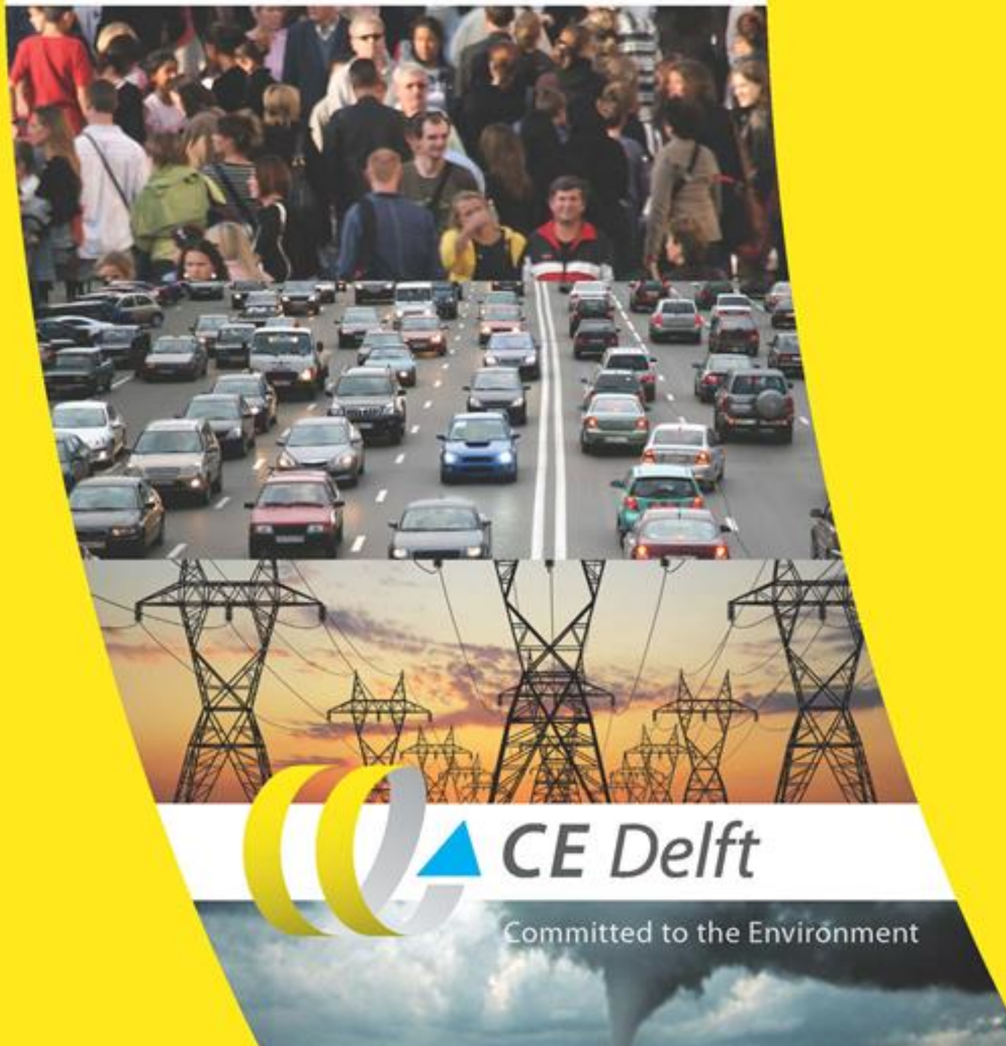
# Investment challenges of a transition to a low-carbon economy in Europe

## What sets the pace?



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## What sets the pace?

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# Content

# Prologue

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# Executive summary

## Purpose of this study

This study investigates the challenges facing Europe up to 2050 in the transformation to a low-carbon economy. The primary purpose of the study is to provide greater insight into the factors setting the pace of decarbonisation, with a particular focus on capital, investments and how revenues are generated. In addition, it aims to provide a deeper understanding of the substantial challenges ahead and in particular for policymakers in designing the overall low-carbon policy framework.

## The investment challenge as 2% of GDP annually

The outcome of our analysis underlines the sheer size of the challenge of reducing greenhouse gas emissions by 80-95% and the far-reaching consequences that this entails for society. To achieve this aim, annual overall investment levels will have to increase to about 2% of GDP on average. Compared with the 2013 levels of investment in low-carbon technologies (a year in which many politicians were already complaining about the high costs of renewable energy subsidies), efforts need to be increased by a factor 5, as things stand at the moment, and these efforts will have to be maintained for the next 35 years. This is a very substantial challenge indeed, but not unprecedented in recent history. For the economy as a whole, as well as for the transport, built environment and power generation sectors, such investments do not exceed the historical variations in investment volumes.

In magnitude as well as implications, the low-carbon transformation can probably best be compared to the economic transformation of Central and Eastern European countries to a market economy between 1990 and 2010. This transformation implied a drastic change in technologies, replacing all the ‘obsolete’ technologies (industrial installations, power generation, transport vehicles, infrastructure) with ‘new’ modern ones. Likewise, the low-carbon transformation implies that the majority of current technologies will have to be labelled “obsolete” and replaced by up-to-date solutions.

## The low-carbon economy transition requires a proper devaluation mechanism

The transformation in Central and Eastern Europe was accompanied by a rapid devaluation of local currencies, which aided a fast depreciation of existing assets and established attractive business cases for investors to step in. To be successful, the low-carbon transformation will have to develop similar mechanisms to render existing assets unprofitable and crate scope for new technologies to step in. **Our analysis points to pricing carbon emissions as the best way to achieve the desired effects on value creation.** An explicit or implicit carbon price in every corner of society will reduce the profitability of existing fossil fuel assets and increase the economic value of new low-carbon investments.

Carbon prices will have to rapidly increase in order to provide sufficient incentives for divestments of fossil fuel assets and make technologies on the right side of the marginal abatement curve (e.g. CCS - carbon capture and storage) attractive. Several studies indicate that expected abatement costs in an 80% reduction scenario could be as high as € 250/t$CO_2$ in 2050. Working back from that level, one would need present carbon prices to be close to € 30/t$CO_2$, rising to over € 100/t$CO_2$ in 2030. Present levels of carbon prices in, e.g., the EU ETS are thus way too low to provide guidance towards the low-carbon transformation.

In the absence of high and rising carbon prices, the low-carbon transition will not be driven by market demand for low-carbon products and technologies, as the vast majority of low-carbon technologies required are not profitable with present prices. Alternatively, the low-carbon transition might be achieved through a mix a mix of subsidies and regulations. Our assessment is that this will lead to higher transition costs, open the floor for lobbying and result in misallocation of resources, making the transition far more costly. Moreover, it will lead to public concerns about worn-out governmental budgets and introduce political pressures to stop subsidy programs, so that investors will demand additional risk premiums – costs that society will have to pay. Finally, without high carbon prices, current assets remain profitable and will prevent replacement through new investments and organize political pressure for keeping those assets profitable. Therefore our assessment is that the alternative route is unlikely to deliver the required emission reductions.

### Capital availability may not pose a problem except for venture capital

Capital markets, according to our findings, will be able to handle the increase in total investment volume. Low-carbon capital has to be attracted mainly from equity in the form of stocks, bonds and bank assets. As the total available investment capital will increase, the higher low-carbon investment demand can be met. **However, there may be a specific problem for 'early-stage' capital**. In particular, demand for high-risk private equity may exceed the available stock. Our assessment is that this may present a problem for the transport sector in particular, where new factories and technologies must be established in a very short time span, and to a lesser extent in the power and industrial sectors. A shortfall in early-stage private equity may hinder the low-carbon transformation and may lead to higher transformation costs in later years.

