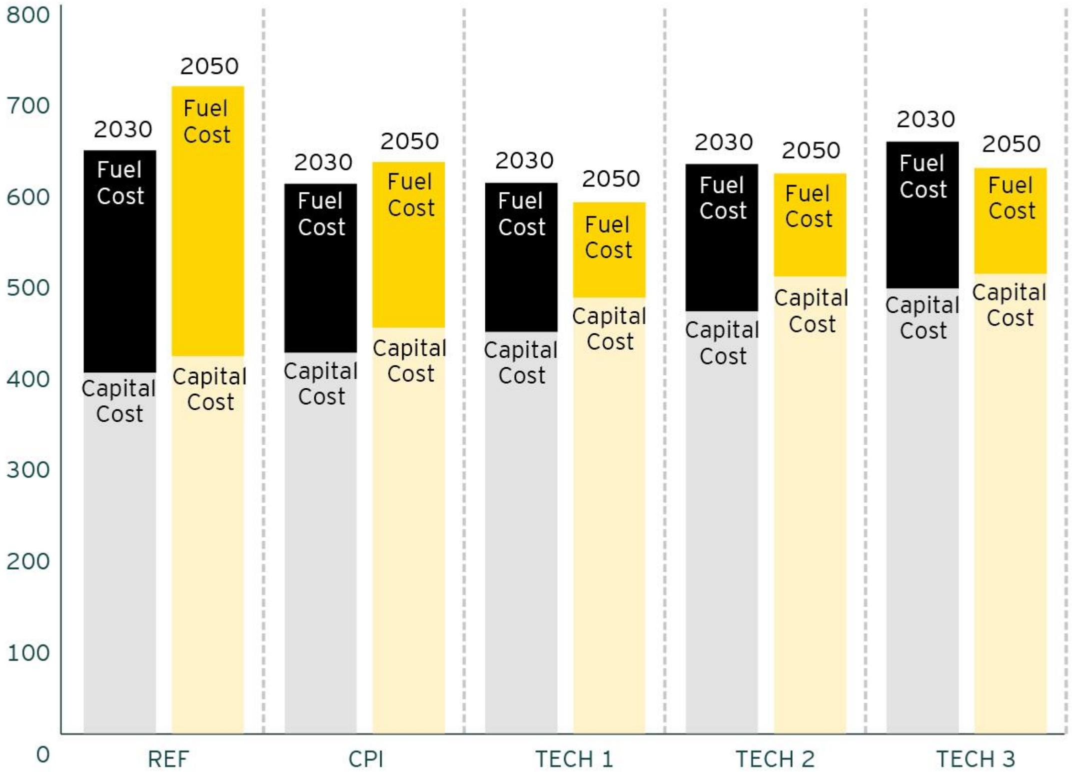

Figure 16: Vehicle total cost of ownership in 2030 and 2050 under BAU and decarbonisation scenarios.
Source: Cambridge Econometrics, Fuelling Europe's Future, 2013

Under different low-carbon technology mix scenarios established by Cambridge Econometrics:

- The TCO would be systematically lower than in the REF scenario, where there would be no technology improvement beyond today's levels.
- In 2050, the TCO would be comparable to CPI, where the 95g/km target for cars and a 147g/km target for vans is fully implemented and achieved in 2020. The TCO would be even lower in the case of TECH1.
- The capital cost increase would be more than offset by fuel savings.

On the whole, the owner of the average new car in 2020 would spend around €300 to €400 less on fuel each year than the owner of the average 2010-manufactured car. Given that the increased capital cost would be less

99 European Commission, Proposal for a regulation of the European Parliament and of the Council amending Regulation (EC) No 443/2009 to define the modalities for reaching the 2020 target to reduce CO_2 emissions from new passenger cars – Impact assessment, 2012

100 http://www.theicct.org/spotlight/eu-2020-vehicle-targets

than the amount saved on fuel across the 12-year lifetime of a vehicle, household budgets would be improved[101].

CAPEX would also be needed for infrastructure to support the deployment of hydrogen and electric vehicles. However, hydrogen vehicles follow a traditional usage pattern, i.e. vehicles are re-fuelled at re-fuelling stations and not at home or work. The cost of the infrastructure would be funded through the sales of hydrogen shortly after deployment of the stations, as installation costs would be directly passed-through to re-fuel customers.

SULTAN SCENARIO	2010	2020	2030	2040	2050
Tech 2	-	8	738	2,872	8,014
Tech 3	-	416	2,235	6,604	15,748

Table 10: Total infrastructure real term cost estimates for hydrogen (2010 €m).

Source: Cambridge Econometrics, Fuelling Europe's Future, 2013

For EVs, the infrastructure associated with the production and distribution of electricity is considered separately in the economic modelling studied by Cambridge Econometrics, but it is financed through the increased sales of electricity both on the wholesale market and also through margins in the retail market to fund improvements in the distribution grid.

SULTAN SCENARIO	2015		2020		2030		2050	
	No. vehi - cles (000)	Costs (€m)	No. vehi - cles (000)	Costs (€m)	No. vehi - cles (000)	Costs (€m)	No. vehi - cles (000)	Costs (€m)
Tech 2 - Low cost	1,7	0,19	1445	164,35	35289	4.251,35	174484	25.616,60
Tech 2 - Grazing	1,7	0,44	1445	1.282,23	35289	8.911,91	174484	48.387,65
Tech 2 - High tech	1,7	0,44	1445	1.282,23	35289	9.642,21	174484	58.492,90
Tech 3 - Grazing	253	65,15	5598	5.130,84	81948	22.816,59	197263	65.783,38
Tech 3 - High tech	253	65,15	5598	5.130,84	81948	24.664,64	197263	79.966,32

Table 11: Total infrastructure cost estimates for EVs (2010 real terms).

Source: Cambridge Econometrics, Fuelling Europe's Future, 2013

Also, little change in transport would be possible without the support of an adequate network and more rational use of the infrastructure. According to the European Commission, the cumulative cost of EU infrastructure development to match the demand for transport has been estimated at over € 1.5 trillion from 2010 to 2030. The completion of the Trans-European Transport Networks (TEN-T) requires about € 550 billion until 2020. This does not include investment in vehicles, equipment and charging infrastructure which may require an additional trillion to achieve the emission reduction goals for the transport system[102].

101 ECF, Fuelling Europe's Future: How auto innovation leads to EU jobs, 2013

102 European Commission, White Paper – Roadmap to a Single European Transport Area: Towards a competitive and resource efficient transport system, 2011

Major investments in decarbonisation of the building sector would entail significantly higher energy savings than under BAU

Europe's greatest energy savings potential lies in buildings. The EC's energy efficiency policy framework includes instruments such as the Energy Efficiency, Ecodesign, Energy Labelling and Energy Performance of Buildings Directives, to encourage the renovation process in public and private buildings and to improve the energy performance of components and appliances. Technology is already available to cut existing consumption of buildings by half or three quarters, and to halve the energy consumption of typical appliances.

In the *Impact Assessment* accompanying its *Roadmap for moving to a competitive low carbon economy in 2050*, the Commission estimated energy-related investments in residential and tertiary buildings. Under BAU, these investments would increase from an average of € 47 billion a year over the period 2011-2020 to an average of € 67 billion a year over the period 2041-2050.

In the case of decarbonisation ("effective technology cases"), investment needs would increase to € 65 billion a year over the period 2011-2020. Investments would follow a strong increase until the period 2041-2050, reaching an annual average of over € 269 billion. Compared to BAU ("reference" scenario), decarbonisation would entail average annual investments over the period 2011-2050 which are € 130 billion, about € 80 billion higher than under BAU.

This greater investment effort would however generate reductions in fuel and electricity expenses. On average the annual fuel and electricity expenses decrease in the effective technology scenarios over the whole period by around € 70-105 billion.

In BPIE's research *Europe's Buildings Under the Microscope*[103], five scenarios were analysed and compared to BAU, assuming various renovation rates and age profiles of the buildings stock being renovated (see section 2.1.3. for a description of BAU and the most relevant decarbonisation scenarios).

According to BPIE's model, BAU would require a total cumulated investment of € 164 billion over the period 2010-2050 (see below for why these figure is so much lower than the Commission's). This work would generate cumulated energy savings for consumers worth € 187 billion, i.e. a net saving of € 23 billion. This scenario would not be sufficient to reach the 90% CO_2 emissions reduction target, as presented in the table below.

Scenario	Results in year...	% CO_2 saved	Cumulated Investment since 2011 (€bn)	Energy cost saving (€bn)	Net saving to consumers (€bn)
Baseline	2020	5-28%	107	94	-13
	2030	14-47%	145	145	0
	2050	18-72%	164	187	23

Table 12: Key effects of BAU for buildings renovation.
Source: BPIE, Europe's Buildings Under the Microscope, 2011

Under the assumption of fast decarbonisation of the energy supply sector, the 2050 savings of the deep and two-stage scenarios correspond to the 90% which are in line with the European CO_2 reduction targets. Yet, there is a significant difference in investment costs between these two ambitious scenarios.

The cumulated investment required in the Deep scenario is €937 billion over the period 2011-2050, while a significantly lower investment of €584 billion for the two-stage scenarios is needed[104]. It must be pointed out that these investment levels come out to €15 billion a year in the two-stage scenario, and € 24 billion a year in the Deep scenario, which are much lower levels than the EC's investment projection for decarbonisation (€ 130 billion a year). This spread is explained as follows:

- The figures presented by BPIE are discounted. The undiscounted figures would be € 91 billion a year for the Deep scenario and € 71 billion a year for the two-stage scenario, which are much closer to the EC's estimates.
- The BPIE model's scope considers fabric and heating measures, but not appliances.

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[103] BPIE, Europe's Buildings Under the Microscope, 2011

[104] BPIE, Europe's Buildings Under the Microscope, 2011

- The BPIE model assumes a learning curve which brings down technology costs, for instance up to 4% per annum for nZEB solutions.

Regarding the BPIE model, the relatively high investment needs of the deep scenario are due to a rapid increase of deep renovation measures in the first decade (up to 2020). The two-stage scenario requires lower CAPEX due to a slower increase in the number of deep renovations while benefitting from a longer learning period which leads to cost reductions. The tables below present the overall investments for both scenarios, acknowledging that the two-stage scenario implies considerably lower investments and allows higher net saving for consumers[105].

Scenario	Results in year...	% CO_2 saved	Cumulated Investment since 2011 (€bn)	Energy cost saving (€bn)	Net saving to consumers (€bn)
Deep	2020	16-35%	477	487	10
	2030	42-65%	801	1,001	200
	2050	71-90%	937	1,318	381

Table 13: Key effects of 'Deep' scenario for buildings renovation.
Source: BPIE, Europe's Buildings Under the Microscope, 2011

Scenario	Results in year...	% CO_2 saved	Cumulated Investment since 2011 (€bn)	Energy cost saving (€bn)	Net saving to consumers (€bn)
Two stage	2020	10-31%	252	265	13
	2030	29-57%	446	598	152
	2050	73-91%	584	1,058	474

Table 14: Key effects of 'Two-stage' scenario for buildings renovation.
Source: BPIE, Europe's Buildings Under the Microscope, 2011

12% of the building stock is owned by the public sector, whose renovation would be paid through public financing. If, in addition, 15% of private building renovation were financed by public subsidies (whether in the form of grants, subsidised loans, structural funds, or support measures), about 25% of the total investment costs needed in decarbonisation scenarios would arise from public funding. 75% would be paid by building owners and private investors. In this case, energy savings would be sufficient to pay for loan interests.

These scenarios are not only key to reach the European targets, but would also leverage important economic, environmental and social 'co-benefits', as discussed in section 2.6. These investments lead to a range of savings for individuals and society, which could be an argument for higher public investment in building renovation.

Increased CAPEX would be required in the industry sector from 2030 onwards (see section 2.4.)

The extra investment needed for the industry sector under decarbonisation mainly regards the implementation of breakthrough technologies such as CCS, whose availability is necessary by 2030-2035 for deployment until 2050. According to the European Commission, the estimated required annual investment up to 2030 for achieving the industry sector's decarbonisation target amounts to €10 billion, a figure confirmed by a study by CE Delft. The case of industry decarbonisation, including CAPEX, is further treated in section 2.4.

105 Although this modelling does not include buildings appliances, around 80% of these are still covered by the model. No major issue regarding CAPEX has to be raised on this subject and return on investment will be much quicker than for building renovation.

It can be concluded from this section that decarbonisation, under different scenarios, would imply high levels of CAPEX. However, there are already high investment needs associated with upgrading, renewing and expanding Europe's ageing energy system. Although most scenarios throughout the available literature expect that more CAPEX would be needed for power sector decarbonisation than under BAU, this picture could change significantly with the rapidly decreasing cost of renewable energy sources, as it is the case for PV. Moreover, it appears that overall energy system costs under BAU and decarbonisation would be quite similar up to 2050, due to a shift in spending from fuel to infrastructure. This concept of shift from OPEX to CAPEX applies to the building and transport sectors as well as the power sector. Whereas investments made in the power and building sectors are expected to pay back after 2030, investments in the transport sector could be offset by fuel savings in the short term. Moreover, a high-pace decarbonisation of the economy by 2030 may result in lower overall costs by 2050 than a low-pace decarbonisation taking place between 2020 and 2030. Finally, an integrated European approach could bring down the costs associated with decarbonisation. In particular, well-chosen investments in grid infrastructure can bring down the cost of switching to a renewables-based energy system.

2.3 Energy costs

The focus of this section is the projected effects of BAU and decarbonisation on energy prices with respect to household bills and consumer purchasing power. The issue of energy prices in relation to industrial competitiveness will be discussed in section 2.4.

2.3.1 Under BAU, the increase in energy prices by 2050 is likely to be significant

In its *Energy Roadmap 2050*, the European Commission uses PROMETHEUS, a stochastic world energy model used for determining fossil fuel prices, to forecast the evolution of world prices of fossil fuels by 2050. The estimates of a scenario simulating the "Current Policies Initiative", hereby treated as BAU, are close to ones produced by other institutions (International Energy Agency, US Energy Information Administration), and predict a steady rise of the prices of oil (+49% in 2050, in constant USD of 2008, compared to 2010), gas (+85%), and coal (+48%).

As shown below, the model includes a High-Price and a Low-Price variant to take into account major uncertainties which remain to date on future fossil fuel prices, such as future global economic development and energy demand, production capacity expansion, conventional and unconventional reserves, and future potential supply disruptions. One can observe that even in the Low-Price variant, international wholesale fuel prices would at best remain constant, and remain significantly higher than in the cheap fossil fuel era. On the other hand, in the High-Price variant, international fuel prices would be 88% higher for oil in 2050 compared to 2010, 145% higher for gas, and 74% higher for coal.

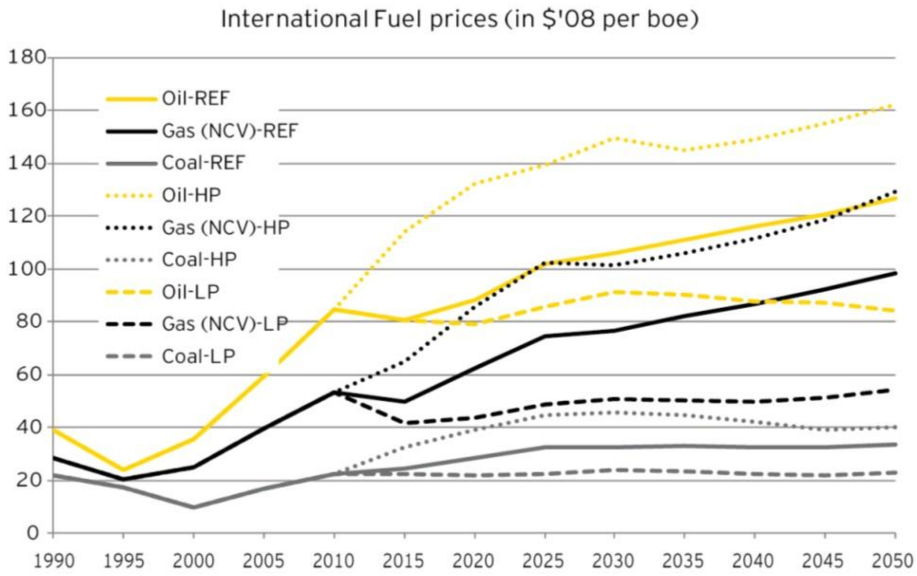

Figure 17: Evolution of international fuel prices and their sensitivity.

Source: European Commission, Energy Roadmap 2050, 2011

Another aspect of energy prices discussed in this section is retail electricity prices, and their components. To forecast these prices, the European Commission uses the PRIMES modelling system. The model simulates the response of energy consumers and the energy supply systems to different pathways of economic development and exogenous constraints and drivers. It was peer-reviewed by a group of recognised modelling experts in September 2011, which concluded that the model is suitable for the purpose of complex energy system modelling.

As expected, the results of the modelling exercise for the BAU case show that variable and fuels costs would steadily increase out to 2030 and 2050, as the price of fossil fuels increases and Europe remains heavily dependent on imports. Another finding is that fixed and capital costs would significantly increase. This is partly due to investments in renewable energy supply, but especially due to the replacement in the next 20 years of old, already fully written-off generation capacity, as well as the need to meet future increases in demand under BAU. A key source of additional electricity demand would be the sustained electrification of heating and transport, with the share of electricity predicted to rise linearly from 21% in 2010 to 25% in 2030, and to 29% in 2050.