### The investments are not wasted, but bring financial benefits that enhance economic growth

Unlike e.g. military spending, low-carbon investments are not only costs to society, but bring substantial cost savings as well. Savings on fossil fuel bills and lower marginal costs of production of RES (Renewable Energy Sourcres) technologies will reduce the energy bill in the long run. Higher CAPEX (capital costs) are thus earned back through lower OPEX (operational costs, which set the price of energy) for society as a whole. This effect explains why the overall impacts on GDP of the low-carbon transformation are minimal and, according to some models, may even bring net benefits in terms of higher employment and GDP.

However, for individual investments the higher CAPEX and lower OPEX characteristics may lead to negative investment decisions. Lower market prices, especially in the power sector, will require the application of different revenue and risk models compared with reference cases in order to make the investments attractive.

### Revenue and risk combinations differ from sector to sector

While capital in the form of public equity (stocks and bonds) is ready to step in, this will crucially hinge on the revenue-generating business case in combination with perceived risks. Revenues and risks tend to be different for the various sectors in the economy.

For the **electricity sector**, the main problem relates to lower revenues and increasing risks. It creates a market signal that lowers investment appetite, while investments need to rise for the low-carbon transition. In our view, the current approach of governments to subsidize low-carbon investments (e.g. through FiT/FiP schemes) is untenable in the long run, since there is a substantial risk premium involved in subsidy programs (i.e. risk of government failures). Moreover, evidence shows revenues tend to decline in the electricity sector at a faster pace than the learning effect of technology. As such, subsidy programs will be self-defeating in the sense that they would eat out a larger share of government budgets or increase charges on consumption.
Higher perceived risks add an additional risk premium that in turn demands even larger subsidies. The only way to reverse this trend is through a very substantial carbon price for fossil fuel-based electricity generation.

For **industry**, the main problem is related to the sheer volume of investments in energy-intensive sectors. Energy-intensive industry operates in a matured EU market with 'zero growth' projections. Decarbonisation demands investments well above the observed historical investment rates. This poses a very substantial challenge. Furthermore, it is likely that up to 2050, owing to the principle of "common but differentiated responsibilities", differences in carbon prices between EU and non-western companies will persevere. Combined with the stagnating EU market and the considerable size of investments required, it becomes clear that the traditional model of taxing carbon-intensive production is untenable for the industry sector. **In our view, the EU ETS production-based regulation approach should be developed into climate policies taxing carbon-intensive consumption goods irrespective of the country of production. A Carbon Added Tax (CAT) could be a blueprint for the EU industrial revival by lowering tax rates for the best performers.** For some sectors such as refineries, future demand is expected to decline and for these sectors a system of 'managed decline' may be required, similar to the closure of the coal mines over the last three decades in many European countries.

Decarbonisation is particularly challenging for **transport and the built environment**. Most studies on transformation for these sectors have only considered marginal changes to the present situation. A major problem for these sectors is what has been labelled 'consumer myopia': consumers tend to weight current expenses much more heavily than future savings.
This limits the uptake of low-carbon technologies and investments in these sectors. We have identified a major knowledge gap related to how situations with high personal 'interest rates', impeding profitable investments, could be handled in a fashion that is suitable for 21st century democratic governments, i.e. without directly forcing consumers to invest. Although an extension of regulations (e.g. product standards) could be very helpful in overcoming consumer myopia, most governments tend not to be ready to accept stricter regulatory approaches for consumers. Other bottom-up approaches may be required that would stimulate and inspire the uptake of zero-carbon lifestyles and products.

### Regulatory risks are a very important determinant

In addition to these sectoral obstacles, we have investigated macro-economic risks. We conclude that price risks (exchange rates, fossil fuel prices) are probably not very important and could, under normal circumstances, be hedged in financial markets. However, institutional risks seem to be much more important. Misleading lobbying and ill-informed policy decisions may be important risks on the low-carbon economy path.

In order to make private capital available, carbon prices should rise substantially to around € 250/t$CO_2$ in 2050. In the current political economy, however, there is a strong lobby against higher carbon prices. Some frontrunner companies do include implicit carbon costs in their investment decisions, but virtually none of those would work with carbon prices above € 50/t$CO_2$. In the absence of a high $CO_2$ price, a myriad of subsidies, regulations and price instruments will have to guide the transition towards the low-carbon economy. In our view, a path along these lines will most likely lead to suboptimal policy choices. Recent examples of drastic changes in support schemes in Spain and the Czech Republic have shown that governments will cut back support schemes if state budget deficits emerge. These experiences drive up the risks for investors, making investments even more expensive.

## Our five specific policy recommendations

A successful and sustainable approach to a low-carbon transformation needs to build on well-founded policymaking. This study makes five specific policy recommendations:

1. **Carbon prices should increase rapidly to create value for low-carbon investments and devaluate the most polluting assets.** The most important policy recommendation is that the low-carbon economy transition cannot be realized without very rapidly increasing carbon prices. In an optimal scenario, carbon prices would have to climb to € 30/t$CO_2$ now and gradually increase to € 100/t$CO_2$ in 2030 and to € 250/t$CO_2$ in 2050. Such high carbon prices will rapidly depreciate existing assets and in this way make room for new investments.

   Policymakers should commit themselves to the urgent need for the carbon externality to be appropriately priced. This implies that they should acknowledge and communicate that carbon prices will likely need to rise to over € 250/t$CO_2$ by 2050. Although such figures are stated in official studies, e.g. the European Commission's Impact Assessments of the 2030 framework, these should be more explicitly communicated and be used to frame the upcoming rapid economic transition.

   In the absence of high carbon prices, complementary policies (i.e. a mix of subsidies and regulation) would be required to create value for the low-carbon investments. Such a pathway will increase the overall cost of the transformation, open the floor to lobbying and consequent misallocation of resources and is likely to be untenable because of public concerns over worn-out governmental budgets and/or consumer bills.

2. **Carbon should be priced in every corner of society and the ETS should be complemented with additional provisions and instruments**
   Policy design should ensure that the carbon externality is appropriately priced economy-wide. Carbon prices cannot be enforced through the ETS alone, since more than half of Europe's emissions are not covered directly by the ETS. Therefore, the ETS should be complemented with additional policies that aim to price carbon explicitly.

   In the design of such a system, special emphasis should be put on feedback loops. Our analysis shows that in the present systems, incentives are sometimes in the wrong place. For example, for the power sector carbon prices need to increase as more renewables are being deployed, to compensate for the decrease in inframarginal rents. However, in the present ETS, deployment of more renewables reduces the carbon price as the supply of carbon allowances is fixed. A provision whereby deployment of a larger share of renewables lowers the ETS ceiling would mitigate this impact.

For industry, inclusion in the ETS may in the long run be problematical as investment costs increase significantly and costs of low-carbon investments cannot be passed through in full to consumers because of international competition. In our view, the EU ETS production-based regulation approach should be developed into climate policies that tax carbon-intensive consumption goods irrespective of the country of production. A Carbon Added Tax (CAT) could be a blueprint for the EU industrial revival by lowering tax rates for the best performers.

For the built environment and the transport sector, inclusion in the ETS may not be required, as the introduction of (high) carbon taxes may be more effective. It is important to understand that, in these sectors, the price mechanism will have to be complemented with other forms of regulation (e.g. technology standards) to mitigate 'consumer myopia'.

3. **Stimulate a wider range of capital sources**
Governments should focus on creating favourable conditions to increase available venture capital for low-carbon investments. Many low-carbon technologies have already been developed, but will need support to be scaled up and deployed. In terms of capital, there seems to be no shortage of capital for R&D, but rather for the next stage, which should lead to commercially attractive options. At the moment there is little policy support for this stage, as there is limited deployment support for low-carbon technologies close to maturity, which need to be deployed in a matured (and often oversupplied) demand market. Governments could subsidize venture capitalist participation in low-carbon technologies by removing potential risks.

In addition, governments could lower the transaction costs for the transport and built environment. In these sectors the volume of small investments is unattractive for most investors other than banks.
For example, governments could provide for bundling of energy saving projects into financial products that would be attractive for larger institutional investors (e.g. pension funds, insurers, sovereign wealth funds).

4. **Reduce regulatory induced risks**
Revenues and risks are the two main criteria against which investors judge their portfolio. The low-carbon transformation most likely increases risks from an investor perspective. Not only technological risks, but also regulatory and price risks need to be considered. Such risks are currently suppressing investments and an active policy to de-risk or to share risks with investors will need to be considered.

Regulatory risks are very important both in the power and industry sectors. The most important barriers for low-carbon investments in the power sector are a lack of a stable policy framework and lack of a shared long-term outlook for RES and fossil demand, both at the EU and at Member State level. Stable policies and stable and reliable demand outlooks will reduce risks to investors as well as the cost of financing.
At present, the relevant EU directives additional to the ETS (i.e. the RED and related policies such as the EED and EPBD) have targets up to 2020. Furthermore, MS policies are quite volatile in many countries and do not present a stable regulatory framework. As the current policy of binding

targets for 2020 at Member State level (defined in the Renewable Energy Directive) will not be continued after 2020, the future of RES development in the EU will remain uncertain. In combination with current generating overcapacity, the market is sending the wrong signals for any investments, let alone low-carbon investments. A more active role of governments, including managing price risks and 'managed decline' of existing assets, may be required to keep up the pace on the path towards a low-carbon economy.

Regulatory risks also exist in the industrial sector. It is clear that free allowances can only be a temporary solution to the risk of carbon leakage. At present, with a very low-carbon price, the risk of carbon leakage is indeed quite minimal. But in the longer run, with prices required to be 30-50 times higher than observed today, free allocation will no longer be able to safeguard companies from competitive disadvantages. The 2030 framework does not address this issue and puts its hopes rather on a weak carbon price signal to continue up to 2030. This, in itself, already creates a lock-in in which industrial installations in Europe are not modernized and industrial lobbying is regarded as more effective than investing in low-carbon measures.

Another issue relates to price risks. In the Impact Assessments of the EC, it was assumed that the oil price would rise from € 110/barrel towards € 140/barrel in 2050. Today, however, prices have dropped to below € 40/barrel. Since the market profitability of low-carbon techniques is used in relation to that of fossil fuel-based technologies, the low fossil fuel prices add additional uncertainty and worsen the revenue base.
The decrease in fossil fuel prices since 2014 has made investments in renewable energy, which were already unprofitable, even less attractive. At present, low-carbon projects often depend on subsidies, making them less attractive for capital markets (as a result of higher institutional risks). In our view, governments should endeavour to stimulate investments by taxing fossil energy more heavily. For example, taxes could be set to fluctuate with the energy price level to guarantee a more stable end-price. This would make the economics of renewable energy projects more predictable.

5. **Manage declining parts of the economy**
   The low-carbon transformation implies a rapid depreciation of current assets. It will introduce a structural shift in the distribution of incomes and hence create new winners and, unfortunately, also bring losers. Sectors losing out in the low-carbon transformation are often deeply embedded in social and economic structures and their decline will have negative consequences both in economic and social terms. As such, a process of managed decline will be required to mitigate possible negative social consequences in industrial locations that heavily depend on these industries. Re-education and social programs may be required to mitigate the worst consequences of the low-carbon transformation and assist a smooth depreciation of those assets that used to be profitable in the old economic framework.

# 1 Introduction

## 1.1 Rationale and aims

Climate change is threatening future wealth, stability and wellbeing of our societies. Although governments, especially in the EU countries, have tried to establish climate policies for more than a decade, the progress up-to-date has not been enough to keep the world off the business-as-usual path to serious risks of high (and partly uncontrollable) temperature increases (PWC, 2014). The international climate negotiations, after the promising start in Kyoto, were cumbersome for several years, when short term financial interests seemed to dominate the debate over long term environmental considerations. In order to meet the (acceptable risk of reaching the) 2°C threshold climate warming in 2100, the decarbonisation efforts must increase by a factor 5 compared to what was done in 2013 (PWC, 2014). This means that five times more windmills, solar power roofs, energy saving efforts, biomass input, etc. is needed than what was done in 2013. It is beyond any doubt clear that it is a very big challenge. If the world wants to adhere to the advised 1.5°C degree threshold from the Paris summit, even a more substantial acceleration of efforts is needed. In a very short period of time we must transform the economy from a fossil fuel-based system towards a low-carbon economy.

For the EU, the transition to the low-carbon economy is documented in the policy plans such as the Low-carbon Roadmap and the 2030 Framework which outlined the targets to be reached if the EU would contribute to an 80% emission reduction in 2050 compared to 1990. The 80% target itself is already minimal to justify a fair share of EU's efforts in reductions to stay within the 2°C thresholds. A 90-95% reduction target in 2050 would probably be more fair. Moreover, the 80% reduction target falls short of the advised 1.5°C degree global warming threshold from the Paris summit.

However, reaching an 80% reduction target will already be a big challenge for the economies of EU Member States that are only slowly recovering from the most severe economic crisis since decades that lowered GDP and raised unemployment rates. The traditional belief is that, since the rate of returns on capital are low in a stagnating economy, the opportunity costs of the transition to the low-carbon economy are nowadays also lower than ever. In other words: the transition to the low-carbon economy has never been cheaper than at this particular moment. Many studies indeed showed that the transition to the low-carbon economy is the right answer to the current economic problems as this transition will stimulate both jobs and, in most cases, economic growth.[1]

Yet, such studies raise more questions than answers. Why are we moving so slowly if everyone can profit? Why are policy plans postponed and meet fierce resistance, especially among the instances that are supposed to stimulate growth? Why does the general public seem to have the feeling that what we are doing at present is the maximum possible and pleas for speeding things up by a factor 5 seem to be ridiculous?

[1] See amongst many: CE Delft (2006); ECF (2010); EC (2011); Potsdam Institute (2012); EC (2014a).

Such questions cannot be answered by undertaking more quantitative analysis alone. Therefore, the present study aims to take the Impact Assessments and Roadmaps one step further by assessing the critical factors that set the pace for decarbonisation of the European economy. The study, undertaken on request of the European Climate Foundation (ECF) and developed in close cooperation with the ECF, aims to add sophistication to the debates by providing deeper insights on the pace of decarbonisation, with a particular focus on capital, investments and revenue generating business cases, as these are believed to be the most critical factors. Rather than from a micro-economic or technical point of view, we will undertake the analysis from a macro- and meso-economic point of view by investigating the risks and challenges both at the level of nations/regions and in specific sectors.
By investigating the required investments and revenue generating business cases in various sectors (power, transport, built environment and industry), more insight can be obtained on the challenges and barriers in the transition to a low-carbon economy.