The result of the model for BAU is that average pre-tax electricity prices would peak in 2030, with an increase of 40% compared to 2005, and stabilise thereafter[106], mostly because the necessary investments in infrastructure would have been absorbed. The updated reference scenario dating from 2013 provides a slightly different picture, since it supposes that the EU is now embarked on a more ambitious decarbonisation trajectory, with the expected implementation of most recent policies (Energy Efficiency Directive, national policies). Consequently, power generation costs increase more significantly than in the previous BAU scenario until 2020, because of higher capital costs (e.g. ENTSO-E provisions, RES 2020 investments). However, beyond 2020, prices are expected to stabilise, and even slightly decrease by 2050, as fuel cost savings materialise.

(Euro'10 per MWh)	2010	2020	2030	2050
Annual capital cost	34	45	41	39
Fixed costs	13	16	16	15
Variable costs	3	2	2	3
Fuel costs	34	39	36	33
Tax on fuels and ETS payments	1	4	9	11
Other costs (imports, recovery for RES)	2	10	6	1
Exercise tax and VAT on electricity	17	20	21	22
Average price of electricity (pre-tax)	70	136	131	124
Comparison with average price of electricity (pre-tax) based on Energy Roadmap 2011	-	-	134	134

Table 15: Cost components of average electricity price
under the European Commission's revised Reference scenario (December 2013)
Source: European Commission, EU Energy, Transport and GHG Emissions: Trends to 2050, 2013

2.3.2 Under decarbonisation, energy price benefits could materialise from 2030

Regarding fossil fuel prices, the *Energy Roadmap 2050* models a single decarbonisation scenario, simulating global action on decarbonisation, with reduction of fossil fuel demand and thus fossil fuel prices. Benefits would materialise as of now, since the increase of fossil fuel prices by 2030 under decarbonisation is less than under BAU. From 2030, fossil fuel prices would start decreasing, while they keep increasing strongly under BAU. As a result, price differences forecasted in 2050 under decarbonisation, compared to the BAU price, are -45% for oil, -50% for gas, and -38% for coal. These figures are similar to recent IEA projections that assessed the impacts of ambitious climate policies[107].

106 European Commission, Energy Roadmap 2050, 2011

107 International Energy Agency, Energy Technology Perspectives, 2010; quoted in European Commission, Energy Roadmap 2050, 2011

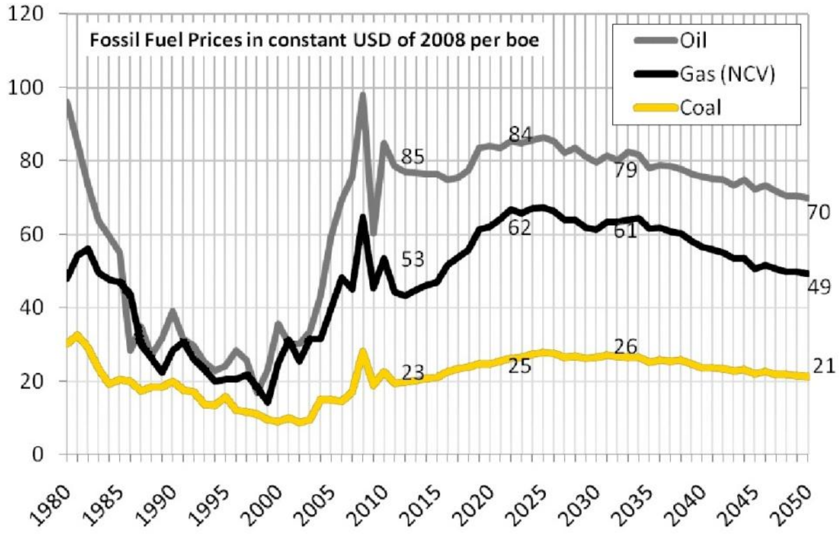

Figure 18: Fossil fuel prices in the decarbonisation scenarios with global climate action.
Source: European Commission, Energy Roadmap 2050, 2011

Europe's energy demand represents 15% of global demand, a share expected to keep decreasing in the future. In the event that global climate action does not occur and Europe acts alone on decarbonisation, prices would be close to the ones predicted in the BAU scenario described in section 2.3.1. Such a situation would make it even more compelling for Europe to reduce its fossil fuel import dependency (cf. section 2.1) and seek energy cost reductions through greater energy efficiency and cost-competitive indigenous energy sources.

Regarding retail electricity prices, the EC's PRIMES model was first applied to assess the impact of the Energy Efficiency Directive by 2020. Additional costs to the total energy system were predicted to rise by between 2.6% and 4.7% compared to BAU. The increase in energy efficiency would tend to increase electricity prices in the short term from €141/MWh to €146/MWh due to the financing of fixed costs of energy efficiency measures. However, in the long run, this increase pays off by stabilising electricity prices through a lower demand[108].

The PRIMES model was further applied in the *Energy Roadmap 2050* to forecast that in all decarbonisation scenarios, except High RES, electricity prices would rise out to 2030, and fall thereafter. As mentioned above, a large share of the increase by 2030 would already be happening in the BAU scenario, and is linked to the replacement of old generation capacity. On top of these investments, each decarbonisation scenario would follow a specific pathway requiring its own investment in energy efficiency, grid infrastructure and generation capacity. Besides the High RES scenario, the other four decarbonisation scenarios (High Energy Efficiency, Diversified supply technologies, Delayed CCS, Low nuclear) would achieve similar results in terms of average electricity prices and cost structures, and are therefore presented as one single combined, average decarbonisation scenario in the figure below. The High RES scenario differs rather significantly from other decarbonisation scenarios, and is presented on its own.

It must also be noted that the figure below presents average prices across all consumer types (industry, households, services). The breakdown specifically for households is not detailed in the source; however the detail exists for total average electricity prices (not broken down by price components) and shows similar trends for households, industry, and services.

108 European Commission, Directive of the European Parliament and of the Council on energy efficiency – Impact Assessment, 2011

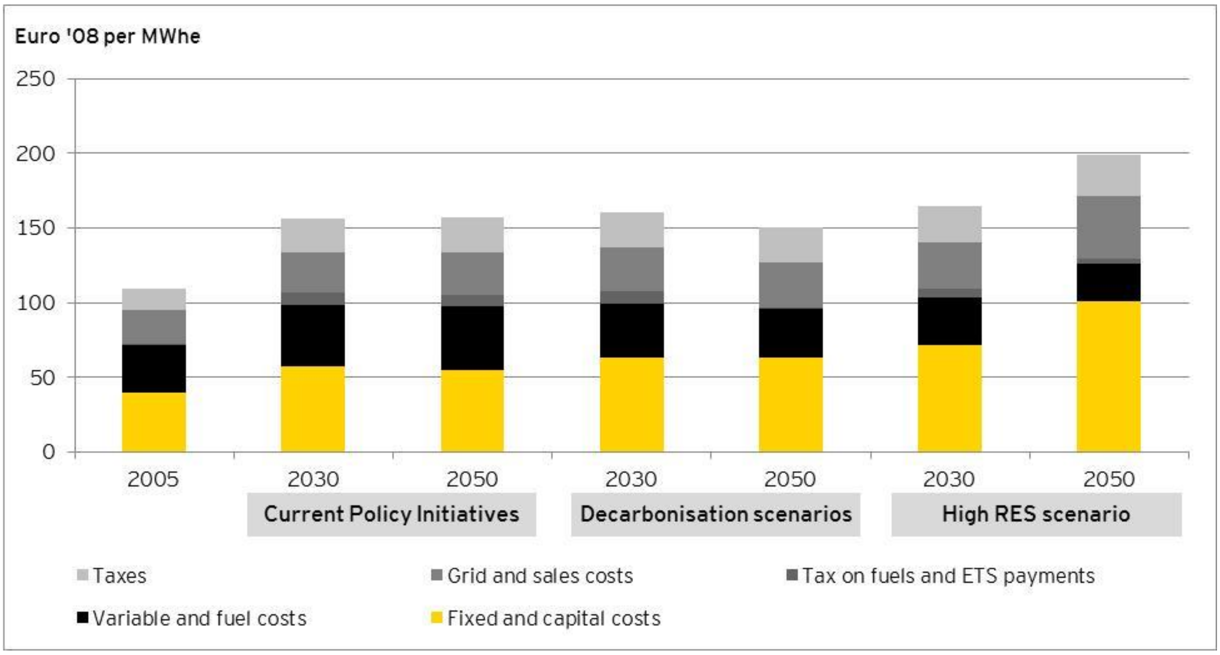

Figure 19: EU-27 retail electricity prices and their cost structure under the European Commission's 'Current Policies Initiative' (BAU) and decarbonisation scenarios.
Source: European Commission, Energy Roadmap 2050, 2011

Compared to the Current Policy Initiatives (BAU), decarbonisation scenarios result in higher fixed capital costs (+12% in 2030 and +16% in 2050 per MWhe), which are however compensated by lower variable and fuel costs. Indeed, total average electricity costs are slightly higher in 2030 in decarbonisation scenario, but slightly lower in 2050.

The results are noticeably different for the High RES decarbonisation scenario. Even though fuel costs steadily decrease until 2050 to reach a relatively low price, capital costs are high due to significant infrastructure needs, both in terms of power generation equipment and grid infrastructure. Total electricity costs are therefore significantly higher in this scenario (+27% in 2050 compared to BAU).

All decarbonisation scenarios (including High RES) rely on the assumption that electrification needs for heating and transport would grow faster than under BAU, with the share electricity predicted to nearly double by 2050 with 36-39% of total energy consumption (VS 29% under BAU). Despite this trend, electricity-efficiency gains achieved overall in the economy, as well as further reductions in the cost of renewable electricity, allow decarbonisation scenarios (outside High RES) to achieve lower electricity prices by 2050 compared to BAU.

The latest analysis by the European Commission confirms the findings of the 2050 Energy Roadmap that fossil fuel pricing is expected to increase and drive up energy costs; however, beyond 2020, costs are expected to stabilise and then slightly decrease as renewable energy replaces fossil fuels[109]. With the uncertainties surrounding such estimates over a distant future, this study interprets the EC's assessments as indications that there would be little significant energy price increase or decrease resulting from decarbonisation.

2.3.3 Energy efficiency measures implemented in the near-term could shorten the timeframe for energy price benefits

In November 2012, the EU's indicative 20% energy savings target for 2020 was adopted as part of the Energy Efficiency Directive. Currently, the EU is discussing the extension of its commitments to include formalised objectives for 2030. A study by Ecofys states that, by reducing the volume of energy consumed, efficiency typically impacts energy costs in both direct and indirect ways[110]. Past studies on the benefits of energy efficiency, including the European Commission's *Impact Assessment of the Energy Efficiency Directive*, tend to

109 European Commission, Communication on Energy prices and costs in Europe, 2014

110 Ecofys, "Saving energy: bringing down Europe's energy prices for 2020 and beyond", Dr Edith Molenbroek and Prof. Dr Kornelis Blok, 2013

underestimate these benefits by focusing on direct cost savings from lower consumption volumes. According to the study by Ecofys, these forecasts neglect indirect savings arising from lower energy demand, which may decrease electricity prices in a nearer-term timeframe.

Indirect energy savings mainly arise via three mechanisms:

1) Decreasing fossil fuel prices through lower demand: as mentioned in previous studies such as the *Energy Roadmap 2050*, the potential effect of global action for energy efficiency is significant due to the price elasticity of fossil fuels: the Ecofys study estimates that 2.40€ would be saved from falling fuel prices for every 1€ cost saving due to lower demand.

   An additional contribution of the Ecofys study is the case where Europe acts alone on energy efficiency. Even though Europe's energy demand only represents 15% of global demand and that this share is decreasing, price elasticity would still induce a fall in fossil fuel prices: for 1% energy savings in the EU, fuel prices are estimated to fall by 0.5-1%. This effect would be more significant when energy markets are regional, which is sometimes the case for natural gas. In addition, one must take into account spill-over effects from Europe's action, which would result in innovation in energy efficiency solutions for the rest of the world, in turn reducing energy demand and prices.

2) Reduction of short-term electricity spot prices through the merit order effect: energy efficiency reduces demand for relatively expensive peak-load generators, resulting in a situation where demand during peak hours would solicit cheaper generators. In addition, certain energy efficiency measures tend to shift demand away from peak hours, thus further lowering prices.

   These effects would weaken in the medium-term as electrification of transport and heating increases electricity demand, and investments in power plants are reduced along with demand. Such potential increases in electricity prices would however remain lower than they would be in a scenario without any energy savings.

3) Fewer investments required in energy infrastructure: fixed costs have already been modelled in the past, for instance as part of the European Commission's *Energy Roadmap 2050* scenarios. It has been pointed out that fixed costs in decarbonisation scenarios would increase fixed costs compared to BAU, which would however be compensated by lower fuel costs starting in 2030. The Ecofys study isolates the impact of energy efficiency measures alone to estimate the benefits as soon as 2020: if the EU meets its 20% energy savings target, the 2020 consumption level would result in 10% savings compared to 2009. This would reduce electricity prices as well as fossil fuel prices. The effect would be strongest for countries with an ageing energy infrastructure and large energy saving potential. Poland, for instance, has 57% of its installed capacity which is over 30 years old, and 30-35% of energy saving potential according to its National Energy Conservation Agency. In such a case, the IEA's estimate that 1€ spent on electricity efficiency results in 1.5€ saved on electricity infrastructure investment would be relevant.

The study by Ecofys indicates that the exact impact of such mechanisms would be country-specific, based on parameters such as the existing energy infrastructure, energy saving potential, and electrification of heating and transport. Overall, however, it is estimated that the process whereby energy efficiency results in lower energy prices can materialise as soon as 2020, and generate €1 of indirect savings from lower prices in addition to every € 1 of direct cost savings. This translates into total net savings in 2020 which are estimated at € 200 billion a year for the EU, half of which are indirect savings, compared to a BAU scenario which is the European Commission's PRIMEs model (2009 version). In 2030, net savings would reach € 250 billion a year compared to BAU. € 50 billion of these savings would be indirect. This lower share of indirect savings in total net savings is explained by the fact that energy markets and infrastructure are expected to be less strained than in 2020.

2.3.4 The recent shale gas boom is likely to create a temporary but uncertain decrease in gas prices

The "shale gas revolution" triggered in 2008 has led to a significant decrease in gas prices worldwide in 2009, and has moved US gas prices downward since then. On the one hand, US net exports of low-cost gas (currently 2.5 times cheaper than European gas and 5 times cheaper than Japanese gas[111]) are predicted to be positive from 2016[112]. Going either to Europe or to Asia, these could fuel Europe's increasing demand for gas and result in a decrease of gas market prices down to -$0.60 by 2030[113]. On the other hand, EIA's baseline "New Policies"

111 IEA World Energy Outlook, 2013
112 EIA, Annual Energy Outlook 2014
113 Deloitte, Global Impacts of LNG exports from the United States, 2013

scenario suggests that market prices would tend to increase in the long run, after the initial period of significant decrease[114]. This finding is in line with Asche et al. who modelled gas and oil prices following the gas boom, indicating that although a gas boom is followed by price differences, a long-term equilibrium leads to equal prices. This indicates that market prices are highly dependent on supply shocks – that occur at regular intervals in the gas industry - and market adjustments to these shocks[115], thus acknowledging the uncertainty surrounding these projections.

2.3.5 Energy markets would remain distorted as long as fossil fuel subsidies are maintained

Support for early-stage renewable energy deployment across the European Union generally takes the form of green taxes or feed-in tariffs. Some critics have argued that this approach has caused market distortions, whose costs are ultimately born by households. This view, however, could be balanced with the fact that conventional energy (fossil fuels and nuclear energy) have also historically benefited from subsidies and tax breaks, which keep increasing at the global scale.

On 11 May 2013, the European Commission stated in a series of non-binding documents that "*subsidies for nuclear and fossil fuels distort competition between different energy sources and increase the overall cost to society of electricity generation*". In 2011, fossil fuels in the EU indeed received €26 billion in subsidies, while nuclear energy was subsidised by an amount of €35 billion[116].

The historical and ongoing support for fossil fuel production and consumption is further documented by the following institutions:

- The International Energy Agency estimates that fossil-fuel subsidies worldwide amounted to $ 409 billion in 2010, an increase of $ 110 billion compared to 2009 due to the rebound in international energy prices[117]. This strategy generally fails to meet its objectives; for instance, in terms of poverty alleviation, only 8% of the $ 409 billion spent on subsidies in 2010 went to the poorest 20% of the population. Without further reform, the IEA predicts that these subsidies would reach $ 660 billion in 2020 (0.7% of global GDP), hence extending "*an economically inefficient allocation of resources and market distortions.*"
- The OECD has identified 550 measures which support fossil fuel production or use in its 34 member countries. A significant share of this support consists of tax expenditures (tax credits, exemptions, or reduced rates). These measures amounted to $50-90 billion a year between 2005 and 2011.
- Green Budget Germany has estimated that coal has received € 418 billion in subsidies in Germany in the period 1972-2012, while nuclear energy has received € 213 billion. During the same period, renewables have received subsidies amounting to € 67 billion[118].

Alternative energy sources thus remain far from cumulating an amount of subsidies comparable to subsidies given to conventional energy. The next section discusses the idea that subsidies to alternative energy may be phased out earlier than expected, as they grow increasingly cost-efficient compared to conventional energy sources.