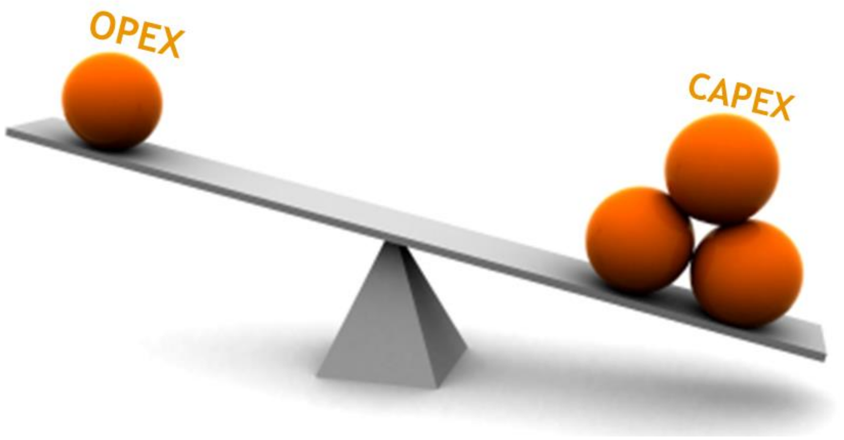
## 1.2 CAPEX/OPEX shifts as important trigger of this study

Despite the fact that many studies have shown that the transition to a low-carbon economy can give net economic benefits, there has been a sentiment of resistance against the pace of transition to a low-carbon economy from some governments and industries. This resistance can, in part, be explained by reference to what is known as the CAPEX/OPEX shift. CAPEX and OPEX refer to two different types of costs. CAPEX refers to the capital costs – which are mostly made of investments – and may be perceived as fixed costs in the economics textbook. OPEX stand for operational costs and include all costs which have been labelled as variable costs in the economics textbook.

### 1.2.1 The nature of the CAPEX/OPEX shift: investments go up and revenues go down

Literally, the CAPEX/OPEX shift implies that CAPEX increases while OPEX decreases. An increase in CAPEX implies immediate economic costs which come at the expense of current consumption and may limit economic growth in the short run. In the long run, however, the operational costs tend to decline implying lower costs which will stimulate economic growth. Such patterns of short run increasing costs and long run declining costs can be identified as a standard mechanism that drives economic progress (Freeman and Perez, 1988). It may not pose a problem if (capital) markets function efficiently, information is perfect and the future is certain (e.g. risk-free) so that loans can be easily settled. The increased CAPEX and decreased OPEX then form a transitional problem that can be solved with the use of investors seeking long term returns on their assets (e.g. in the case of pensions).

However, in case of poorly functioning financial markets, imperfect information, uncertain futures and hesitant investors, the CAPEX/OPEX shift may be an obstacle for the low-carbon transformation. CAPEX may weight so heavily that the low-carbon investments do not take off.




*"CAPEX may weight so heavily that investments do not take off"*
Illustration Ellen Vanhamme, CE Delft.

This may be aggravated by the fact that revenues, in competitive markets, are determined more by OPEX than by CAPEX. Standard economic textbooks teach us that in competitive markets prices equal marginal costs of production. As OPEX (variable costs) is the precursor of marginal costs, falling OPEX implies lower sales prices.[2] And lower sales prices make it more difficult to generate revenues for recovering the CAPEX.

The CAPEX/OPEX shift therefore has a very clear economic implication: the lower returns combined with increased investments imply **increasing difficulties in finding revenue-generating investments.** This effect is eminent, and widely recognized, in e.g. renewables such as solar and wind. Once the windmill or solar panel is installed, the operational costs are quite minimal and imply downward pressure on power prices, impeding recovery of the capital costs. [3]

### 1.2.2 Political dimensions

The CAPEX/OPEX shift is primarily a financial barrier. However, it can also be a political and institutional barrier. While the transition to the low-carbon economy may in the long run stimulate growth by lowering the costs of the economy to deliver goods and services, there is an increase in short- and medium term costs as a result of higher investment levels and internalisation of externalities. These higher costs often dominate public and political debates as they are more visible than the long term benefits. For instance, in the electricity sector, the public is initially confronted with higher electricity prices as a result of regulatory costs to stimulate the accelerated investment needs, what meets political opposition. The long run benefits in terms of lower electricity prices are much less tangible and tend to be neglected.[4]

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2 The marginal costs curve is mathematically the derivative of the variable costs curve.

3 For example, Tveten et al. (2013) estimate that (subsidised) solar electricity generation has depressed average electricity prices by 7% in Germany between 2010 and 2011. McConnell et al. (2013) have observing price decreases between 8.6 and 12% in the Australian power market due to solar-PV.

4 Similar observations can be made in other sectors, like the built environment and transport sectors, where major upfront investment costs dominate the debate over the potential long term lower operational costs.

Political opposition plays a particular role in the CAPEX/OPEX shift which, in the end, may form one of the biggest obstacles in the low-carbon transformation.

### 1.2.3 Investor dimensions

Above we have identified the CAPEX/OPEX shift as a financial and institutional barrier. There is another dimension to this, closely related to the other ones, and that relates to the investor perspective. What would the CAPEX/OPEX shift imply for investors? What would the challenges for investors to participate in the low-carbon economy transformation be?

In this study we discuss the investor perspective from three particular angles:
1. Investment needs (volume).
2. Revenues.
3. risks.

**Volume** matters since the total investments into a low-carbon economy may crowd-out current investments if very substantial. A large demand for capital may drive up interest rates. This is not only relevant for the total bulk of investments, but may also be relevant for specific sub-components. Investor capital is usually divided into various capital streams, each demanding specific risk/revenue combinations. This may be relevant for the low-carbon economy investments since capital for R&D has a different revenue/risk combination than capital for large-scale windmill farms.

Expected **revenues** form the prime rationale why investment can be attracted. Expected revenues must be compared with expected revenues from alternative investments. Revenues in the low-carbon economy transformation must thus be on par with expected revenues from other investments – otherwise there will be no business case. In formal calculations, revenues can be identified as the rate of return on investments.
**Risks** are crucial as well. Risks can be defined as the chance that the expected revenues will not materialize. Therefore, risks are often discussed in one go with revenues. Investments with high risks require higher returns.

Risk management is a very conceivable part of investment analysis and various strategies to minimize risks, or diversify risks, have been developed in the literature. While we will not dive too deep into the details of risk management, economic developments and decisions of economic actors may influence the risk perception of low-carbon investments and eventually drive up the required revenues. This can form an impediment to the low-carbon economy transformation.

### 1.2.4 Cost dimensions

Next to financial, institutional and investment barriers there may be a fourth one, that relates to the total costs of the transition towards the low-carbon economy. The general perception is that this may be accompanied with substantial costs for the economy and will form a heavy burden for society. However, such perceptions are primarily constructed by confusing system costs with societal costs. It is beyond any doubt that the low-carbon transformation will entail substantial costs for some groups in society. However, economic analysis using economic models indicates that the total impacts on GDP may be very limited or even absent (see also Paragraph 2.4).

It is therefore useful to elaborate for a moment on the various costs concepts. The abatement cost of a technical measure can be assessed from the perspective of the end user or that of the society as a whole.

These perspectives do result in different abatement cost figures because taxes and subsidies should be taken into account by the end user perspective, while they are not relevant from the perspective of the society where they merely constitute a transfer.[5] From the societal (or social) perspective, the taxpayer transfers the tax as income to the government and in the case of a subsidy, the government transfers income as a subsidy to the recipient. In both cases, taxes and subsidies do not influence GDP or welfare directly and are primarily transfers.[6]

A closely linked distinction is between total societal costs and energy system costs. Energy system costs are the costs for providing energy functions to energy users. These costs do include carbon taxes. From the social perspective, carbon costs are not a cost component but rather a transfer.

Within this study, most of the analysis in the main report (Chapter 1-6) has taken a societal perspective while most of the analysis in the sectoral chapters (see Annexes) has taken an end-user perspective. In general, the low-carbon transformation has lower costs for society than for specific end-users of energy-intensive products.