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114 IEA World Energy Outlook 2013

115 Asche F., Oglend A. & Osmunden P., *Gas versus oil prices: the impact of shale gas.* Energy Policy, 47, pp. 117-124, 2012

116 Electric Light and Power, http://www.elp.com/articles/2013/11/eu-commission-fossil-fuel-nuclear-subsidies-distort-market.html, 11 May 2013

117 IEA, World Energy Outlook – IEA analysis of fossil-fuel subsidies, 2011

118 Green Budget Germany, http://energytransition.de/wp-content/themes/boell/pdf/en/GET_Graphics_en_Questions-Answers.pdf, 2013

2.3.6 Alternative energy generation is increasingly cost-competitive compared to conventional generation and can be made more so with the right policy and financial conditions

As previously mentioned in section 2.2.3, Levelised Cost of Energy (LCOE) for renewable energy has seen strong reduction since 2010, falling even below the most recent assumptions from the European Commission. LCOE analyses allow comparison of various generation technologies on a cost per kWh basis, being the discounted lifetime cost per kWh of ownership and use of a generation asset. Calculations rely on certain assumptions and local project-specific parameters (e.g. load factors, capital and operating costs, effective tax rates), causing a degree of uncertainty and cost ranges which are sometimes large.

The general trend of falling LCOE for renewable energy is confirmed by other recent studies where it appears that alternative energy sources are growing increasingly competitive compared to conventional energy sources:

- Lazard's LCOE Analysis, conducted for the United States, estimates that the most competitive renewable energy technologies, even unsubsidised (wind with range of $45-95/MWh, thin-film Solar PV with $89-99/MWh) are cost-competitive with conventional generation technologies (gas combined cycle with $61-87/MWh, coal with $65-145/MWh, nuclear with $86-122/MWh)[119]. The study points to the fact that a key challenge for alternative technologies is actually the cost and availability of capital, as the capital cost component of their LCOE is significant.
- The World Energy Council has stated that the most mature alternative energy technologies (hydro and onshore wind) are globally close to reaching parity with traditional sources, though ranges can vary significantly between regions. The LCOE range of onshore wind in Europe is $71-117/MWh, while the cost of nuclear energy is $91-147/MWh (worldwide) and the cost of gas combined cycle is $114-141/MWh in the United Kingdom[120].
- The Department of Energy and Climate Change in the United Kingdom has produced LCOE estimates for projects starting in 2013, with a 10% discount rate. These are £80/MWh for gas combined cycle, £90/MWh for nuclear, £100/MWh for onshore wind, £120/MWh for offshore wind, and £160/MWh for large-scale solar PV[121].
- RE New Economy, citing a UBS analysis, reports that most recent wind energy contracts in Texas, which account for about one fourth of US installations, put that source of energy below $50/MWh. This is due to a capacity factor reaching 50%, with nearly half of this performance occurring during peak-load hours. The same UBS research states that solar PV plant contracts in Colorado were being signed for $60/MWh, and would produce for an effective $40/MWh by the end of the contracts. These figures are to be compared with an all-in cost of gas plants of $60/MWh[122].

Besides current LCOE estimates, a study by Fraunhofer in 2012 highlights the importance of access to capital as an enabler for further cost reduction. In Spain, despite lower current LCOE and higher irradiance compared to Germany, ground-mounted PV would become competitive against the fossil fuel and nuclear energy mix in the same period as in Germany[123]. This is mainly due to current capital financing conditions in Spain, thus confirming one of Lazard's conclusions that access to capital will be a key enabler of alternative energy deployment.

Another fundamental necessity for further alternative energy cost development is the establishment of a stable, predictable policy framework securing the horizon for the industry. One of the studies which best illustrates this idea was conducted by the Lawrence Berkeley National Laboratory, in an initiative led by the US Department of Energy, which analysed the cost structure of residential solar PV in the US ($6.19/W), which is over twice the cost in Germany ($3.00/W). The key finding of this study, based on a survey of German PV installers, is that the price difference is almost entirely explained with the difference in "soft costs" (customer acquisition costs,

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119 Lazard, Levelised Cost of Energy Analysis, 2013

120 World Energy Council, World Energy Perspectives – Cost of Energy Technologies, 2013

121 DECC, Electricity Generation Costs, 2013

122 RE New Economy, Wind and solar costs challenge fossil fuels in the US, 9 December 2013

123 Fraunhofer, Levelized Cost of Electricity – Renewable Energies, 2012

installation labour costs, permitting/interconnection/inspection costs, sales taxes, balance of system costs) [124]. Module prices were indeed almost identical. The difference in soft costs is explained by:

- Much lower overhead soft costs (rent, utilities, inventory, insurance, and general administrative costs) in Germany, accounting for almost half of the soft-cost difference ($1.32/W effect);
- Lower customer acquisition costs for the German industry, due to the long-standing partnerships between installers and manufacturers, as well as a simpler value proposition, enhanced installer learning, and critical mass of word of mouth ($0.62/W effect);
- Low installation labour costs in Germany, especially due to a learning curve which has reduced installation times to half the US level ($0.36/W effect);
- Negligible permitting, interconnection, and inspection costs in Germany, due to very low permit fees and efficient processes which optimise labour costs ($0.21/W effect);
- Sales tax exemptions in Germany ($0.21/W effect).

A secondary analysis by the same institution has taken a different angle by examining project development times, economies of scale, and Chinese module market share. This analysis highlights that Chinese module market shares are the same in both countries, and do not explain the price difference. On the other hand, shorter project development times in Germany (~$0.2/W effect), and larger residential PV systems yielding economies of scale ($0.15/W effect) further explain the differences.

Both analyses by the Lawrence Berkeley National Laboratory highlight the significant difference made by learning curves, as well as a stable, predictable policy framework in alternative energy deployment.

2.3.7 Energy taxation can be an effective and relatively low-burden path towards energy efficiency and renewable energy deployment

Energy prices are made up of a number of components, which differ between countries depending on local energy resources, market conditions, network costs, taxation systems, and taxpayer opinion, In the UK, for instance, the Department for Energy and Climate Change (DECC) has estimated the breakdown of household dual fuel bill (electricity + gas) in 2013 : 47% of the fuel bill could be attributed to wholesale energy costs, 20% to network costs, 19% to other supplier costs, 9% to energy and climate change policies, and 5% to VAT[125]. A study by PwC, *Decarbonisation and the Economy*, has estimated that the average price of electricity in Denmark in 2011 of nearly €0.30/kWh (nearly twice the price in the UK) was made up of electricity production price for 44%, energy tax for 37%, and VAT for 19%[126].

The fact that the energy price components, and their respective evolutions, are largely country-specific entails the necessity of investigating particular country case studies in order to measure more precisely and empirically the interactions between energy efficiency on the one hand, and energy prices and their components on the other.

The PwC study provides an empirical analysis of the economic impact of environmental policies in five countries which have taken various paths to decarbonisation: Denmark, Sweden, Germany, UK, and the Netherlands. These countries have been largely successful in decoupling economic growth with carbon emissions (cf. section 2.5.4). Their compound annual decarbonisation rates (CO_2 per GDP) since 1970 all exceeded the OECD average of -2.0%, with -3.8% in the case of Sweden. Their respective strategies can be summarised as follows:

- Denmark: high share of wind energy, with consumers financing investments through taxes.
- Sweden: change in fuel mix with rapid development of nuclear energy; development of renewables (hydro-energy); increase of environmental taxes (compensated by reduction of labour and income taxes) to stimulate energy efficiency and renewable investments.
- Germany: increase in energy efficiency and share of renewables; renewable feed-in tariffs ultimately passed on to consumers

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124 Lawrence Berkeley National Laboratory & SunShot (US Department of Energy), Why Are Residential PV Prices in Germany so Much Lower Than in the United States?, 2013

125 DECC, Estimated impacts of energy and climate change policies on energy prices and bills, 2013

126 PwC, Decarbonisation and the Economy, 2013

- UK: change in fuel mix with rise of gas; recent development of renewables; policies focussing on Buildings Regulations, with limited energy and environmental taxation.
- Netherlands: rise of gas and recent development of renewables; energy taxes introduced to stimulate energy efficiency and use of sustainable energy.

Industry has generally been sheltered from environmental taxation, which mostly focused on households. The table below thus summarises the effects of environmental policies on domestic consumers:

Country (year since when change is calculated)	Energy price evolutions for domestic consumers by 2011				Share of environmental taxes in total tax revenue in 2011
	Change in electricity prices	Share of taxes (VAT + environmental) in the change	Change in gas prices	Share of taxes (VAT + environmental) in the change	
Denmark (1991)	+127%	79%	N/A	N/A	2.8%
Sweden (1997)	+105%	29%	N/A	N/A	4.2%
Germany (1991)	+79%	77%	+127%	32%	1.1%
UK (1991)	+50%	10%	+100%	8%	0.1%
Netherlands (1991)	+89%	76%	+179%	64%	10%

Table 16: Share of energy and environmental taxes in energy price increase and total tax revenue.
Source: PWC, Decarbonisation and the Economy, 2013

The study illustrates a variety of situations but summarises the following general conclusions:

- Environmental taxes have proven to be effective in stimulating energy efficiency and financing R&D and deployment of low-carbon energy.
- Though in some cases, environmental taxes have largely contributed to energy price increases, other significant factors (e.g. fossil fuel wholesale prices, exchange rates, infrastructure investment) play a role as well. Within the historical time span of the study, energy price increases due to taxes have been partially offset by energy efficiency gains.
- Environmental taxes remain a small part of overall taxation. Except in the case of Netherlands, they have been kept tax-neutral, compensated for instance by lower labour taxes; the overall tax burden has therefore not increased.

The UK is a singular case in that environmental taxes have remained low for all end-consumers, in an attempt to protect the competitiveness of businesses, as well as households already suffering from fuel poverty. Nevertheless, between 2010 and 2012, household dual fuel bills (electricity + gas) have increased by 13% in real terms, with 60% of the increase due to wholesale energy costs, 25% due to network costs as well as supplier operating costs and margins, and only 15% due to energy and climate change policies[127]. Since 2000, the number of fuel-poor households (spending more than 10% of their income on fuel to maintain an adequate level of warmth) has risen nearly twice[128]. These trends illustrate that EU economies, even in the case of gas-rich and low-tax UK, remain vulnerable to energy price rises, thus the need for further energy efficiency gains.

DECC has estimated the impact of recently approved energy and climate change policies, including Building Regulations, on household energy prices and bills. Though energy bills are expected to keep rising by 2020, they would be 11% lower than what households would incur in a scenario without policies, hence offsetting the cost of investing in new capacity and efficiency.

127 DECC, Estimated impacts of energy and climate change policies on energy prices and bills, 2013

128 DECC, Annual Report on Fuel Poverty Statistics 2013, 2013

It can be concluded from this section that compared to BAU scenarios, decarbonisation scenarios result in higher fixed and capital costs for energy; however these are compensated by lower variable and fuel costs. Regarding electricity specifically, total average electricity costs are slightly higher in 2030 in most decarbonisation scenarios than under BAU, and slightly lower in 2050. The effects on retail energy prices will vary depending on the nature of the decarbonisation path chosen, notably whether there is greater emphasis on energy efficiency or on renewable energy deployment. In the short run, energy efficiency can, by 2020, significantly limit the price increase predicted under BAU or even have a decreasing effect on prices depending on the country's energy context, especially when indirect savings are taken into account. Renewable energy deployment would have effects in the longer-term, with important capital investment by 2030, and energy price benefits which would materialise thereafter compared to BAU. Decarbonisation scenarios involving substantial investment in renewable energy tend to project rises in electricity prices compared to BAU. Up-to-date research, however, calls for reviewing capital cost assumptions behind such forecasts, as these costs have recently tended to decrease beyond expectations.

2.4 Competitiveness of traditional industries

Even though in 2012 70.1 % of the employed persons in the EU worked in the service sector[129], manufacturing remains a key part of the EU economy. According to the European Commission's DG Enterprise and Industry, before the present economic crisis, in 2007, manufacturing contributed to 17.1% of GDP and accounted for some 22 million jobs[130]. The EU has a target that 20% of European GDP should be contributed by industry by 2020[131]. However, the industrial base in Europe stretches beyond the core of manufacturing. When taking a wider perspective and including other productive sectors (power generation, construction) and accounting for the share of market services on which industry depends and which depend on industry (transport, communications, financial services, real estate etc.), the "servo-industrial economy" accounts for close to half of European GDP[132].

Energy is a minor part of the cost structure of European manufacturing enterprises. Most manufacturing sectors rely on drivers such as productivity and innovation to remain competitive in the global market, and would be little affected by decarbonisation. This section discusses the place of energy as part of European industrial competitiveness, especially in energy-intensive industries at the centre of the industrial low-carbon transition. As of 2011, the EU accounted for more than two-thirds of the export market for energy-intensive goods[133]. The expert contributions hereby synthesised consider the way to lead the transition while preserving the global competitiveness of these industries.

2.4.1 Decarbonisation would only affect certain parts of EU industry

Before laying out the Commission's roadmap for decarbonising the EU industry sector by 2050, it is important to place the challenge of industrial decarbonisation within the more general context of EU industrial competitiveness in the global economy. The following summarises recent European Commission contributions on the issue.

Energy prices are a rather secondary aspect of overall EU industrial competitiveness compared to other drivers

Globalisation and the integration of the emerging market countries into the world economy have offered new markets for European industry. EU exports have grown by 4.7% per year over 2000-2008, higher than the growth of industrial production. European trade performance has thus managed to hold up against intensified international competition.

To illustrate this trend, but also to illustrate the variety of situations across different industry sectors, the following table shows EU's Revealed Comparative Advantage (RCA) across industry sectors[134].

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129 European Commission, Eurostat, 2012

130 European Commission, DG Enterprise and Industry, EU Manufacturing Industry: What are the Challenges and Opportunities for the Coming Years?, 2010

131 European Commission, A Stronger European Industry for Growth and Economic Recovery, Industrial Policy Communication Update, 2012

132 European Commission, DG Enterprise and Industry, EU Manufacturing Industry: What are the Challenges and Opportunities for the Coming Years?, 2010

133 European Commission, Energy prices and costs report, 2014

134 The RCA index compares the share of an EU sector's exports in the EU's total manufacturing exports with the share of the same sector's exports in the total manufacturing exports of a group of reference countries. A value higher than 1 means that a given industry performs better than the reference group and has comparative advantage, while a value lower than unity indicates comparative disadvantage.

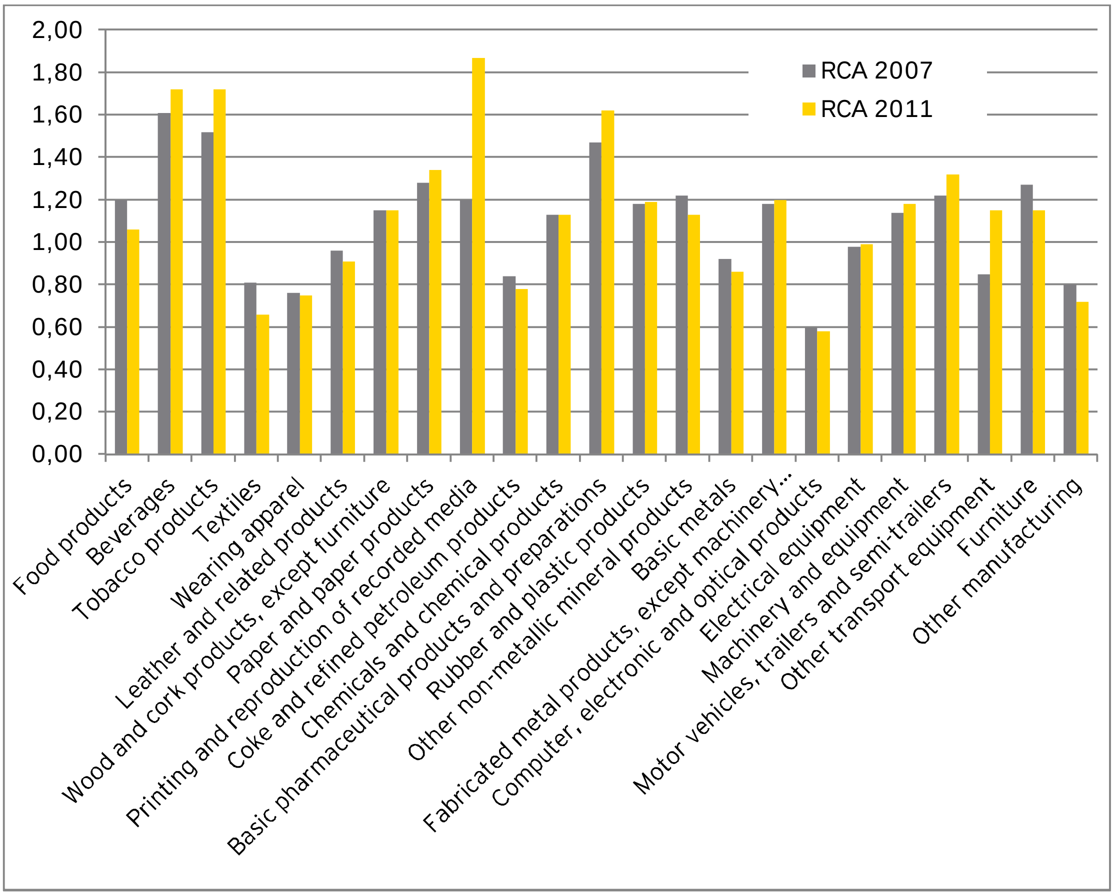

Figure 20: EU-27 Revealed comparative advantage index.

Source: European Commission, European Competitiveness Report, Towards Knowledge Driven Reindustrialisation, 2013.

According to RCA indices, 14 of the 23 manufacturing industries had comparative advantages in 2011. The trend has generally remained positive throughout the economic crisis, though some sectors have suffered from market share losses. In particular, the EU has comparative advantages in most medium-high-technology industries as well as the high-technology sector of pharmaceuticals.

Regarding the five energy-intensive industries which are the focus of this section, it can be noted that:

- The paper industry achieves RCA of about 1.3, which has slightly increased since 2007.
- The chemical industry achieves RCA of about 1.1, which has remained constant since 2007.
- The basic metals industry, which the aluminium and steel sectors are part of, has an RCA below 0.9, which has decreased since 2007.
- Other non-metallic mineral products, which the cement sector is part of, achieves an RCA of about 1.1, which has slightly decreased since 2007.

Future evolution of Europe's comparative advantage and industrial competitiveness in all sectors will mostly depend on their ability to leverage the main drivers of competitiveness described by the *2013 European Competitiveness report*:

- Labour productivity: through technological and organisational improvements, as well as other non-observable factors, labour productivity in the EU grew fastest (over 5% per year) between 2000 and 2012 in high-tech manufacturing, as well as Information and Communication Technology. Some low-tech and medium low-tech industries such as textiles and rubber and plastics also performed relatively well. However, labour productivity growth in US manufacturing in 2000-2011 was 3.5% on average, against 2.4% in EU manufacturing.
- Labour cost: this is a significant factor for firms which produce undifferentiated goods and face strong competition from low-cost regions. It is, however, not such a relevant indicator for firms which produce differentiated goods, with some room for setting prices. EU manufacturing labour costs have seen more favourable trends between 2000 and 2012 in high and medium–high-tech industries. For the overall manufacturing industry, trends in the EU and the US have been similar.

- Human capital and skills: though a comparison of the EU with other regions of the world is not available in the European Competitiveness Report, some strategic European industries rely on a high share of “high-skilled” labour (as defined by the International Standard Classification of Education), such as chemicals, pharmaceuticals, and computer, electronic and optical.
- Investment and capital formation: this is presented in the 2013 European Competitiveness report as a key driver for improving total productivity by “*bringing technology, innovation and intangibles, thereby facilitating reorganisation and adaptation of the production process to shifts in consumer demand*”. Again, though an international comparison is not available, some key European manufacturing industries rely on high investment ratios (defined as the ratio of gross fixed capital formation to value added), that is above 0.20: pulp and paper, refined petroleum, chemicals, basic metals, telecommunications, computers electronic and optical products, and transport equipment.
- Technology and Innovation: the EU is losing some competitiveness on this driver. R&D expenditures represented 1.85% of EU GDP in 2007 against 2.7% in the US, mainly due to private enterprise R&D. The spread can be observed in almost all industry sectors.

Other success factors which do not appear in the *European Competitiveness Report*, but are nonetheless important, include the regulatory landscape, costs of administrative procedures, and public infrastructure. Industrial competitiveness is a complex and multi-faceted issue which goes beyond the drivers listed above, and necessitates a deep understanding of industry-specific dynamics.

The discussion on the breadth and complexity of competitiveness drivers illustrates that energy prices make up a small share of competitiveness for EU industry overall. Though product costs make up an important share of competitiveness in some manufacturing sectors, energy prices make up a relatively small part of total product costs, with much larger shares being contributed by costs such as wages and materials.

A case study by the German Development Bank KfW further confirms this assessment. In the case of shale gas extraction in the US, KfW’s analysis shows that energy cost savings, even when significant, have little impact on industrial competitiveness. Since 2010, shale gas extraction through hydraulic fracking has resulted in a cost reduction of 30% for industrial gases for US businesses. In the meantime, German businesses have faced an increase of around 15 % for gas and 10 % for electricity. On average, this has not translated into significant cost differences between US and German manufacturing companies, due to the low share of energy costs in total costs (2.2% on average for the US, 2.3% for Germany). Overall producer price indexes have shown a similar trend since 2010 both in the USA and in Germany (each around +10%), despite an energy cost advantage in US enterprises[135].

The KfW study points out that another reason why lower energy prices, in this case, have weak effects on industrial competitiveness is that the German economy is far more energy efficient (over 4 PJ per USD billion GDP) than the US economy (over 7 PJ per USD billion GDP). Germany is indeed poor in fossil fuels and more incentivised to pursue energy efficiency.

Similarly, a study by IDDRI estimates that the US unconventional oil and gas revolution will have a small impact on US manufacturing and overall macroeconomic performance. The impacts remain limited to gas-intensive sectors, which comprise about 1.2% of GDP. Net exports from these industries have increased from USD 10.5 billion in 2006 to USD 27.2 billion in 2012, to be compared to a manufacturing trade deficit of USD 779 billion in 2012, up from USD 662 billion in 2006[136].

Energy prices remain an important driver of competitiveness for a limited number of Energy-Intensive Industries (EII)

A number of energy-intensive industries fall outside the general picture described in the previous section. Energy intensity is the value of the purchases of energy products used as fuel in the production process of the sector relative to the value of production and value added respectively. An energy-intensive industry is commonly defined as an industry whose share of energy costs relative to the value of production exceeds 3%, and whose share of energy costs relative to value added exceeds 10%.

According to the Commission’s 2011 Industrial Structure report, most industry sectors fall below this threshold. For instance, a sector like electrical machinery has 0.9% of its value of production and 2.8% of its value added spent in energy products. The sectors which exceed the threshold and can be considered as energy intensive are:

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135 KfW, Focus on Economics, N° 19, Fracking – you snooze, you lose?, 9 April 2013

136 Institut du Développement Durable et des Relations Internationales, Unconventional wisdom : an economic analysis of US shale gas and implications for the EU, February 2014

- Some sectors which are performing well in the global market, namely pulp and paper, non-metallic mineral products, and chemicals;
- Some sectors in which the EU has become less competitive, namely textiles and basic metals.

Calculations by the German Institute DIW (Deutsches Institut für Wirtschaftsforschung) based on Destatis lead to a similar picture. 92% of Germany's manufacturing industry (as measured by Gross Value Added) spends on average 1.6% of revenue on energy. On the other hand, for 8% of the German manufacturing industry, energy costs represent over 6% of total revenue. These sectors cover 1.5% of the German economy's value added[137].

As mentioned previously, the bulk of EU's CO_2 emissions from industry (power excluded) are concentrated in five EIIs (steel, cement, aluminium, chemicals, and pulp & paper) whose share of energy costs exceed the thresholds mentioned above. These sectors are also among the ones at most under threat from international competition. Besides some sub-segments of specialised and consumer chemical production, these sectors have limited room for product and service differentiation, and their products are increasingly traded globally as commodities. Even the cement industry, whose trade intensity is low, can also be under the threat of international competition for plants located in coastal areas, inland plants remaining protected by high road transport costs.

These energy-intensive industries, where product costs are key drivers of competitiveness, would be particularly sensitive to rising energy costs. A study by Climate Strategies has measured the impact of CO_2 pricing (in a scenario of € 30 / t CO_2) on these sectors' product costs. The exercise was done both for direct and indirect costs, which are costs incurred from carbon emitted upstream. Indirect costs would be significant for an electricity-intensive industry such as Aluminium.

The results are summarised in the table below, highlighting both the trade intensity (the value of imports and exports to non-EU countries over the total market size of the sector within the EU) and sensitivity to energy and CO_2 price rises in these industries[138]. Increase in total costs, as a result of a € 30 / t CO_2 price, are indeed significant for most EII sub-sectors, especially for steel, cement, and aluminium. The study also confirms the high trade intensity of EIIs, except for the cement industry which remains protected by high transport costs.

137 DIW, Staying with the leaders – Europe's path to a successful low-carbon economy, 2014

138 Climate Strategies, Carbon pricing and its future role for energy-intensive industries, 2013

Sector	Nace - 4 Code (Rev. 1.1)	(Sub)sector description	Increase in direct costs/ GVA (%)	Increase in indirect costs/ GVA (%)	Increase in total costs/ GVA (%)	Trade Intensity (%)
Steel	2710	Manufacture of basic iron and steel and of ferro - alloys (ECSC 20)	6.5	3.6	10.6	32.3
Cement	2651	Manufacture of cement	41.1	4.4	45.5	6.8
Aluminium	2742	Aluminium production	1.7	10.3	14.0	35.9
Chemicals	2412	Manufacture of dyes and pigments	0.7	1.4	3.2	43.1
	2413	Manufacture of other inorganic basic chemicals	4.8	6.0	11.9	31.7
	2414	Manufacture of other organic basic chemicals	2.5	2.2	5.4	46.3
	2415	Manufacture of fertilizers and nitrogen compounds	14.0	3.7	70.2	27.4
	2416	Manufacture of plastics in primary form	1.4	1.7	3.0	27.1
	2417	Manufacture of synthetic rubber in primary forms	>5 and <30	<5	>5 and <30	38.1
Pulp & Paper	2111	Manufacture of pulp	2.9	<5	<5	46.1
	2112	Manufacture of paper and paperboard	5.3	4.8	10.2	25.7
	2124	Manufacture of wallpaper	<5	0.9	<5	38.7

Table 17: EU industrial subsectors with high projected rise of production costs as a result of €30/t CO_2 price.
Source: Climate Strategies, Carbon pricing and its future role for energy-intensive industries, 2013

- EIIs make a sizeable contribution to EU employment and value-added and will be needed to help provide decarbonisation solutions

The five energy-intensive industries mentioned above cumulate a sizeable share of EU employment, especially when the entire supply chain (indirect jobs) is taken into account. The five sectors' cumulated contribution to employment is about 7.6 million jobs (3.5% of total EU employment), as detailed in the table below:

Industry	Direct employment in EU	Indirect employment in EU	Source
Steel	350,000	N/A	Eurofer, 2013
Cement	366,000 (breakdown between direct and indirect employment not available)		Cembureau, 2013
Aluminium	255,000	1 million	European Aluminium Association, 2013
Chemicals	1.2 million	2.4 million	Eurostat, 2011
Pulp & Paper	224,000	1.8 million	CEPI, 2010

Table 18: Direct and indirect employment in energy-intensive industries.
Sources cited in the table.

While specific value-added figures for these five industries are difficult to collect, for data from Eurostat shows that the total value-added in EU-27 of the four sectors which these industries are part of ('paper and paper products', 'chemicals and chemical products', 'other non-metallic mineral products', 'basic metals') was € 277 billion in 2010, of which € 111 billion were produced by chemicals and chemical products. These four sectors account for about 17% of value-added in EU-27 manufacturing sector.

The 2050 industrial landscape will need to be significantly different from today: traditional sectors will need to have gone through a transition whereby they play a fundamental role in decarbonising the economy by providing solutions to the power, transport, and buildings sectors, hence addressing new market opportunities and gaining global competitive advantage. This point will be detailed in section 2.4.6. , but it seems clear that these five industries can be part of the EU's decarbonisation solution by contributing towards innovation and enabling Europe's low carbon transformation through cross-sector cooperation.

2.4.2 Under BAU, European industry is set to achieve about 40% CO_2 emission reduction by 2050 compared to 1990

The industry sector emitted 18% of the EU's GHG emissions in 2005[139]. The bulk of EU's CO_2 emissions in industry (power excluded) are concentrated in the five energy-intensive industries (EII) referred to in section 2.4.1: steel, cement, aluminium, chemicals, and pulp & paper. Though there is an advantage to the fact that the required effort is concentrated in a limited number of sectors and industrial processes, deviating from BAU and decarbonising the industry sector presents the challenge that EII's are the ones at most under the threat of international competition, and those that are most sensitive to energy price rises. This explains why they have historically been protected from energy and environmental taxes levied across Europe since 1970 as part of national energy and climate change policies[140].

In the absence of a specific definition of BAU for industry in the Commission's roadmaps, the present study defines BAU on the basis of the main threads in the reviewed literature. BAU is hereby a situation where, in the coming decades:

- Industry, and in particular energy-intensive industry, continues to implement economically viable energy efficiency solutions and fuel mix changes, as part of their cost competitiveness strategy, as they have done in the past decades. This strategy had already achieved 20% CO_2 reduction in 2005 compared to 1990[141].
- Industry in the rest of the world undertakes no significant decarbonisation effort. As a result, European EII's are not asked to undertake any effort in addition to the existing policy framework. Decarbonisation of European industry remains limited to economically viable solutions, and ETS carbon prices remain low.
- Current EII production levels remain within EU borders, with slow growth. Economic effects of decarbonisation under BAU are therefore neutral.
- Investment and R&D in breakthrough technologies remain at current levels and their deployment by 2050 remains limited.

As a starting point, it is important to agree on the quantitative scale of CO_2 reduction possible under BAU. On one hand, the European Commission's *Roadmap for moving to a competitive low carbon economy in 2050* foresees 40% CO_2 reductions by 2050 compared to 1990 under BAU. The revised reference scenario dating from December 2013 estimates 44% CO_2 reductions by 2050 compared to 2005[142].This figure, however, is not detailed by sector. The present study thus assumes the forecast to be the same across all sectors, including industry.

Each EII has recently produced its own 2050 roadmap for moving to a low carbon economy. These roadmaps study the possibilities for further carbon abatement using economically viable technologies, and lay out the following decarbonisation perspectives under BAU by 2050, compared to 1990:

- Cement: CEMBUREAU, the European Cement Association, estimates that a 32% reduction can be achieved, mainly by pursuing efforts in kiln efficiency, fuel mix change, clinker substitution, and novel

139 European Commission, A roadmap for moving to a competitive low carbon economy in 2050, 2011

140 PwC, Decarbonisation and the Economy, An empirical analysis of the economic impact of energy and climate change policies in Denmark, Sweden, Germany, UK and the Netherlands, 2013

141 European Commission, A roadmap for moving to a competitive low carbon economy in 2050, 2011

142 European Commission, EU Energy, Transport and GHG Emissions : Trends to 2050, 2013

cements[143]. This is under the assumption that the same amount of cement is produced in 2050 as in 1990.

- Chemicals: CEFIC, the European Chemistry Industry Council, estimates that CO_2 emissions from the chemical industry can be reduced by 15 to 25% in 2030 compared to 2010, through energy efficiency improvement, fuel mix change, N_2O abatement and decarbonisation of electricity production. This is in addition to 50% reduction already achieved between 1990 and 2010. Further reduction by 2050 would require breakthrough technologies[144]. This is under the assumption of limited growth in all chemical sub-sectors by 2050, as CEFIC projects partial relocation and lost growth of the chemical industry due to the existing policy framework, in a context where the rest of the world undertakes no significant action.
- Steel: Eurofer, the European Steel Association, assuming 0.8% annual growth of EU steel production by 2050, estimates that CO_2 emissions from the steel industry can be reduced by 9%, mainly by further shifting from basic oxygen steelmaking to electric arc furnace, and achieving further efficiency gains[145].
- Aluminium: according to the European Aluminium Association, since 1990, the aluminium industry has reduced its CO_2 equivalent emissions by 53% for its primary production and by over 90% for PerFluorocarbon (PFC) emissions from the electrolytic process[146]. The Association roadmap, however, makes little distinction between BAU and decarbonisation, as it does not put forward the need for significant breakthrough technologies: a 79% CO_2 reduction target can be achieved by the sector by reducing direct emissions with technological enhancements which would occur by 2030, and by reducing indirect emissions from electricity consumption. This second point, however, partly depends on the EU's ability to decarbonise its power sector as set out in the Commission's roadmap.
- Pulp & Paper: CEPI, the Confederation of European Paper Industries, estimates that a 40% reduction of direct emissions is possible with best available technologies, fuel mix change, and infrared dryers[147]. When accounting for indirect emissions (transport, electricity consumption), a 50-60% total reduction is deemed possible, assuming the EU is able to decarbonise its power and transport sectors as set out in the Commission's roadmap. These assessments are made under the assumption that annual growth of the pulp & paper industry by 2050 would be 1.5%, in line with EU GDP growth.

It can be concluded that EII's, which are at the forefront of the necessary GHG reduction effort for industry, have responded to the EC's Roadmap by assessing the potential of best available technologies that can be foreseen under BAU, in a context of global competition where the rest of the world also stays under BAU. These responses present a diversity of situations, with some variations around the 40% baseline:

- In the case of cement and pulp & paper, BAU assessments come close to the EU prediction.
- In the case of chemicals and aluminium, the 40% reduction level under BAU is already achieved and even exceeded, and the challenge is now the technical achievement of the 83-87% reduction target.
- In the case of steel, the 40% reduction target is deemed infeasible by the Association under BAU.

This section has described the characteristics of BAU and its effects. Despite the specificity of each sector, a 40% carbon reduction for industry overall under BAU appears realistic, with neutral economic effects. The next section describes the European Commission's position on more concerted efforts to decarbonise of the industry sector and its possible effects.

[143] CEMBUREAU, The role of Cement in the 2050 Low Carbon Economy, 2012

[144] CEFIC, Ecofys, European Chemistry for Growth – Unlocking a competitive, low carbon and energy efficient future, 2013

[145] Eurofer, A Steel Roadmap for a Low Carbon Europe in 2050, 2013

[146] European Aluminium Association, Lightening the Load – An aluminium 2050 roadmap to a low-carbon Europe, 2012

[147] CEPI, 2050 Roadmap to a low-carbon bio-economy, 2011

2.4.3 The Commission has set a 83-87% CO_2 reduction target by 2050 compared to 1990 for industry, with safeguards to protect competitiveness of EIIs

Under its decarbonisation scenario, the European Commission's *Roadmap for moving to a competitive low carbon economy in 2050* indicates the following decarbonisation objectives for industry below 1990 level:

- 20% by 2020, a target well under way;
- 34–40% by 2030;
- 83-87% by 2050.

The path proposed by the roadmap includes further implementation of advanced energy-efficiency industrial processes and equipment, increased recycling, and abatement technologies for non-CO_2 emissions. In addition, breakthrough technologies such as carbon capture and storage would also need to be deployed on a broad scale starting in 2035. This will require an annual investment of over €10 billion, according to the European Commission. These suggested routes are however subject to caution by the Commission itself for two reasons:

1. Solutions are sector-specific, and the Commission suggests cooperating with each sector to develop specific roadmaps. This is the subject of the following section, which will present the response of the five EIIs which concentrate the bulk of EU industrial CO_2 emissions.
2. In the absence of stronger global climate action, the Commission acknowledges that the decarbonisation investments needed may curtail the competitiveness of EU energy-intensive industries. In such a scenario, existing safeguards would need to be kept in place in order to maintain EII production within EU borders.