## 1.3 Objective of this study and framing

The objective of this study is to provide insight to what extent the CAPEX/OPEX shift forms a barrier to the transformation into a low-carbon economy in 2050.

In order to do this, the following sub-objectives have been formulated:
- to analyse the expected developments in the various sectors of the economy (electricity, transport, built environment, industry) in their transformation to the low-carbon economy with respect to targets and investments;
- to identify potential bottlenecks especially with respect to investments, risks and returns on investments (CAPEX/OPEX shift);
- to analyse to what extent current policies are fit to overcome these bottlenecks and/or alternative frameworks may be required.

This study thus focuses on investments as the key driver that sets the pace of decarbonisation. The study is not a deep-dive in the abatement opportunities and business models in the various sectors discussed, but rather aims to identify key trends and characteristics that impact the overall pace of decarbonisation and the total challenge for policymakers in designing the overall low-carbon policy framework. In this way the study aims to provide an additional step beyond the top-down information included in the various Roadmaps and Impact Assessments that were published in the last five years. Although we aim for an additional step beyond the top-down perspective, we have not aimed for a strict bottom-up perspective either, as this may become very technical in nature and influenced by short term perceptions that may not be that relevant in the time-frame of the 35 years ahead up to 2050. Therefore, the perspective chosen in this study can best be labelled as bridging the gap between the macro- and meso-economic framing.

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[5] Potential changes in consumption from the implementation of taxes and subsidies can result in changes in producer and consumer surpluses which matter for welfare.

[6] Indirect impacts may exist, see also Footnote 5.

The meso-economic perspective necessitated the use of a sectoral approach as the low-carbon transformation may pose different challenges for the various sectors in the economy. We have selected in this study four sectoral perspectives:
- power;
- industry;
- transport;
- built environment.

These sectoral perspectives have been used to construct an overall view on the pace and challenges of the low-carbon economy transformation. However, in order to keep the story floating we have decided to move the sectoral chapters to specific Annexes (Annex C-Annex F).

## 1.4 Methods

This study will be based on a literature review. We started from the Impact Assessments from the EC on the Low-carbon Roadmap (EC, 2011b) and the 2030 Framework (EC, 2014a). The quantitative information in these studies have been used by us and complemented with additional statistical information to provide more background and insight to the abstract numbers mentioned in these impact assessments. Then they has been put further in perspective by performing a literature analysis. In addition, we have conducted telephonic interviews with experts to learn their perception and insights on identified risks from the literature.

## 1.5 Structure of the report

In Chapter 2 we will present the targets, system costs and economic impacts of the low-carbon economy transition up to the year 2050 with special focus on the investments and operational costs that can be expected. In Chapter 3 we will analyse which potential hurdles can be expected with respect to the transition to a low-carbon economy from an investment perspective. In Chapter 4 we will expand this analysis to include specific macro-economic risks that will be relevant for all sectors in the economy. Chapter 5 draws then general conclusions of this study and tries to give account of the hurdles that can be expected in the transition towards the low-carbon economy.

Annex A and Annex B provide further information and technical descriptions of PRIMES and the Impact Assessment scenarios. Annex C-Annex F present sectoral perspectives. In these Annexes we will analyse the volume of investment needs, revenues and risks for four relevant sectors: Electricity markets (Annex C); Industry (Annex D); Transport (Annex E) and Built Environment (Annex F).

# 2 Targets, investments, costs and impacts up to 2050

## 2.1 Introduction

In this chapter we will first investigate the targets (Paragraph 2.2), investments and costs (Paragraph 2.3), and economic impacts (Paragraph 2.4) of moving to a reduction of 80-95% in 2050. We will do this through analysing the Impact Assessments accompanying the EU Low-carbon Roadmap and the 2030 framework. Each of these Impact Assessments used the PRIMES model in order to do forecasts. PRIMES was accompanied by economic models (GEM-E3 and E3ME) and other models (e.g. on land use, acidification, etc.).

PRIMES is a partial equilibrium model of EU energy markets and is used for forecasting, scenario construction and policy impact analysis up to the year 2050. Basically PRIMES consists of a cost-optimisation model where individual consumers and producers of energy (e.g. companies) have choices among fuel inputs, investment of abatement technologies, etc. Optimisation is acquired by assuming that marginal costs of energy consumption (including $CO_2$ taxes or EUAs) equalize among various users.

When PRIMES is used in Impact Assessments, it is for comparing the proposed policy plans with a reference scenario. The reference scenario contains the policy instruments in place (but no new policy instruments) and is updated every few years in order to take account of the most recent economic and policy developments. It is in this light important to notice that the PRIMES Reference scenario differs between the Low-carbon Roadmap and the 2030 IA. The LCR uses the PRIMES reference scenario of 2009, while the IA uses the PRIMES reference scenario of 2013. More about PRIMES and the differences in the Reference Scenario can be found in Annex A.

We will investigate forecasts with PRIMES from both the Low-carbon Roadmap and the 2030 Framework for one specific scenario. From both Impact Assessments we have chosen the scenario that most precisely resembles the current policy initiative. For the 2030 Framework this is the GHG40 Scenario, while for the Low-carbon Roadmap, this is the Delayed Climate Action scenario. The fit of the GHG40 Scenario with the current policy proposal (see Paragraph 2.2.1) is a bit better than the fit with the Delayed Climate Action scenario, since in the Delayed Climate Action Scenario it is assumed that a 2030 GHG emission reduction of only 35% is achieved. For that reason, our main treatment in the analysis below will be from the 2030 Framework. The results for the Low-carbon Roadmap are presented in Annex B for reference.

## 2.2 Targets

### 2.2.1 Political reality

There are no binding 2050 EU targets yet, but EU leaders have endorsed the objective of reducing Europe's greenhouse gas emissions by 80-95% compared to 1990 levels as part of efforts by developed countries as a group to reduce their emissions by a similar degree (EC, 2014a).[7] This ambition was restated in the EU's submission to the UNFCC in 2015 with a particular ambition to reduce in 2030 40% of domestic emissions of greenhouse gasses compared to 1990. The 2030 intermediate goal was formulated and designed in the proposal for the 2030 framework (COM 2014/15 final) in January 2014. In this document the EC proposes to use a single GHG target in 2030 of -40% reduction domestically compared to 1990. The EU level target must be shared between the ETS and what the EU Member States must achieve collectively in the sectors outside of the ETS. The ETS sector would have to deliver a GHG reduction of 43% in 2030 and the non-ETS sector a reduction of 30%.[8] For the ETS, the annual reduction factor would be increased from the present 1.74 to 2.2% after 2020 and a Market Stability Reserve would be created to prevent the oversupply of allowances to continue after 2020.

This proposal was largely taken over by the European Council. It has further been agreed on the objective of increasing the share of renewable energy to at least 27% of the EU's energy consumption by 2030 and on an indicative energy saving target of 27% to be reviewed in 2020, having a 30% target in mind.

It should be noted that the outcome of the Paris summit may lead to a renewed discussion on required GHG targets. The Paris summit asked for efforts for "*holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C*". In this context a pathway of 80% reduction in 2050 may be no longer aligned with the outcome of the Paris summit and more reduction efforts up to 2050 may be required.

### 2.2.2 Targets and scenarios in the 2030 IA

In the impact assessment of the 2030 EU policy framework for climate and energy, several policy options with different energy and climate targets are analysed and compared with the EU Reference Scenario 2013. The EU Reference Scenario 2013 assumes full implementation of the 2020 climate and energy package and continuation post-2020 of the ETS (annual 1.74% reduction of the cap).

The GHG40 policy scenario mostly resembles the currently chosen policy proposal of October 2014 and will therefore be used in this chapter as the policy scenario. In the GHG40 policy scenario 40 and 80% GHG reduction targets respectively in 2030 and 2050 are achieved. The GHG targets are thereby met through the equalisation of increasing carbon prices and values (which implies a tightening of the linear reduction factor in ETS) whereas it is assumed that no additional energy efficiency policies or additional policies to

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7 The European Parliament stressed in their 2009 recommendations for the EU's future integrated policy and climate change (EP, 2009), the importance of setting, for the EU and the other industrialised countries as a group, a long term reduction target of at least 80% by 2050, compared to 1990.

8 Both figures compared to 2005.

stimulate the share of renewables are implemented. The overall share of renewables will nevertheless increase and it is estimated to reach approximately 27 and 51% in 2030 and 2050 respectively. For passenger cars it is assumed that as of 2035, more stringent $CO_2$ standards will apply to stimulate electrification. For the GHG targets to be met in the GHG40 scenario, so-called enabling conditions are assumed, presupposing effective structural changes in all sectors of economy, timely and effective market coordination as well as public acceptance. While these enabling conditions are in particular affecting energy system changes closer to 2050, they already start to have an effect as of 2030.

Table 1 gives an overview of the projected sectoral emission reductions compared to 2005 for the sectors analysed in this study.

**Table 1 Emission reductions in 2050 compared to 2005 for both the PRIMES Reference scenarios and the 80% reduction scenario**[9]

| Targets | Ref | 80% scenario |
|---|---|---|
| Total EU28 | 40% | 80% |
| Power, CHP and district heating | 73% | 98% |
| Industry | 44% | 78% |
| *ow EU ETS* | *NA* | *68%** |
| *ow non-ETS* | *NA* | *61%* |
| Transport | 10% | 64% |
| *ow road transport* | *NA* | *70%*** |
| Built Environment | 39% | 82% |

* This includes the reduction of refineries from the reduced demand from decarbonized transport sector. If this reduction is not taken into account, the reduction of the ETS sector is 60% - similar to the non-ETS industrial sector.

** Not calculated in the Impact Assessment but from Sultan model runs for the EC White Paper from 2011 – see Annex E for more detail.

This table (see for more detail Annex C-Annex E) shows that in order to achieve the 80% emission reduction, especially the power sector should be completely decarbonized. Next to the power sector, major emission reductions were formulated for the built environment – which is in total size the largest sector (with about 36% of total GHG emissions). Annex B.4 gives more information on the prices that have been used for these scenarios.

## 2.3 Investments and costs

### 2.3.1 Investments from the 2030 IA

In the documents following the original Impact Assessment, the energy system costs are not only given from an end-user perspective but also from the perspective of the sectors that have to invest in the first place (see Table 2 and Figure 1.They show the total investments that are required to meet the targets).

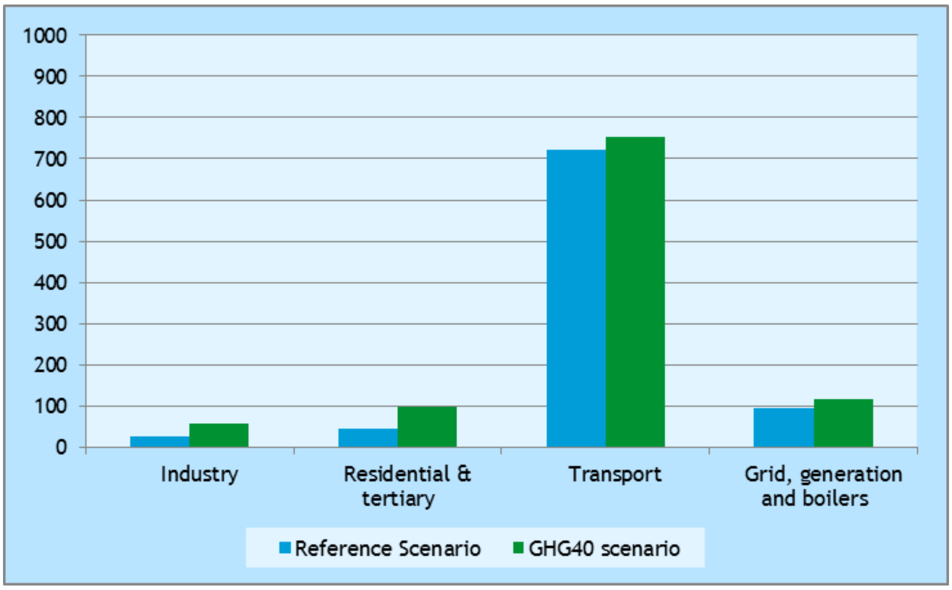
9 PRIMES Reference scenario of 2013 is used (EC, 2013a) and the GHG40 scenario from the Impact Assessment (EC, 2014a).

**Table 2** Average annual investment expenditures per investing sector (€ 2010 billion)

| | Reference Scenario | | GHG40 policy scenario | |
|---|---|---|---|---|
| | 2011-2030 | 2031-2050 | 2011-2030 | 2031-2050 |
| **Investment expenditures** | **816** | **854** | **949** | **1,188** |
| Industry | 19 | 30 | 24 | 88 |
| Residential | 36 | 28 | 49 | 77 |
| Tertiary | 14 | 10 | 25 | 41 |
| Transport | 660 | 782 | 662 | 843 |
| Grid | 37 | 41 | 41 | 56 |
| Generation and boilers | 50 | 59 | 53 | 85 |

Source: EC, 2014b.

**Figure 1** Average annual investment expenditures 2011-50 per investing sector (€ 2010 billion)




Very high investment expenditures in the transport sector, both in the reference and the GHG40 policy scenario relate both to infrastructure investments and vehicle (replacement) purchases which constitute a large share of investments in today's economies (see also Annex F).

In the GHG40 policy scenario investment expenditures rise in all four sectors compared to the reference scenario. The expenditures of the industry and the residential & tertiary sector increase most profoundly. The total additional investments will rise from € 130 billion annually in the period 2011-2030 to € 330 billion in the period 2030-2050. In terms of GDP, this implies that annually about 1.25% of GDP in 2025 to 1.75% of GDP in 2040 needs to be spent on new investments.

There is some reason that the perceived investments may be larger.
The Reference scenario itself is already policy intensive since the reference scenario contains all existing policies up to 2020 and a continuous reduction of $CO_2$ of 1.74% annually in the EU ETS afterwards. Investments needed for a low-carbon economy are thus partially included in the reference scenario.
In the reference scenario, energy-related investments (excluding transport) are 47% higher in the decade 2021-30 compared to the decade

2001-10.[10] Transport-related investments are projected to exceed those in 2001-10 by 31%, while they are expected to be 20% higher than such investment in the current decade. Therefore, the additional investments needed for transforming to a low-carbon economy are substantial and may be potentially perceived as a hurdle.

### 2.3.2 Costs from the 2030 IA

The increase in investments is accompanied by a – less substantial - increase in energy system costs. The fact that costs increase less than investments is one indication of the CAPEX/OPEX shift. The energy system costs are given in two different ways in the Impact Assessment.[11] First, from an end-user perspective and, second, from the perspective of a sector that has to invest in the first place.