This second point was further confirmed on 22 January 2014, when the Commission released its *Policy Framework for climate and energy in the period from 2020 up to 2030*, with an accompanying *Impact Assessment*. Regarding the industry sector, the GEM E3 model takes a step further compared to previous EC reports in terms of forecasting the impact of decarbonisation on the competitiveness of energy-intensive industries. The results of the modelling of 40% decarbonisation by 2030 (in line with the decarbonisation scenarios in the 2050 Roadmap) can be summarised as follows[148]:

- In a scenario of effective international action, EU energy-intensive industries could potentially benefit from the decarbonisation path, and increase their output, as well as their relative global market shares.
- Without effective international action, the carbon price differential between the EU and other world regions would increase, with negative impacts on competitiveness. In such a scenario, the *Impact Assessment* recommends limiting production losses for energy-intensive sectors, via a system of continued free allocation of carbon credits, to be periodically reviewed.

The Commission thus intends to protect EU's energy-intensive industries, a position defended strongly by the EIIs themselves. The employment and value-added contributions made by these sectors are key grounds for this stance, noting also concerns that without these industries, macroeconomic decline and social unrest may result from rising unemployment in rural and semi-urban areas that are dependent on them - thereby increasing the economic gap with service-based metropolitan areas.

EIIs also argue that, in the event that these industries are lost to competing region, the world would run the risk of increased CO_2 emissions from the displacement of relatively CO_2-efficient EU industrial output towards less CO_2-efficient regions (so-called 'carbon leakage'). These claims are starting to be more closely examined as it seems such risks may vary substantially between sectors and sub-sectors.

2.4.4 Industry Associations have responded to the Commission's 2050 target with caution

Section 2.4.2 referred to the sector-specific roadmaps that have been produced by EII associations in order to assess the technical and economic feasibility of the CO_2 reduction target. The industry groups have put forward their CO_2 reduction achievements over the last 20 years, driven by the need to remain competitive in the global economy. Regarding future CO_2 emission reduction efforts, the roadmaps generally concur that that:

148 European Commission, Impact Assessment Accompanying the Communication "A policy framework for climate and energy in the period from 2020 up to 2030", 2014

- Some economically viable abatement options remain in sight, with further implementation of Best Available Technologies over the next 40 years, as discussed in the BAU case in section 2.4.1. Industry groups intend to pursue such solutions as they have done in the past, as part of their global competitiveness strategy. With these measures alone, however, EIIs would remain far from achieving the 80% reduction target by 2050 compared to 1990 levels.
- Given the global competition environment, and in a scenario where the rest of the world does not undertake CO_2 pricing effort similar to the EU, there is generally little possibility to pass rising energy or CO_2 costs through to customers, except for some industrial sub-segments such as inland cement production and specialised chemicals.
- Further abatement of CO_2 emissions would require economically viable technological breakthroughs, such as Carbon Capture and Storage, to be available by 2030, for the industries to be in line with 2050 emission targets while remaining competitive in the global economy.

As discussed in section 2.4.1, the main distinction between BAU and decarbonisation in industry is the implementation of breakthrough technologies, as market forces already tend to encourage industries towards implementing available energy efficiency technologies. The following table summarises the position of each industry group on the potential scale of decarbonisation for their sector.

<table>
<tr><th rowspan="2">Industry</th><th colspan="2">Decarbonisation potential by 2050 below 1990</th><th rowspan="2">Main assumptions</th></tr>
<tr><th>without breakthrough technologies</th><th>with breakthrough technologies available by 2030</th></tr>
<tr><td>Steel</td><td>9%</td><td>56% (combining economically unviable solutions and CCS breakthrough technology)</td><td>► EU steel production growth of 0.8% per annum</td></tr>
<tr><td>Cement</td><td>32%</td><td>80%</td><td>► Cement production constant from 1990 to 2050</td></tr>
<tr><td>Aluminium</td><td>79%</td><td>79%</td><td>► EU power sector successful in decarbonising as set out in the Commission roadmap
► Non-emitting technologies for metal production available by 2030
► EU aluminium consumption nearly doubles between 2010 and 2050</td></tr>
<tr><td>Chemicals</td><td>35% (below 2010)</td><td>90% (below 2010)</td><td>► Global climate action
► Growth of chemical industry by 200% between 2010 and 2050</td></tr>
<tr><td>Pulp & Paper</td><td>50-60%</td><td>80%</td><td>► EU power and transport sectors successful in decarbonising as set out in the Commission roadmap
► Global climate action
► Annual growth of the industry 1.5% per annum</td></tr>
</table>

Table 19: Economic and technical possibilities of decarbonisation for EIIs with and without breakthrough technologies. *Source: European Industry Associations*

The picture emerging from the industry group roadmaps is that it would be technically possible to maintain EIIs within EU borders even while achieving, on the whole, a total industry decarbonisation target nearing 80%. The economic effects projected in such a scenario are in fact rather positive, with stable growth of output, and even strong growth in the chemical sector. These assessments, however, hinge on coordinated global climate action (especially in the cases of chemicals and pulp & paper) and on the availability of breakthrough technologies by 2030. The following section discusses the prospect of the latter assumption.

2.4.5 The potential exists for breakthrough technologies to enable over 80% reduction in EII's by 2050

A study produced by CE Delft, commissioned by CAN Europe in 2010, assesses the technical potential and economic feasibility of breakthrough technology deployment by 2030 in three industrial sectors: cement, steel, and paper. These breakthrough technologies in pilot phase would reach market maturity by 2030 or earlier, enabling emission reductions of 80% or more[149]. The sector-specific findings can be summarised as follows:

- Steel: the most promising technology is the Hisarna coke free steelmaking process, potentially enabling CO_2 emissions reduction by 80% in combination with CCS (20% without CCS). The technology is expected to reach market maturity by 2025. Other promising technologies also exist, with fastmelt process of direct reduction deployed in the market since 2010, with 55% CO_2 reduction potential if combined with CCS. Top gas recycling with CCS is currently in the pilot phase and could be deployed from 2020, resulting in 50% CO_2 reduction.
- Cement: magnesium oxide cement clinker has the ability to become a net CO_2 absorber or reduce 100% of emissions. Oxyfuel firing with CCS, on the other hand, has a 90% reduction potential. Both technologies would likely become commercially available by 2025.
- Pulp & Paper: the efficient use of by-products (e.g. black liquor) generated in the pulp making process can capture and store CO_2 emissions, making net emissions of the paper sector even negative. The technology is expected to reach commercial maturity by 2030, possibly earlier.

Completing these findings, the pulp & paper industry has recently demonstrated not only the feasibility of deploying breakthrough technologies by 2030 (earlier in some cases), but also its economic priority in terms of competitiveness in the global market, as the industry strives to save on energy, water and materials in an increasingly resource-constrained world. CEPI has indeed set up the "Two Team Project" in 2013 to identify eight breakthrough technologies to be pursued by the industry in order to remain at the forefront of innovation in the global market. These breakthrough technologies combined together could make the pulp & paper industry CO_2 neutral, but also nearly water neutral (hence significantly reducing the cost of effluent treatment) and less material-intensive[150].

In order to enable the deployment of these breakthrough technologies in the most CO_2-intensive industries, the study by CE Delft recommends an annual investment of € 10 billion for further research, development and deployment. This amount corresponds to the estimation of the European Commission's *Roadmap for moving to a competitive low carbon economy in 2050*. In order to finance this amount, the recommended course of action is to mobilise a portion of the auctioning revenues of the EU ETS.

Some uncertainties nevertheless remain following the literature review on the potential deployment of breakthrough technologies, in particular:

- The potential of breakthrough technologies in the chemicals sector, not covered by the CE Delft report;
- The actual pace of research and development which would take place, on which depends the availability of the technologies by 2030;
- The availability of financing;
- The commercial potential of reusing the captured carbon, unknown at this stage.

149 CE Delft, Technological developments in Europe: a long-term view of CO2 efficient manufacturing in the European region, 2010

150 CEPI, The Two Team Project, 2013

2.4.6 The way forward: decarbonisation raises market opportunities for traditional industries

As mentioned previously, it is in the interest of the European Union to protect its industrial basis within its borders for macroeconomic reasons, as well as climate change mitigation purposes related to its relatively CO_2-efficient industrial processes.

As a complement to this rather defensive vision, a forward-looking approach would consist of leveraging decarbonisation opportunities for energy-intensive industries. Decarbonisation would induce deep transformations of the economy and the power, transport, and buildings sectors, resulting in demand for low-carbon solutions and new products provided by EIIs. Though the scale of this economic opportunity has not been quantitatively measured to date, all energy-intensive industries have identified such prospects for growth and global competitiveness by achieving first-mover advantage, as global demand rises for new products in an increasingly resource-constrained world.

In their respective roadmaps, industry groups have indeed put forward their potential contributions towards decarbonisation, summarized in the table below:

Industry	Some proposed contributions towards EU's decarbonisation
Steel	► Weight reduction of cars and trucks ► Wind power ► Rubber-enforcing steel structure for tires ► Efficient motor systems
Cement	► Smart buildings and sustainable construction (e.g. thermal efficiency) ► Recycling concrete ► Recarbonation (CO_2 trapping)
Aluminium	► Car weight reduction ► Intelligent building facades ► Increasing recycling rates (currently 60% aluminium recycled in packaging)
Chemicals	► Energy efficiency of buildings (e.g. insulation, lighting, smart windows) ► Polymer electrolyte fuel cells in electric cars ► High Temperate Superconductors for extension of grids ► High performance packaging materials ► Renewable energy (wind, advanced solar cells)
Pulp & Paper	► Fibre-based insulation ► Biofuels ► Bio-based construction materials ► Energy from biomass, bio-refinery

Table 20: Market opportunities arising from decarbonisation for EIIs.
Source: European Industry Associations

The CEPI Two Team Project, led by the Pulp & Paper industry, estimates that in addition to saving costs, the identified breakthrough technologies can significantly add value to the industry, hence contributing towards its objective of increasing added value by 50% by 2050 and gaining strong competitive advantage in the global market. In particular:

- Deep Eustetic Solvants: in addition to delivering significant CO_2 savings, chemicals produced as by-products of the innovative process can generate a value increase of 200-300 euros per tonne of wood.
- Flash condensing with steam: using steam for lignin-based bonding would enable the production of a new range of stronger, lightweight products, offering savings to packaging manufacturers. Other new

products may include nonwovens, moulded products, composites and multi-layered products, and lightweight construction material for use in building.

- Production with 100% electricity: the side-effect of this process would be for the industry to act as an energy storage player. It could produce Thermo-Mechanical Pulp and hydrogen, and sell these by-products, for instance to the chemical industry, or sell electricity on site when electricity prices are high.
- Functional Surface: besides costs savings from lower resource volumes (raw materials, water, energy), the process would allow enhancing the performance and features of paper products, hence adding more value.

Furthermore, according to the International Council on Clean Transportation (ICCT), the pulp & paper industry could enjoy further opportunities through EU's decarbonisation by mobilising and valuing its share of wastes and residues available for re-use, estimated at over 220 million tonnes per year, currently and in 2030[151]. If that resource were entirely dedicated to biofuels, it could supply 16 per cent of road transport fuel in 2030, generate up to €15 billion of additional annual revenues for the pulp & paper industry and the rural economy annually, and create up to 300,000 additional jobs by 2030.

The pulp and paper industry has thus gone relatively far in identifying the feasibility of breakthrough technologies, as well as the cost reduction and revenue generation opportunities arising from EU's decarbonisation. This forward-looking approach has yet to be generalised and implemented in order to place traditional industries sustainably into the decarbonised 2050 economic landscape.

With the "servo-industrial" economy accounting for close to half of EU's GDP, the ambition of the European Commission is to maintain a strong industrial basis in the decades to come. Most industrial sectors would be little affected by decarbonisation initiatives and potential effects on carbon and energy prices, as their priority is to enhance their key global competitiveness drivers (labour productivity, labour costs, skills, capital formation, technology and innovation). Energy-intensive industries (EIIs), are likely to be most affected by decarbonisation, but can also make some of the most important contributions to it. The European Commission has proposed an 80% carbon reduction target for these industries, which they have responded to with a commitment to continue pursuing energy efficiency, as part of their global competitiveness strategy. Some of them (aluminium, pulp & paper) have expressed optimism regarding the prospect of reaching the reduction target in an economically viable way, while others (steel, cement, chemicals) state the need for major technological breakthrough, such as CCS, to be available by 2030. Beyond the question of whether decarbonisation is technically feasible, all five EII Associations have identified the route as an opportunity for expanding their business by providing new products to all economic sectors (power, building, transport, industry) and supporting them in reaching their decarbonisation targets.

Prospects thus exist for the development of breakthrough technologies and the rise of business opportunities from decarbonisation, altogether potentially resulting in a favourable decarbonisation equation for industry. However, uncertainty remains at this stage on these perspectives, as well as on the extent of climate action in other industrialised regions of the world.

151 ICCT, Availability of cellulosic residues and wastes in the EU, 2013

2.5 Aggregate effects on GDP and employment

2.5.1 The European Commission's analysis estimates that decarbonisation would have net positive effects on GDP growth and employment compared to BAU

The EC's *Roadmap for moving to a competitive low carbon economy* projects that on a 2020 horizon, the effects on GDP of putting the EU on a long-term decarbonisation pathway would be limited. If access to international carbon credits is allowed, GDP growth is projected to reduce by around 0.2%-0.5% compared to BAU. On the other hand, if the EU uses additional revenues from auctioning CO_2 emissions allowances in EU ETS sectors and raises tax revenues from the non-ETS sectors, reductions in labour costs would improve overall macroeconomic results leading to 0.4%-0.6% increase in GDP by 2020.

Projected impacts in the EC's January 2014 Impact Assessment for the period 2020 to 2030 for a scenario with a 40% GHG reduction compared to the reference scenario are estimated at a loss of 0.1% to 0.45% of GDP if only a GHG target is used, without separate targets for renewable energy or energy efficiency. The range relates to the approach to carbon pricing in the non-ETS sectors and the use of auctioning under ETS. Scenarios with more ambitious EE policies result in 0.46% to 0.55% GDP increases in 2030 as compared to the EC's reference scenario, or 0.53% in the case of a 45% GHG target with complementary efficiency and renewables efforts. Overall the impact on economic growth of achieving a 40% GHG reduction target, with or without additional EE policies or RES targets is limited, with impacts by 2030 expected to be less than 1% of GDP (in either direction)[152].

As for a longer-term assessment, the Commission acknowledges in its *Energy Roadmap 2050* the difficulty of going beyond a qualitative assessment for the long-term perspective of 2050. BAU has higher fuel costs than decarbonisation pathways but will require lower levels of investments in new technologies. On the other hand, decarbonisation scenarios imply higher investment in equipment, renewable energy sources and energy efficiency while lowering OPEX on fossil fuels. The Commission foresees that the CAPEX investments required under decarbonisation could generate further GDP growth and technologies to be exported worldwide if the EU maintains a front-runner position on low carbon technologies. Thus, decarbonisation scenarios that rely on energy efficiency measures and investments in renewable energy technology have the potential to generate jobs and economic growth.

A recent report by CE Delft[153] points out that while the EC's impact assessments is fairly extensive, it does not contain a specific discussion on impacts for SMEs, which could potentially benefit from more ambitious climate policies by providing innovative low carbon solutions.

Regarding employment, the overall effects analysed in the EC's *Roadmap for moving to a competitive low carbon economy* yield modest net positive impacts from decarbonisation policies. Overall impacts would be higher if industries follow a price-setting strategy that does not include opportunity costs of free allocation (i.e. they do not add the cost of ETS allowances that they have received for free to their prices). The net job creation estimated in the Commission impact assessment is an increase of 0.7% by 2020 compared to BAU, representing around 1.5 million jobs by 2020.

The 2014 Impact Assessment covering the period 2020 to 2030 projects that compared to the reference scenario, a decarbonisation scenario with a 40% GHG reduction by 2030 would create an estimated 0.7 million additional jobs and that a decarbonisation scenario with a 40% GHG reduction, ambitious EE policies and a 30% RES target would generate 1.25 million additional jobs in 2030.[154]

The Commission's roadmaps do not address the social dimension of decarbonisation in a broad manner, i.e. treating all the interdependencies between sectors such as energy, transport, industry and agriculture. However, it has commissioned a study from Cambridge Econometrics on *Employment effects of selected scenarios from the Energy roadmap 2050*[155], which provides more insight into possible job creation from decarbonisation. This study presents the quantitative results of running the various Commission scenarios in two macro-sectoral models: E3ME and GEM-E3. Both models have an extensive track record of being applied

[152] European Commission, EU Energy, Transport and GHG Emissions : Trends to 2050, 2013

[153] CE Delft, Review of the Impact Assessment for a 2030 climate and energy policy framework, 2014

[154] European Commission, Impact Assessment Accompanying the Communication A policy framework for climate and energy in the period from 2020 up to 2030, 2014

[155] Cambridge Econometrics, Employment effects of selected scenarios from the Energy Roadmap 2050, 2013

for policy analysis and impact assessment at the European level, particularly with regard to energy and climate policy.

As presented below, both models predict a net employment increase from decarbonisation compared to BAU by 2050, across all the sectors of the economy. This increase is more significant in the E3ME model than in the GEM-E3 model. The range of outputs is an increase in employment of 0 to 1.5% depending on the scenario used. On average, results with the decarbonisation scenarios suggest they could lead to an increase of around three million jobs compared to BAU by 2050 (E3ME model). Job creation would be largest in the construction sector and sectors that produce energy-efficient equipment. The higher use of biofuels should also induce an increase in agricultural employment. Employment in the power sector could either increase or decrease slightly, depending whether or not Europe engages on a pathway that would imply a higher share of RES. The 2014 Impact Assessment anticipates that underlying structural changes would have a relatively small positive or negative impact on overall employment, depending on the assessment methodology, but that significant shifts in employment among or within sectors is expected[156].

Regarding GDP, both models (E3ME and GEM-E3) acknowledge that the impact of decarbonisation would be minor by 2050, either positively or negatively.

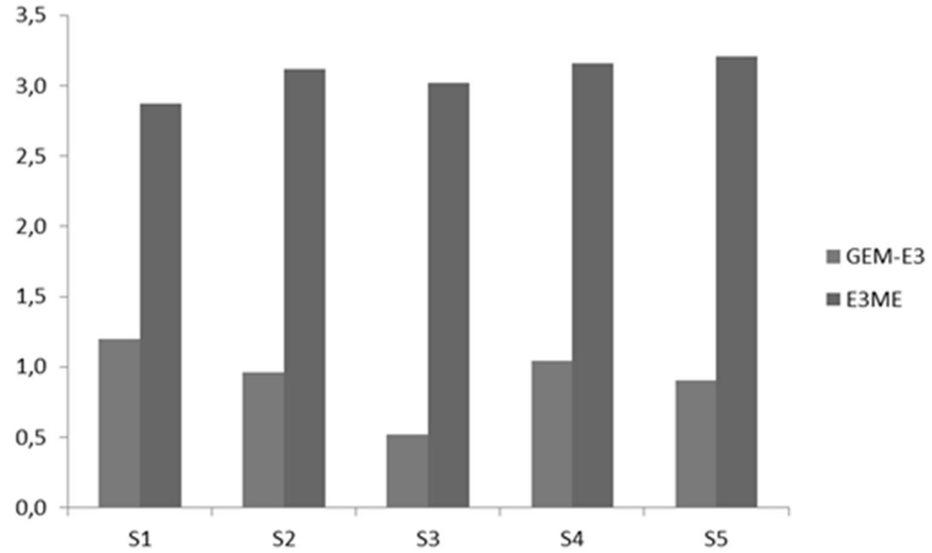

Figure 21: EU-28 absolute change in employment from BAU in 2050 (millions).
Source: Cambridge Econometrics, Employment effects of selected scenarios from the Energy Roadmap 2050, 2013

Both of these models have a broadly similar scope. However, they embody quite different views about how the economy functions, which explains the important differences between the findings of the two models. For instance, it appears in Cambridge Econometrics' study that assumptions on baseline rates of GDP growth and labour intensity of new technologies (jobs per GW capacity) have a relatively low sensitivity. On the other hand, recycling options of carbon tax revenues, fossil fuel prices and investment crowding out effects present a relatively high sensitivity.

[156] European Commission, Executive Summary of the Impact Assessment for A policy framework for climate and energy in the period 2020 up to 2030, 2014

2.5.2 Other models reviewed agree that net impacts of decarbonisation on GDP growth and employment would be limited but net positive

Models other than the EC's roadmap tend to confirm that GDP and employment effects of decarbonisation would be net positive. Some models contribute to filling certain gaps in the EC's roadmap, especially regarding prospects beyond 2020.

The ECF Roadmap estimates GDP growth under decarbonisation as being 2% above BAU and employment being 1.5% above BAU by 2050, though with substantial differences between sectors

An assessment of the macroeconomic impact of European decarbonisation objectives towards 2050 was performed in the ECF's 2050 Roadmap. According to ECF's projections:

- Annual GDP growth rates are 0.1% lower in decarbonisation scenarios than under BAU in the early years, resulting in a 0.5% lower GDP by 2015. This trend is slowly reversed starting from 2015, ultimately resulting in a GDP that is 2% higher than under BAU by 2050. It should be noted that, given the uncertainties in long-term projections, this difference is not significant. Sensitivity analyses predict that a doubling of fossil fuel prices reduces GDP in decarbonisation scenarios by 0.3 to 0.5% less than it would under BAU over 40 years, underlying the benefits of a decreased dependency on fossil fuels. If electricity costs were to be 25% higher than projected, GDP would be around 1% lower than projected by 2050. This would bring the GDP of decarbonisation scenarios to the same level as under BAU.
- The low-carbon transition has a limited net impact on overall employment, but differences across sectors are significant. Sectors related to clean technology would benefit most and energy-intensive and fossil fuel industries would decline by the most. By 2020, the total employment stock in decarbonisation scenarios is 0.06% below BAU. However benefits would materialise from 2020 onwards, and by 2050 the total employment stock in decarbonisation scenarios would be 1.5% higher than under BAU. The employment in sectors related to decarbonisation, especially those related to renewable installations, energy efficiency measures and equipment manufacturing, would increase by 420,000 jobs through decarbonisation. On the other hand, around 260,000 fewer jobs would be required in the traditional fossil fuels sector.

The transition towards more RES would foster job creation in the renewables sector

The energy sector employed 2.5 million people directly across EU-28 in 2013, which represents about 1% of total employment in all sectors. Among these, 0.6 million people are directly employed in power generation, 0.5 million in transmission and distribution of electricity, and about 140,000 in transmission and distribution of natural gas[157].

The transition towards a low-carbon economy would have a significant impact on employment numbers in the energy sector if Europe takes a decarbonisation trajectory that relies on a higher share of renewables in its energy mix. The nature of jobs in the power sector is also likely to change with a shift from conventional power sources to RES.

The development of RES has already led to an important job increase from 230,000 in 2005 to 550,000 in 2009 in the renewables sector[158]. The *EmployRES* report[159], funded by the European Commission, assesses that achieving a 20% share of renewables in final consumption could provide a net effect of about 410,000 additional jobs by 2020 and up to 656,000 additional jobs by 2030.

A study by the European Wind Energy Association (EWEA), *Green Growth*[160] provides an estimation of job creation in the onshore and offshore wind energy sector by 2030. EWEA expects 230 GW of wind energy to be operating in the EU in 2020 and 400 GW by the end of 2030, with an increasing share of offshore installations.

157 Cambridge Econometrics, Employment Effects of selected scenarios from the Energy roadmap 2050, 2013

158 European Renewable Energy Council, http://www.erec.org/statistics/jobs.html

159 European Commission, DG Energy and Transport, EmployRES – The impact of renewable energy policy on economic growth and employment in the European Union, 2009

160 EWEA, Green Growth – The impact of wind energy on jobs and the economy, 2012

Wind energy employment in the EU is expected to increase from 238,000 direct and indirect jobs in 2010 to 520,000 in 2020, and 794,000 by 2030.

According to the study by Cambridge Econometrics referred to in Section 2.5.1, employment in fossil fuel sectors would decrease across all decarbonisation scenarios examined in the EC's *Energy Roadmap 2050*. Employment related to other power technologies depends on their deployment suggested by the different scenarios, as illustrated in the table below.

	High Efficiency	High RES	Diversified technologies	Low CCS	Low nuclear
Coal fired	-31.5	-29.8	-39.7	-41.0	-40.6
Oil fired	-55.9	-52.1	-51.1	-52.3	-40.9
Gas fired	-23.9	-27.8	-25.1	-22.7	-18.7
Nuclear	-10.8	-36.5	0.4	11.0	-48.5
Biomass	17.5	10.0	14.1	18.4	12.3
Hydro electric	4.2	-15.5	0.1	1.8	0.3
Wind	25.7	62.6	29.3	35.3	33.5
PV	39.0	120.2	45.0	53.3	42.0

Table 21: Evolution in employment per power generation sector and per scenario, 2015-2050 (% changes from CPI).
Source: Cambridge Econometrics, Employment Effects of selected scenarios from the Energy roadmap 2050, 2013

Decarbonisation would have a net positive impact on employment and GDP in the transport sector

The European transport sector has specific economic characteristics that can be considered as presenting opportunities for the EU in the transition to a low carbon economy:

- Vehicle production has a long supply chain that is dominated by European suppliers.
- Europe is a net exporter of vehicles (and of vehicle designs) to other world regions.
- The value chain is more labour-intensive than the oil supply chain.

In its *White Paper on Transport*, the European Commission examined four policy initiatives that need to be considered for the transport sector. Policy option 1 assumes that there is no additional EU action regarding the decarbonisation of transport (considered as BAU in the present study). In this case (i.e. under BAU), total employment in the transport sector is expected to barely maintain its relative share by 2050, resulting in lower absolute employment level in the sector.

The Commission's Policy Option 2 focuses on the completion of the internal market, infrastructure development, pricing and taxation. It enables achievement of the 60% CO_2 emission reduction target for the transport sector by 2050 through improved efficiency, better logistics, modal shift and reduced mobility. In this scenario, employment in transport services is expected to grow and depends on each mode's labour intensity. The largest employer in this scenario would be road freight transport whose job losses due to modal shift may be compensated by new jobs in multimodal transport services, collective modes and logistics.

Policy Option 3 relies on large-scale deployment of technologies, in particular starting from 2030, through the introduction of rigorous standards for all vehicles. This scenario estimates that employment in the transport equipment manufacturing sector would grow significantly.

Policy Option 4, which relies on a combination of system improvement measures and technology improvement measures, would provide the most positive impacts on employment both in transport services and in manufacturing equipment for the transport sector.

Cambridge Econometrics' study *Fuelling Europe's Future*[161] predicts that a strong penetration of electric vehicles would have, on average, a positive impact on the EU economy. This finding is further supported by a study by CIRED[162]. In all decarbonisation scenarios, benefits are higher in a long term perspective than under BAU, and

161 Cambridge Econometrics, Fuelling Europe's Future: How auto innovation leads to EU jobs, 2013

162 CIRED, Electric Vehicles: What economic viability and climate benefits in contrasting futures?, 2009

none of them generates GDP losses. Three main macroeconomic factors explain why the EV generates GDP gains on average:

- The oil import bill of European countries is reduced;
- European countries are less forced to balance their current account by exportation; this allows for higher terms of trade and higher real wages, which in turn generates higher domestic demand, lower unemployment and more production;
- An early and strong penetration of electric vehicles lowers the cost of climate policies.

The study by Cambridge Econometrics suggests that the net effect of reduced expenditure on fossil fuels and increased expenditure on vehicles translates to € 222 billion of additional GDP in 2050 after second-order multiplier effects. Infrastructure investment also has a positive impact on GDP. The positive impact arises because infrastructure projects are inherently domestic and require relatively high labour input.

Overall, reducing the EU's fossil fuel bills and shifting spending towards other, more labour intensive, areas of the economy induces net job creation. Furthermore, Europe is a in a world-leading position in auto technology. Therefore, increased spending on low-carbon vehicle components would create supply-chain jobs.

Between 660,000 and 1.1 million net additional jobs could be generated by 2030 in the three low-carbon technology scenarios examined in Cambridge Econometrics' study, compared to a reference scenario in which cars continue to run on today's technology. In 2050, this figure rises to between 1.9 million and 2.3 million additional jobs, taking into account the jobs lost during this transition. These benefits would take time to achieve, because Europe's vehicle fleet takes 12 years to renew, but new jobs would be created from day one.

The figure presented in this study is rather high compared to another estimate made by Cambridge Econometrics for DG Energy on employment effects of scenarios from the *Energy Roadmap 2050*. This gap is due to several differences in assumptions underlying each analysis. For one thing, the baseline used is not the same in both studies (reference vs. CPI), neither is the level of decarbonisation in the scenarios. Models used in each study also lead to inherent differences in fuel demand projections, energy prices, carbon prices and recycled revenues. Also, unlike the study *Fuelling Europe's Future*, the study for DG Energy did not take into account the increase in vehicle costs and the additional jobs in the vehicle supply chain (which was beyond the scope of the *Energy Roadmap* analysis).

All these different aspects show that a direct comparison between two studies' outcomes would be difficult. However, a more feasible approach would be to compare the study's Tech 2 scenario with CPI, which leads to a net job creation of 760,000 by 2030. Given the share of road transport in total EU emissions, this estimation is roughly in line with the projections made in the study for DG energy – despite the major differences in methodology.

(2010 bn €)	2030	2050	2030	2050	2030	2050	2030	2050	2030	2050
	REF		CPI		TECH 1		TECH 2		TECH 3	
GDP (2010 bn euro)	17519,62	25604,52	36,74	168,22	40,67	223,36	53,04	264,13	72,49	293,09
Employment (m)	229,98	217,68	0,50	1,38	0,66	1,95	0,85	2,14	1,08	2,35

Table 22: GDP and employment per decarbonisation scenario of the transport sector (The data in the scenario columns represents absolute difference from the REF reference scenario).

Source: Cambridge Econometrics, Fuelling Europe's Future: how auto innovation leads to EU jobs, 2013

Most new jobs would be created outside the automotive value chain, in sectors such as services and construction, which benefit from the shift in spending away from the fossil fuel value chain and towards domestically-produced goods and services. This is illustrated in the figure below for the study's Tech 3 scenario, which focuses on what might be achieved using conventional ICE and hybrid technology, and includes the deployment of advanced powertrains and accompanying infrastructure.

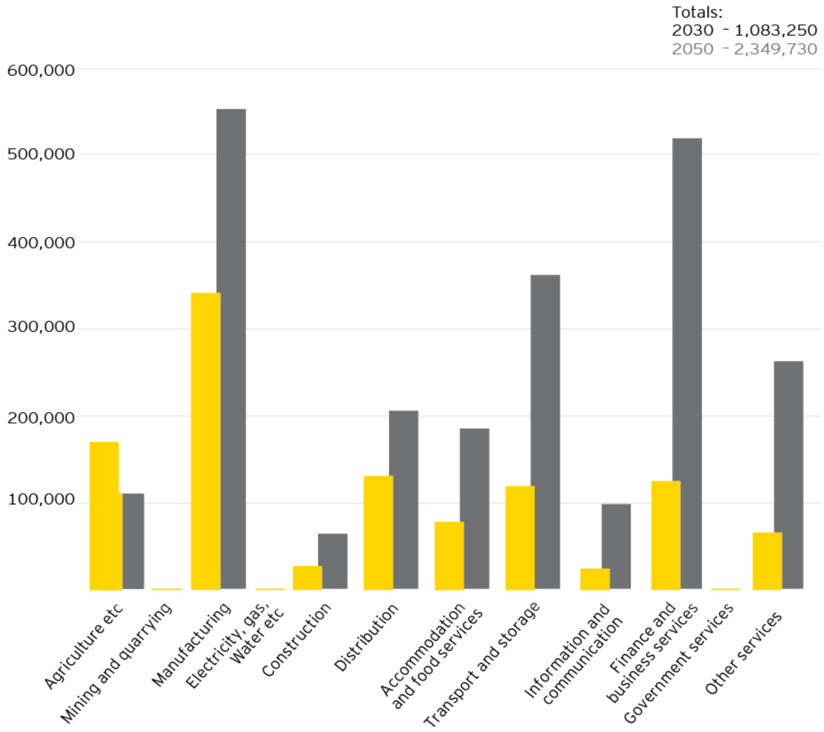

Figure 22: Net employment impact, compared to BAU, in main economic sectors for Tech 3 scenario.
Source: Cambridge Econometrics, Fuelling Europe's Future: how auto innovation leads to EU jobs, 2013; E3ME

As another point of comparison, according to a study conducted by Roland Berger[163], automotive-related industries such as transportation, retail and other services could create one million jobs in Europe by 2025, outweighing the loss in manufacturing jobs. On balance, there would be an increase of 700,000 jobs in the European automotive sector in 2025.

Decarbonisation of the building sector could create between 500,000 and 1 million net jobs by 2050

In its *Energy Efficiency Plan*, the European Commission estimates that through decarbonisation (i.e. full implementation of existing measures, and new measures regarding energy efficiency of buildings) up to 2 million jobs could be created or retained by 2020[164], though this is not specified as *net* job creation..

163 Roland Berger, Automotive landscape 2025: Opportunities and challenges ahead, 2011
164 European Commission, Energy Efficiency Plan – Impact assessment, 2011

BPIE's study *Europe's Buildings Under the Microscope*[165] predicts that, while BAU would yield a net creation of about 200,000 jobs over the next 40 years, the accelerated renovation scenarios would generate between 500,000 and 1.1 million net jobs.

Scenarios	2020	2030	2050
Business-as-usual	0.3	0.2	0.2
Slow & Shallow	0.4	0.4	0.5
Fast & Shallow	0.6	0.6	0.5
Medium	0.6	0.8	0.7
Deep	1.2	1.4	1.1
Two-stage	0.6	0.8	0.8

Table 23: Net jobs generated in the building sector by 2020, 2030 and 2050 (in millions).
Source: BPIE, Europe's Buildings Under the Microscope, 2011

BPIE's modelling is based on a review of employment impact in the building sector, conducted by the Centre for Climate Change and Sustainable Energy Policy at the Central European University in Hungary. The study particularly investigates the degree to which employment effects may vary depending on the comprehensiveness of the renovation scenario. It finds that a large-scale, deep programme in Hungary could create by 2020 up to 131,000 net new jobs, as opposed to approximately 43,000 in a less ambitious scenario. These figures include the workforce losses in the energy supply sector. Up to 38% of the employment gains are due to the indirect effects on other sectors that supply the construction industry and the induced effects from the increased spending power of higher employment levels[166].