**Table 3 Annual average energy system costs in reference and GHG40 policy scenario (€ 2010 billion) - end user perspective**

| | Reference scenario | | GHG40 scenario | |
|---|---|---|---|---|
| | 2011-2030 | 2031-2050 | 2011-2030 | 2031-2050 |
| **Capital costs** | **590** | **939** | **598** | **1,071** |
| Industry | 57 | 84 | 60 | 91 |
| Residential | 304 | 450 | 305 | 438 |
| Tertiary | 52 | 83 | 51 | 67 |
| Transport | 177 | 322 | 182 | 474 |
| **Direct Efficiency Investment** | **35** | **35** | **47** | **274** |
| Industry | 1 | 5 | 2 | 74 |
| Residential | 24 | 22 | 29 | 128 |
| Tertiary | 10 | 8 | 16 | 71 |
| Transport | 0 | 0 | 0 | 0 |
| **Energy purchase costs*** | **1,454** | **1,586** | **1,436** | **1,394** |
| Industry | 279 | 291 | 273 | 258 |
| Residential | 426 | 498 | 421 | 455 |
| Tertiary | 238 | 262 | 234 | 218 |
| Transport | 510 | 534 | 508 | 463 |
| **Total system costs**** | **2,067** | **2,520** | **2,069** | **2,727** |

Source: EC, 2014b.

* Including capital costs corresponding to power & gas infrastructure (plants & grids), refineries and fossil fuel extraction, recovered in the model through end user prices of energy products as well as supply side auction payments under energy purchases, embedded in the energy prices.

** The sum of capital costs, direct efficiency investment and energy purchase costs is higher than the total system costs, because total system costs do not take supply side auction payments into account.

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10 The decade 2000-2010 was marked by rather low investments; the estimated investments in the next decade are however 21% lower than those during this decade to 2020, where strong efforts are needed for implementing the 2020 targets and policies.

11 In the following we present the energy system costs that have to be incurred in both the reference scenario and the so-called GHG40 policy scenario which most resembles the current decision by the parliament in October 2014.

In Table 3 the costs are given from the end-user perspective.[12] This table shows the annual energy costs categorized to various components. The table shows that, compared to the Reference scenario, capital costs tend to go up and energy purchase costs down – especially and most remarkably in the period after 2030. This evidences the potential CAPEX/OPEX shift.

When comparing sectors it evidences that energy costs are higher in the transport and residential sector than in the industry and service sectors. Furthermore, the comparison of the reference and the GHG40 scenario reveals that:

- The direct efficiency investments increase, in relative terms, the most, compared to the capital and energy purchase costs, with 2011 levels being very low. Only in the transport sector no direct efficiency investments are included both in the reference and in the GHG40 scenario.
- Capital costs increase significantly for the transport sector and to a lesser extent for the industry whereas capital costs for the residential and tertiary are lower than in the reference scenario.
- The average annual energy purchase costs decline for each of the four sectors.

For the four sectors taken together, the average annual total system costs, i.e. the sum of the annual capital costs, the annual average direct efficiency investments, and the annual average energy purchase costs amount in the reference scenario to 14.03 and 12.3% of GDP in 2030 and 2050 respectively, whereas in the GHG40 scenario the share increases to 14.18 and 13.96% of GDP in 2030 and 2050 respectively.

There is one important caveat to this analysis. In the Impact Assessment of the 2014 Framework, energy savings were estimated with a forecasted oil price development increasing from $ 110/barrel towards $140/barrel in 2050. While such price increases seemed logical in 2013 when the scenarios were constructed, we know that the oil price actually followed a reverse trend. Since the summer of 2014 prices of crude oil have been falling steadily to quote less than $ 40 in the beginning of 2016. Analysts do not predict any soon recovery to the high price path of 2005-2014 (see also Chapter 5). Therefore, the calculated energy savings from the IA of the 2030 Framework will be probably substantially less profitable, what implies higher costs. At this moment, there have not been any studies undertaken to quantify the costs of the low-carbon transformation for lower fossil fuel price paths.

## 2.4 Macro-economic impacts of the 2030 Framework

Both the Low-carbon Roadmap (Annex B) and the Impact Assessment of the 2030 framework conclude that the transition to the low-carbon economy can bring about net economic benefits although initially the costs prevail.
The IA of the LCR identifies that the transition to a low-carbon economy may hamper economic growth up to 2030 slightly by about 2% if other countries do not adhere to stronger climate policies. However, employment impacts are expected to be positive.

[12] The end user perspective implies that capital costs corresponding to power & gas infrastructure (plants & grids), refineries and fossil fuel extraction are not explicitly given, but are expected to be recovered by end user energy product prices.

This slightly contrasts with the IA of the 2030 Framework that predicts lower negative economic costs, and possible economic benefits according to one model. The GEM E3 model run shows that there will be a loss of between 0.1% and 0.45% of GDP in 2030, depending on the approach to carbon pricing in the non-ETS sectors and the use of auctioning in the ETS. Energy-intensive sectors could be adversely affected if they cannot pass the opportunity costs of free allocations on to consumers.

This contrasts slightly with the result of the E3ME model runs that show that net economic benefits can be expected to stimulate economic growth by between 0-0.5% depending on the extent to which auxiliary renewable energy and energy efficiency policies are formulated. The increase in GDP can be attributed to removing existing inefficiencies and reducing fuel costs.
The reduced fuel costs will positively impact the EU's trade balance and keep funds in the EU. While higher investment expenditures add to system costs, sectors and companies providing technologies and solutions for the reduction of emissions, the improvement of energy efficiency, the deployment of renewables, etc. can profit. Part of this revenue will go to companies outside the EU, but such investments have greater potential for driving jobs and growth in the EU than fuel imports.

E3ME model runs shows that in GHG40 in 2030 0.7 million additional jobs (+0.3%) will be generated, especially in the basic manufacturing, engineering and transport equipment, utilities, construction and supply chain. However, extraction industries and refineries will show negative employment figures. Moreover, the GEM E3 model runs indicate that the way of recycling auction revenues is highly influencing possible employment benefits. The biggest increases in employment result from the changes in energy efficiency requirements in the residential and tertiary sector. The employment changes due to increased investments in the power generation sector are smaller but positive on the aggregate level, with losses in oil, gas and coal power plants and nuclear power.

## 2.5 Conclusion and discussion

In this chapter we have analysed the investments that are needed in the overall economy to transform to the low-carbon economy in 2050. In order to comply with the 2°C degree threshold a minimum of 80% reduction in the EU compared to 1990 is required, although it is likely that the outcome of the Paris summit would point at the necessity of even further emission cuts.
The investments to achieve 80% reduction are given relative to the reference scenario and grow from 1.25% of GDP in 2025 to 1.75% of GDP in 2040. However, in reality investments may be perceived as higher since the PRIMES Reference Scenario is already quite policy intensive with substantial investments in the ETS sectors ahead.[13] It is therefore prudent to regard investments in the range of 2% compared to GDP.

[13] E.g. for the power sector, the additional investments due to the current policy package (2011-2020) compared to the investments in the previous decade (2001-2010) shows that the additional investments can be perceived as substantial – contributing to an even larger pressure on investments than the comparison of the GHG40 policy scenario with the Reference Scenario.

One should bear in mind that these are substantial investments since GDP can be regarded as the reward on the input of production factors of labour and capital. If 2% of GDP is to be reserved to finance the transition to a low-carbon economy, this will most likely reduce the consumption at the expanse of additional investments. However, these investments bring out benefits as well. First, the investments will realize savings in costs. Due to savings on fossil fuel bills and the lower marginal costs of production of RES technologies, we are capable of bringing the energy bill down in the long run. Since we are, according to PRIMES, already spending more than 12% of our GDP on energy, these investment costs could be perceived as part of the energy system costs, which would make it perhaps easier to swallow. Since the benefits accrue directly to the consumer of energy, there can be some room to finance these investments – although considerable time lags between costs and benefits exist. However, the lower oil price developments than anticipated may imply that the carbon reduction measures become less profitable than anticipated in the IA.