Employment and economic impacts stimulated by investing in a more sustainable building stock can indeed be seen across a wide range of players in the value chain, from manufacturing and installation through to provision of professional services such as financing and project management[167]. New jobs would also be stimulated by the need for products, components and material used or installed in better-performance buildings.

Another contribution to the estimation of employment impacts of energy efficiency investments was made by the Energy Efficiency Industrial Forum. Synthesising findings from a range of studies, the Forum found that about 19 net jobs are generated per €1 million investment in energy efficiency in the buildings sector. The specific measures for *public* buildings proposed by the European Commission in the Energy Efficiency Directive in June 2011 would lead to an annual rate of net job creation of 29,000 full time new direct jobs, by addressing "*just a very small fraction of the total EU building stock*"[168].

Finally, empirical data is available on the effect of energy efficiency schemes on tax revenues. A report from the Jülich Research Centre on the effects of the KfW energy-efficient refurbishment scheme in Germany found that for every Euro spent on the scheme, public authorities collected €4-5 in tax revenue. This multiplier effect is due to the construction investments and employment effects of the scheme, leading to additional tax revenues paid by companies and employees and reduced expenditure on unemployment and social benefits[169].

165 BPIE, Europe's Buildings Under the Microscope, 2011

166 Central European University, Employment Impacts of a Large-Scale Deep Building Energy Retrofit Programme in Hungary, 2010

167 BPIE, A guide to developing strategies for building energy renovation, 2013

168 Energy Efficiency Industrial Forum, A Survey of the Employment Effects of Investment in Energy Efficiency of Buildings, 2012

169 Jülich Research Centre, 2010
Press release: www.kfw.de/KfW-Group/Newsroom/Aktuelles/Pressemitteilungen/Pressemitteilungen-Details_10137.html

2.5.3 Avoided spending on fossil fuel imports achieved through decarbonisation would be reallocated within the EU economy

It has been shown that under a range of decarbonisation scenarios, Europe could reduce its dependence on fossil fuel imports. This reduction of the overall fossil fuel bill would benefit consumers directly, in particular regarding fuel savings related to personal transport and energy savings in buildings, which ultimately lead to lower energy bills for households compared to BAU.

This avoided spending can have further macroeconomic effects if consumers spend their increased available income on other products or services. This mechanism has been assessed, for instance, in the Cambridge Econometrics study *Fuelling Europe's Future*, where it comprised about half of the estimated job creation. Further modelling would be required, however, to capture the full economic potential of EU household spending transferred away from fossil fuels.

2.5.4 Implementing decarbonisation policies could enable GDP growth to be decoupled from emissions growth

Empirical evidence suggests that countries which have put in place specific decarbonisation policies to increase energy efficiency in industry and households, and to encourage fuel shifts to low carbon power production, have succeeded in decoupling GDP growth from emissions at higher rates than countries without such policies.

In a study commissioned by the European Climate Foundation, PriceWaterhouse Coopers (PWC)[170] assessed energy and climate policies and resulting economic impacts for five countries – Denmark, Sweden, Germany, The Netherlands and the UK. Apart from the Netherlands, all these countries outperformed the average high-income OECD country in decarbonisation rates, and have a long history of relevant energy and climate policies. Thus, this analysis can provide relevant lessons for other European countries that are behind with decarbonisation.

All five countries have experienced economic growth decoupled from CO_2 emissions and energy use, but the pace and the magnitude of decarbonisation differs from one country to another. PwC identifies two types of decoupling – relative and absolute. Absolute decoupling occurs when CO_2 emissions are stable or decreasing while GDP is growing. Relative decoupling refers to the situation where the growth rate of CO_2 emissions is positive, but lower than the growth rate of GDP.

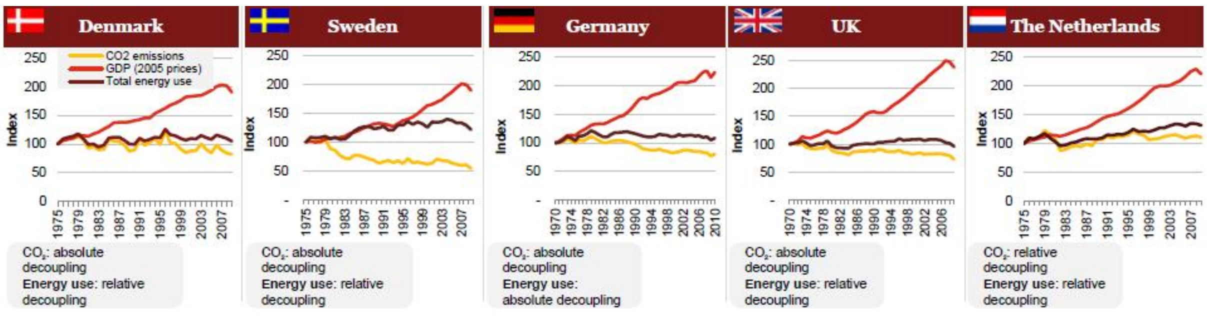

Figure 23: CO_2 emissions, energy use and GDP in 1970-2010.

Source: PwC, Decarbonisation and the Economy, 2013

The difference in decarbonisation pace, magnitude and type of decoupling depends on each country's specific energy policies. The main variables for these policies are fuel mix choices and efficiency measures, as presented in the figure below.

170 PwC, Decarbonisation and the Economy, 2013

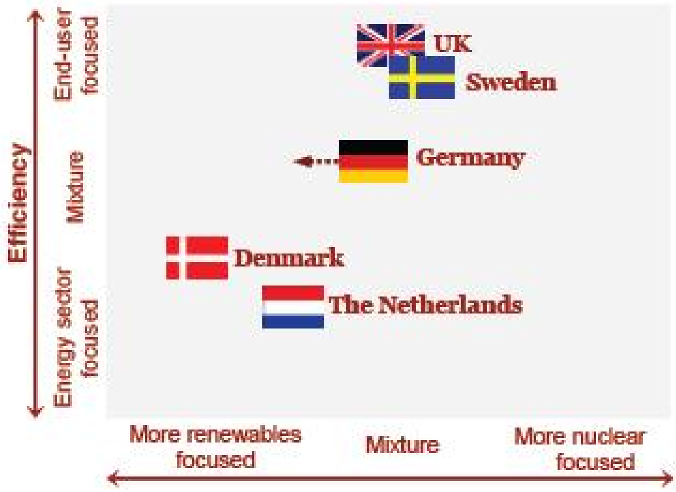

Figure 24: Decarbonisation profiles.
Source: PwC, Decarbonisation and the Economy, 2013

Overall, it appears in this study that the UK and the Netherlands' decarbonisation pathways led to a slightly lower pace and magnitude of decoupling of GDP growth from emissions. These two countries have taken a different decarbonisation pathway than other countries analysed by PwC, implementing higher energy efficiency and structural changes in the economy, and limiting industry creation, while Denmark, Sweden and Germany remained open and export-oriented economies and showed above-average decarbonisation rates.

It can be concluded from this section that although net job opportunities under decarbonisation remain modest compared to BAU, decarbonisation would contribute towards a revival of employment across Europe, concentrated in several labour-intensive sectors. Employment opportunities exist in the main decarbonisation sectors, i.e. vehicle technology, building renovation and renewable energies – sectors whose labour intensity within the EU would be higher than that of fossil fuel importation. Impacts of decarbonisation on GDP are limited but appear to be net positive compared to BAU according to the reviewed literature. Moreover, avoided spending on fossil fuel would enable a reallocation of these monetary benefits within the EU economy and stimulate GDP growth and job creation. As far as empirical evidence goes, several countries have put in place specific decarbonisation policies, such as Denmark, Sweden and Germany, and achieved absolute decoupling of GDP growth and energy use to a higher extent than the average European nation.

2.6 Co-Benefits

Co-benefits arise from decarbonisation strategies as net positive impacts which are not directly related to conventional economic indicators, and / or the avoidance of costs that would arise under BAU but that are not necessarily always spelt out. These include a wide range of categories, including health improvement, agricultural productivity, energy security, or air quality, as illustrated in the table below. Although there is broad agreement that co-benefits add to the net benefits of decarbonisation as compared to BAU, only limited evidence can be provided by the literature for factors other than health and agricultural productivity improvements[171]. An extended focus on health issues, identified as the most documented and therefore allowing a relevant discussion on their monetisation, follows in this section. This section also briefly considers the avoided costs of dealing with climate change, which are already being increasingly felt across Europe.

Category of co-benefit	Examples
Health	Reduced medical/hospital visits, reduced lost working days; reduced acute and chronic respiratory symptoms, reduced asthma attacks, increased life expectancy.
Emissions	Reduction of dust, CO, CO_2, NO_x and So_x; reduced environmental compliance costs.
Waste	Reduced use of primary materials: reduction of waste water, hazardous waste, waste materials; reduced waste disposal costs; use of waste fuels, heat and gas.
Production	Increased yield; improved product quality or purity; improved equipment performance and capacity utilization; reduced process cycles times; increased production reliability; increased customer satisfaction.
Operation and maintenance	Reduced wear on equipment; increased facility reliability; reduced need for engineering controls; lower cooling requirements; lower labour requirements.
Working environment	Improved lightning, temperature control and air quality; reduced noise levels; reduced need for personal protective equipment; increased worker safety.
Other	Decreased liability; improved public image; delayed or reduced capital expenditures; creation of additional spaces; improved worker morale.

Table 24: Co-benefits of greenhouse-gas mitigation or energy-efficiency programmes of selected countries.
Source: IPCC, Climate Change 2007 – Mitigation of Climate Change, 2007

171 IPCC, Climate Change 2007 – Mitigation of Climate Change, 2007

2.6.1 Health benefits

Monetisation of health risks is a controversial exercise, as there is a wide range of existing methodologies to translate, for instance, mortality reduction into financial savings. While the range of estimates may be broad, the notion that monetised health benefits may significantly add to the net benefits of decarbonisation as compared to BAU is associated with a “high [level of] agreement, much evidence”, according to the Intergovernmental Panel on Climate Change[172].

The impact of CO_2 emissions on human health is in particular associated with other air pollutant emissions, in particular NOx, SO_2, and particulate matter emissions, which would be the cause for a high number of premature deaths that could amount to several thousands per year in Europe[173]. The total regional air pollutant impact on human health and the environment, across all sectors of the EU-25 economy, would have cost € 280-794 billion in 2000[174]. The example of industrial emission costs shows that a significant number of industrial facilities were estimated to cost over € 200 million on the basis of life years lost in 2009, as presented below.

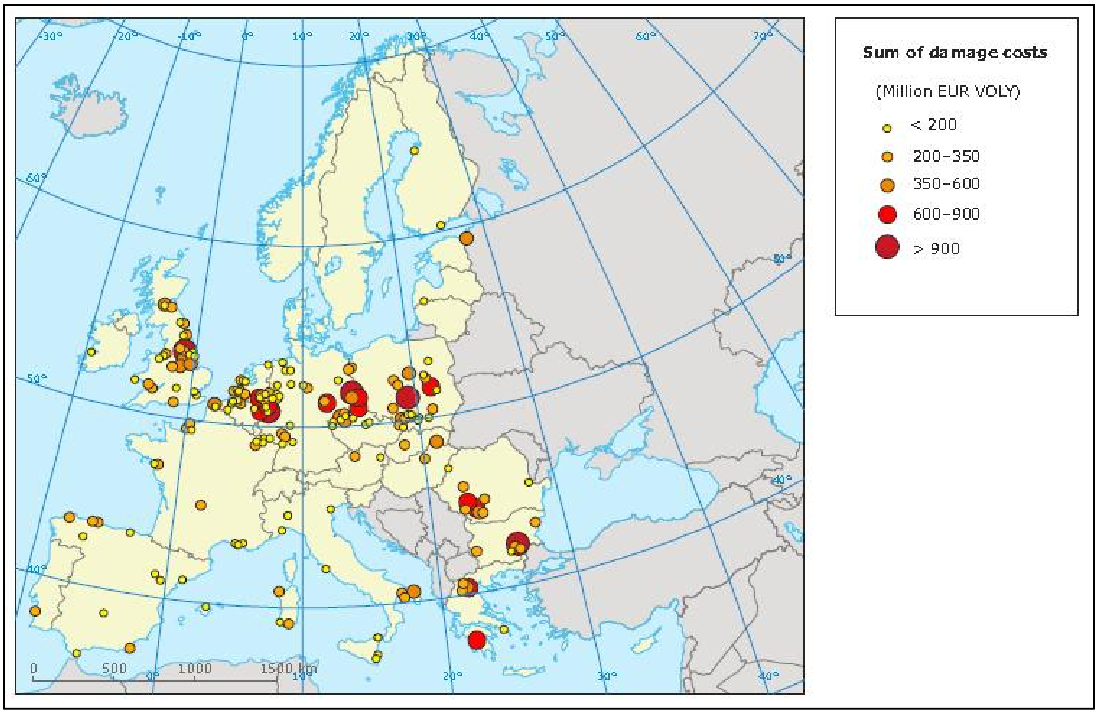

Figure 25: Cost distribution for the 191 facilities generating the highest impact on health and the environment, according to the 2011 E-PRTR[175].

Source: European Environment Agency, Revealing the costs of air pollution from industrial facilities in Europe, 2011.

Although figures published in the literature for health benefits arising from decarbonisation span a broad range of values, they are of the same order of magnitude. The European Union projections developed in the *Low Carbon Roadmap* anticipate up to € 17 billion of savings in 2030 and up to € 38 billion Euros in 2050[176]. The most recent decarbonisation scenarios published by the Commission in January 2014 for the period 2020 to 2030 involve expected positive health benefits for all scenarios due to lower pollutant emissions from the energy system, with impacts more pronounced in scenarios with ambitious energy efficiency policies and renewable energy targets, resulting in lower fossil fuel consumption.[177] Monetised health benefits in 2030 as a

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172 IPCC, Climate Change 2007 – Mitigation of Climate Change, 2007

173 IPCC, Climate Change 2007 – Mitigation of Climate Change, 2007

174 European Environment Agency, Revealing the costs of air pollution from industrial facilities in Europe, 2011

175 E-PRTR : European Pollutant Release and Transfer Register, following the United Nations Economic Commission for Europe (UNECE) Aarhus Convention regarding access to environmental information

176 European Commission, A Roadmap for moving to a competitive low carbon economy in 2050, 2011

177 European Commission, Impact Assessment Accompanying the Communication A policy framework for climate and energy in the period from 2020 up to 2030, 2014

percentage of GDP for the EU-28 range from 0.02% in the least ambitious decarbonisation scenario up to 0.21% in the most ambitious decarbonisation scenario.

However, a recently-published report by CE Delft suggests that air pollution-related benefits from decarbonisation are underestimated, as they do not take into account increased welfare[178]. The CE Delft study indicates that by taking into account assumed income growth of 1.5%[179], air quality benefits increase by a factor of 1.27, as shown in the table below.[180]

	GHG -40%	GHG -40% + EE	GHG -40% + RES 30% + EE	GHG -45% + RES 35% + EE
Benefits assuming no correction for income growth	7.2 to 13.5	17.4 to 34.8	16.7 to 33.2	21.9 to 41.5
Benefits with correction for income growth	9.1 to 17.1	22.1 to 44.2	21.2 to 42.1	27.8 to 52.7

Table 25: Impact income growth on air quality (€ 2010 bln/year)

Source: CE Delft, Review of the Impact Assessment for a 2030 climate and energy policy framework, 2014

Based on the Clean Air Force Europe methodology for valuing health improvement, expected benefits generated by the 20% EU objective for greenhouse gas emission decrease could amount to € 13-52 billion by 2020[181]. Further decarbonisation could even provide higher reduction. Indeed, according to a joint report from the Health and Environment Alliance (HEAL) and Health Care Without Harm Europe (HCWH E), the additional benefits associated with a 30% greenhouse gas emission cut instead of 20% could rise to € 10-30 billion per year in 2020[182]. Germany, Poland, France and Italy would be the main beneficiaries of such improvements (Figure 26), though some small countries, such as Luxembourg, would be the highest per capita beneficiaries. These forecasts anticipate improvements in life expectancy, respiratory and cardiac health, reductions in hospital admissions, chronic respiratory disease, asthma attacks and various other respiratory and cardiac conditions, and the reduction in days of restricted activity due to respiratory health problems[183].

178 From an economic perspective, air quality benefits increase with increased welfare, meaning that people value environmental quality more highly when they become richer.

179 1.5% represents the GDP growth until 2030 in the reference scenario

180 CE Delft, Review of the Impact Assessment for a 2030 climate and energy policy framework, 2014

181 Econometrics Research and Consulting, UK, The co-benefits to health of a strong UK climate change policy, 2008

182 HEAL – HCWH E, Acting Now For Better Health – A 30% Reduction Target for EU Climate Policy, 2010

183 HEAL – HCWH E, Acting Now For Better Health – A 30% Reduction Target for EU Climate Policy, 2010

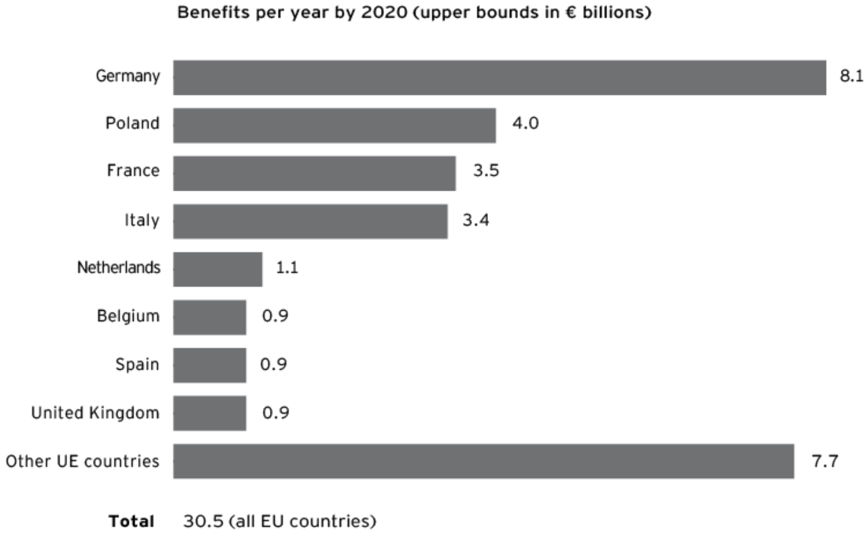

Figure 26: Health benefits for EU countries.

Source: HEAL – HCWH E, Acting Now For Better Health, A 30% Reduction Target for EU Climate Policy, 2010

It is worth noting that timing matters: expected health improvements depend on the trajectory followed to reach the objective. For instance early action estimated and reported in the HEAL - HCWH E study yields benefits more than twice as high when considering action from 2010 as when considering action from 2015, to reach the same 2020 objective, as presented below.

Achieving 30% domestic reduction in greenhouse gas emissions	Cumulative Benefits	Percentage benefit
Action starts today	€58-163 billion	100%
Action starts in 2015	€22-63 billion	39%

Note: the cumulative benefits range (lower and upper estimates) is from €22-63 billion if action starts in 2015 as against €58-163 billion if action is started in 2010

Table 26: Early action now brings greater health savings.

Source: HEAL – HCWH E, Acting Now For Better Health, A 30% Reduction Target for EU Climate Policy, 2010

2.6.2 Other co-benefits

Other avoided costs

Attempts to quantity co-benefits other than health savings have been less documented. A few figures nevertheless emerge from the literature.

Fuel poverty – Fuel poverty occurs when a household is unable to adequately warm the home at a reasonable cost[184]. In this sense fuel poverty is directly impacted by household energy costs. Co-benefits arising from fuel poverty alleviation and household energy efficiency improvement could also be associated with net positive values. According to the European Commission, the 20% energy efficiency saving target by 2020 could cut consumer bills by up to € 1000 per household per year[185]. Besides, fuel poverty abatement would be correlated to health improvement, and therefore add to the benefits described in the previous subsection: physical and mental health issues would indeed be improved by energy efficiency gains[186].

In the UK where further analysis was conducted, both the conventional measurement of fuel poverty by the Department of Environment and Climate Change (defined when household energy costs exceed a threshold of 10% of the household income) and the absolute fuel poverty gap (defined as the difference between energy needs and reasonable costs) are predicted to increase by 2016; based on the latter measurement for fuel poverty, 8.5 million individuals would be considered fuel-poor in the UK in 2016[187]. According to the World Health Organization's case study in the UK, poor housing mitigation could help the National Health Service save € 717 million per year, among which a number of expenses are related to fuel poverty, such as costs entailed by excess cold (€ 21 million a year) or dampness (€ 9 million a year)[188]. According to the European Fuel Poverty and Energy Efficiency project (EPEE), fuel poverty would include between 50 million and 125 million people at European scale[189]. Southern and Eastern Europe would be more deeply affected, and the proportion of households unable to keep their house warm could amount up to 35% in Portugal, 32% in Bulgaria and 31% in Cyprus[190].

Household dependency on energy prices would be affected by vehicle fuel prices as well: the fuel bill for consumers would decrease by 10% in the wake of vehicle energy efficiency improvement[191]. What is more, the specific case of improvements in energy efficiency of buildings could allow reducing the stress of household energy costs for national public finances. This would be characterised by public finance benefits as a result of reduced expenses on subsidies to energy consumption: €9 billion to €12 billion, depending on the intensity of energy efficiency enhancement, would be saved annually in Europe through these improvements[192].

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184 European Fuel Poverty and Energy Efficiency Project, Tackling Fuel Poverty in Europe – A Recommendation Guide for Policy Makers, 2009

185 European Commission, Commission Staff Working Paper, Analysis associated with the Roadmap to a Resource Efficient Europe Part I, 2011

186 Liddell, C. and Morris, C., *Fuel Poverty and Human Health: A Review of Recent Evidence.* Energy Policy, 38, pp. 2987-2997, 2010

187 John Hills, Getting the Measure of Fuel Poverty – Final Report of the Fuel Poverty Review, Center for Analysis of Social Exclusion The London School of Economics and Political Science, 2012

188 World Health Organization, Environmental Burden of Disease Associated with Inadequate Housing, 2011

189 European Fuel Poverty and Energy Efficiency project, Tackling Fuel Poverty in Europe: Recommendations Guide for Policy, 2009

190 Thomson, H., Snell, C., *Quantifying the prevalence of fuel poverty across the European Union,* Energy Policy, 52, pp. 563-572, 2013

191 European Commission, Commission Staff Working Paper, Progress report of the Energy Efficiency Action Plan 2006, 2011

192 Copenhagen Economics, Multiple Benefits of investing in energy efficient renovation of buildings, 2012

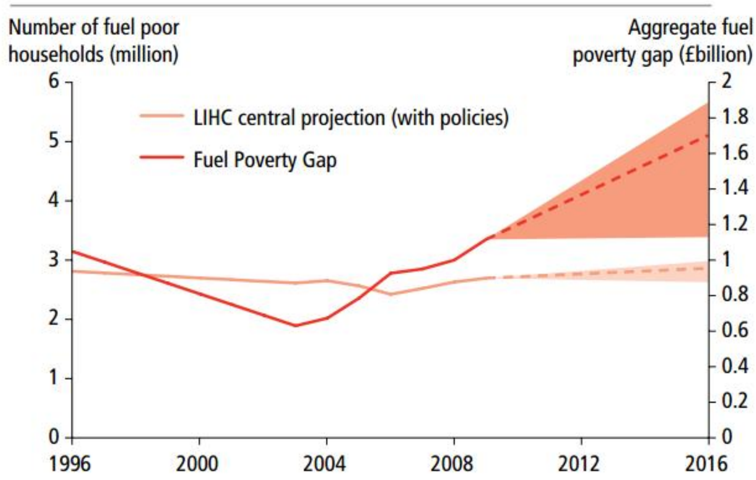

Figure 27: Projected levels of fuel poverty under the Low Income High Cost indicator and fuel poverty gap, 1996-2016, England.
Source: John Hills, Getting the Measure of Fuel Poverty – Final Report of the Fuel Poverty Review, Centre for Analysis of Social Exclusion, The London School of Economics and Political Science, 2012

Air pollution control savings – In its *Roadmap for moving to a competitive low carbon economy in 2050*, the European Commission anticipates that the control costs of traditional air pollutants could decrease by more than € 10 billion per year by 2013, and by close to € 50 billion by 2050[193]. With policies consistent with the 2°C objective for global warming by the end of the century, analyses from the International Energy Agency for the European Union provide results of the same order of magnitude, $ 8 billion of savings by 2020 and $ 30 billion by 2035[194]. The 2020 to 2030 scenarios presented in the European Commission's 2014 Impact Assessment estimates reduced air pollution control costs in 2030 as a percentage of GDP in the EU-28 at 0.01% in less ambitious scenarios up to 0.04% in the most ambitious scenario.[195]

Adaptation to Climate Change

The impact of greenhouse gas emissions on ecosystem services was extensively covered in the Millennium Ecosystem Assessment, which establishes that most of them are facing substantial decline[196]. Since the world value of ecosystem services was estimated at $ 16-54 trillion per year in 1997 (when global GDP amounted to $ 18 trillion)[197], potentially significant monetary savings would be linked to conservation actions through greenhouse gas mitigation. In the 2006 Stern review, valuating in particular impacts on water resources, food production, health and the environment, it was estimated that overall costs of climate change could range from around 5% to more than 20% of global GDP per year[198].

A recent report by CE Delft provides an estimation of the avoided damage costs for CO_2, with damage costs established based on a broad literature review and multiplied by the tonnes of CO_2 avoided in each decarbonisation scenario. Calculated benefits range from € 10,2 billion to € 48,6 billion in 2030 for scenarios with a 40% GHG emissions reduction and from € 16,4 billion to € 74,3 billion for a scenario with a 45% GHG emissions reduction.[199]

[193] European Commission, A Roadmap for moving to a competitive low carbon economy in 2050, 2011
[194] IEA, World Energy Outlook Special Report - Redrawing the Energy Climate Map, 2013
[195] European Commission, Impact Assessment Accompanying the Communication A policy framework for climate and energy in the period from 2020 up to 2030, 2014
[196] Millennium Ecosystem Assessment, 2005
[197] Costanza et al., The value of the world's ecosystem services and natural capital, Nature, 387, 1997
[198] Stern Review on the Economics of Climate Change, 2006
[199] CE Delft, Review of the Impact Assessment for a 2030 climate and energy policy framework, 2014

The United Framework Convention on Climate Change (UNFCCC) estimates the costs of possible adaptation strategies to climate change as amounting to between 0.3 and 0.5 percent of global GDP in 2030[200].

Although studies acknowledge that estimates span a wide range of values, they tend to draw similar conclusions: additional investments would amount to $ 49-171 billion per year globally by 2030 according to the same UNFCCC study, or $ 70-100 billion by 2050 according to the World Bank[201]. In spite of the uncertainty on the exact value, these figures on global investments for climate change adaptation are significantly lower than climate change costs, for which low estimates would range from € 100 billion ($ 135 billion) per year in 2020 to € 250 billion ($ 340 billion) per year by 2050 for the European Union[202]. CE Delft has also provided an estimation of the avoided damage costs for CO_2, with calculated benefits ranging from € 10.2 billion to € 48.6 billion in 2030 for scenarios with a 40% GHG emissions reduction and from € 16.4 billion to € 74.3 billion for a scenario with a 45% GHG emissions reduction[203]. These projections need to be considered with care, as comprehensive cost-benefit analyses of adaptation strategies are challenging and rely on many assumptions. As of today, limited empirical data exist on costs and benefits of adaptation strategies at EU or European country level, and assessment methods are currently improving but remain an emerging field of work[204].

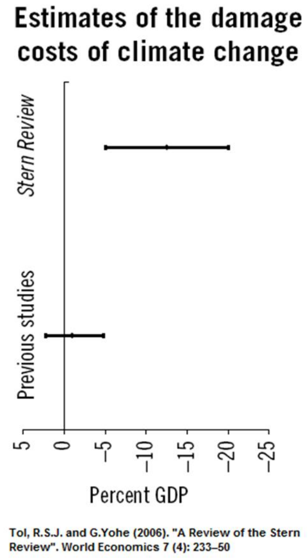

Figure 28 : Estimates of the damage costs of climate change.
Source: Stern Review on the Economics of Climate Change, 2006.

2.6.3 The importance of assumptions: figures are consistent and yet remain context-specific

As pointed out previously, monetisation of co-benefits is a controversial issue, with differing assumptions on the relationship between the value of co-benefits and the intensity of decarbonisation. Econometrics Research and Consulting has focused on the impact of a 10% cut in greenhouse gas emissions in addition to the 20% set as the European Union objective for 2020. Based on the Clean Air For Europe (CAFE) methodology, the analysis concluded that cutting greenhouse gas emissions by this further 10% would contribute health co-benefits worth 6-25 billion health co-benefits. In light of their findings regarding the 20% cut scenario (€13-52 billion health co-benefits), these figures suggest a linear relationship between decarbonisation intensity and health co-

200 United Framework Convention on Climate Change, Investment and Financial Flows to Address Climate Change, 2007

201 World Bank, Economics of Adaptation to Climate Change – Synthesis Report, 2010

202 European Commission, An EU Strategy on adaptation to climate change, 2013

203 CE Delft, Review of the Impact Assessment for a 2030 climate and energy policy framework, 2014

204 European Environment Agency, Adaptation in Europe – Addressing risks and opportunities from climate change in the context of socio-economic developments, 2013

benefits, at least for a range of decarbonisation scenarios including the scenario meeting the EU 2020 objective[205].

However, conclusions are highly sensitive to assumptions: a 2012 analysis published by the European Commission underlines that a 20% greenhouse gas emission cut scenario, involving the assumption of an increase in the use of biomass for domestic energy, would lead to negative health impacts (€ 90-250 million costs by 2020) through an increase in particulate matter emissions. Further analysis from this study concludes that an additional 5% cut in greenhouse gas emissions would be required for co-benefits to turn positive and outweigh the 20% scenario figure. This 25% cut scenario provides figures consistent with the ones mentioned in the previous paragraph (from € 3.3 billion to € 7.6 billion of net positive impact)[206].

It can be concluded that in spite of consistent evidence that co-benefits add to the net benefits of decarbonisation as compared to BAU, their monetisation remains a challenging issue. Results of analyses are highly sensitive to specific assumptions, yet most estimates are in the same order of magnitude: health benefits in a decarbonised economy, which are best documented, could amount to tens of billion euros a year in the long term. Further benefits include savings on air pollution control, reduction of fuel poverty, and reduced pressure on nations' social spending. These benefits have also been estimated to a few tens of billion euros a year in the long term for the EU. Finally, benefits would accrue from avoided spending on climate change adaptation costs, though this is a global issue requiring worldwide climate action.

[205] Econometrics Research and Consulting, UK, The co-benefits to health of a strong UK climate change policy, 2008

[206] European Commission, Analysis of options beyond 20% GHG emission reduction : Member State results, Commission Staff Working Paper, 2012

3 Conclusion

Debates about decarbonisation tend to start from an implicit assumption that BAU will be a “comfortable” continuation of the present-day situation, and that decarbonisation and its macroeconomic effects need to be considered against this backdrop. However, even without looking in detail at the costs of dealing with climate impacts that might result if serious decarbonisation efforts are not made, this report has highlighted that:

- BAU differs from a mere continuation of the current situation, and will have macroeconomic impacts that are not benign. Even a small net positive effect under decarbonisation, as may be the case with electricity prices and employment, is still an improvement compared to what would happen under BAU.
- While the Commission’s roadmaps to 2050 depict overall positive economic impacts of decarbonisation, on balance the trends and findings from additional evidence from the literature lead to the conclusion that the roadmaps' findings are sometimes rather conservative. For instance, this is the case regarding the cost of renewable energy sources, which has decreased in the past few years beyond expectations. In reflection of this, the Commission has revised its own estimates downwards since 2011. Several sources also expect greater benefits than the Commission from the decarbonisation of the transport and building sectors on a range of parameters (import dependency, GDP, employment, etc.).

These are two main threads that emerge from this report’s exploration of some of the key recent expert forecasts of the macroeconomic effects of decarbonisation. The evidence set out in the report also helps to address some of the fears that are sometimes associated with an ambitious decarbonisation route - notably:

- Concerns regarding industrial competitiveness: future competitiveness of European industry will mostly rely on drivers which are unaffected by whether Europe engages in decarbonisation. Energy costs would remain a key competitiveness driver for a number of energy-intensive industries which represent the bulk of industrial carbon emissions. However, there are encouraging signs that important energy efficiency opportunities and breakthrough technologies could be commercially viable and usable by these industries by 2030. Furthermore, energy-intensive industries would be part of the decarbonisation future, with opportunities to develop and sell new products to other sectors engaged on the route.
- Concerns regarding energy and electricity prices: energy and electricity prices would both increase under BAU. While fossil fuel prices would naturally fall under decarbonisation due to reduced demand, the situation with electricity prices is indeed a little more complicated. The studies reviewed in this report highlighted that decarbonisation would induce investments which could slightly raise electricity prices up to 2030. But the difference compared to BAU is small; under both cases the average retail electricity price would remain close to 150 Euro ’08 per MWhe in 2030 according to the Commission’s Energy Roadmap 2050. After 2030, returns on investments made in energy efficiency and alternative energy would materialise under decarbonisation scenarios, with electricity prices falling slightly below 150 Euro ’08 per MWhe in 2050 i.e. lower than under BAU.
- Concerns regarding possibly negative effects on employment: though job opportunities in the power, building, and transport sectors under decarbonisation remain modest compared to BAU, decarbonisation would contribute towards reviving employment across Europe by fostering labour-intensive sectors (renewable energy, transport, buildings), and net effects across the economy are projected to be positive.
- Concerns regarding possible impacts on trade balance: doubts exist as to whether decarbonisation would displace EU’s dependency from fossil fuels towards renewable energy generation equipment (e.g. solar PV modules imported from China). However, decarbonisation entails investments in energy efficiency solutions and enhancement of grid capacity, with equipment historically manufactured within Europe, and installation labour which must be carried out on European soil. Moreover, estimated savings on external fossil fuel bill make the case that decarbonisation would improve the EU’s trade balance: Europe could save € 518-550 billion in 2050 by taking a strong decarbonisation pathway. The prospects for Europe’s competitiveness in low-carbon industries will be further studied as part of a separate report.

Europe’s industrial competitiveness and relative resource efficiency are two historically important features of its socio-economic success. With energy efficiency gains across all sectors of the economy, Europe has come out of past energy price shocks on a strong footing, and built a certain degree of resilience, despite limited fossil fuel reserves. By consolidating competitive advantage in key industries, Europe has been able to seize opportunities in global markets, and to compensate its natural raw material trade disadvantage.

Notwithstanding these achievements, recent trends in energy trade deficits, and predictions for the decades to come, indicate that the energy challenge remains unresolved. Moreover, the rise of emerging industrial regions, and continued strong innovation in developed regions, require Europe to renew its industrial fabric. The expectation from players in the energy, industry, transport, and buildings sectors who provide solutions to those challenges is a 2030 EU-wide policy framework that offers visibility on investments, incentives and regulations that will achieve a decarbonised and economically successful future.

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