The other benefit is economy-wide: the transition to the low-carbon economy can have wider economic benefits and result in an increase in employment and productivity. As labour participation is currently quite low in the EU (with relatively high shares of involuntary unemployment), this is a desired policy outcome with little risk of inflating labour markets and wages. The wider economic benefits can be divided into four categories:

1. Stimulation through investments. Especially if the EU could attract more foreign capital, or reduce the outflow of capital, the volume of production would increase which may stimulate employment. However, if the investments would merely crowd out existing investments, no positive impacts on growth can be expected.
2. Short run stimulation through reduced energy imports. The reduction in energy imports will favour the terms of trade in the EU and can present an economic benefit. However, exchange rate modifications will dampen this effect in the long run.
3. Reducing costs through tackling existing inefficiencies. By rationalising energy use existing inefficiencies could be taken away which may reduce total costs and improve labour productivity. This may also reduce employment but enhance economic growth.
4. A short run compositional benefit. As energy saving and production of renewable energy tends to be more labour-intensive, the increase in energy saving and RES and decrease in production of fossil fuels has benefits for employment in the short run.

Although each of these benefits can be sweeteners to the bitter investment needs, they are more conditional, and uncertain, than the investment challenge itself.

# 3 Further elaboration of the investment challenge

## 3.1 Introduction

In the previous chapter we have seen that the investments needed for the transformation to the low-carbon economy are substantial and amount most likely to 2% of GDP annually for the next 35 years. This chapter analyses in more detail the consequences of this amount of required investments on the economy and the investors. First, in Paragraph 3.2 we will try to frame the overall investment needs and compare the magnitude and pace of the investment challenge to other historical periods of substantive investments. This will give a sense of knowledge on what actually is needed for the transformation towards the low-carbon economy. Then in Paragraph 3.3 we take a sectoral perspective and discuss the magnitude and direction of investments in the four investigated sectors in this study (power, industry, transport and built environment). In Paragraph 3.4 we will further elaborate on the investment challenge by taking a technological and institutional perspective: what is actually needed to achieve the necessary emission reductions for Europe's share to global emission cuts to achieve (a fair chance) of staying within the 2°C degree threshold. Finally we will investigate to what extent the capital required poses a challenge for the capital market. We will discuss if enough capital is available to finance the transition and if the right distribution of capital is available. Paragraph 3.5 concludes.

Risk profiles and the question to what extent the low-carbon transformation will generate enough revenues to form an attractive investment climate with acceptable risks will not be dealt in this chapter but it will rather be the focus of Chapter 4.

## 3.2 Interpretation of investment efforts

### 3.2.1 Total investments

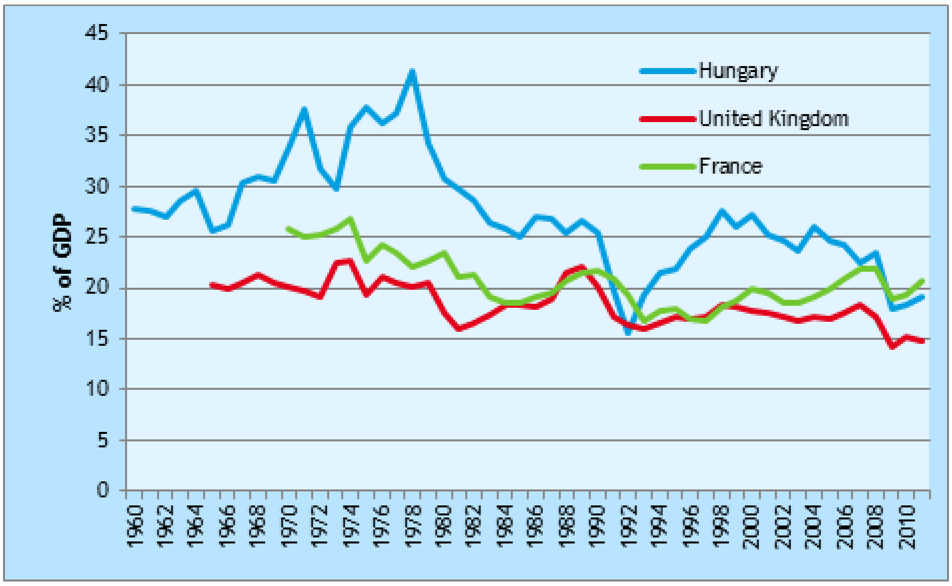
The investments needed for the transformation to the low-carbon economy are substantial and amount to 2% of GDP annually up to 2050. First we will compare this with the general investment into an economy. Generalized figures on investment can be taken from the system of SNA by investigating the indicator 'Gross capital formation'. Gross capital formation equals the sum of additions to the fixed assets of the economy plus net changes in the level of inventories.[14] In general, gross capital formation in EU economies fluctuates around the 20% of GDP. This implies that the investments needed for transformation to a low-carbon economy are equivalent to a total of 10% of total investments in the economy. One should understand that this figure is quite high indeed.

[14] Additions to fixed assets include land improvements; plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings and machinery. Inventories are stocks of goods held by firms to meet temporary or unexpected fluctuations in production or sales, and 'work in progress'.

While the figure of 10% gives an average for the total economy, the impact at the sectoral level will be much larger. The ECF 2050 Roadmap, for example, indicates that investments in the power sector needs to be more than doubled compared to BAU (ECF, 2010, p70).

However, in terms of the historic development of investments, such a figure may not be prohibitively high. Figure 2 gives a long term overview of the gross capital formation in percentage of GDP.

**Figure 2 Gross capital formation as percentage of GDP in three selected countries**




Data: Worldbank.

This figure shows that in the UK investments have gradually decreased over time from around 20-25% of GDP in the 1960s and late 1980s (related to the Thatcher-liberalisations) to a meagre 14% in present times. In France, the investments have been increasing again after the turn of the century and are now around the 20%. In Hungary investments were much higher during Communist times – especially before the 1980s – due to an overstimulation of the economy through ill-placed investments. Also after the collapse of the Communist regimes, investments started to increase rapidly due to the transformation to a market economy that implied replacement of most of the obsolete technologies. Since the year 2000 investments have been gradually falling to levels comparable with other EU countries.

We therefore conclude that an additional 2% of investments is a substantial input, but is not impossible given the historical fluctuations in the investment rates.

### 3.2.2 Comparing with other expenditures and programs

The question is what the investment effort must be compared to. If one would compare the required investments to military spending, one could observe that the required investments are in general about a half of the current military spending. According to the Stockholm International Peace Research institute, SIPRI (2015), the world military spending in 2015 was estimated to be $ 1563 trillion, corresponding to 2.1% of the world GDP of that year. In the US this was almost $ 600 billion, corresponding to 3.3% of their GDP. For the EU member states the annual military expenditures between 2005 and 2014 corresponded with 0.5-2.5% of their GDP (SIPRI, 2015). The average military spending of the EU15 in the 1990s was 2.2.% of GDP which thus is comparable to the expected expenditures for the low carbon economy transformation.[15]

The additional investment efforts can also be viewed against large transitional stages in single economies. From Figure 2 we can see that the transformation to a market economy resulted in a temporary steady increase in investments in Hungary compared to EU countries like France. These additional investments were done in a relatively short timeframe of 15 years (e.g. 1992-2007). In that period, the investments as % of GDP were on average 5% higher in Hungary than in France. Although it is difficult – if not impossible - to compare, the investment efforts may be similar in scope. The 5% higher investments over a period of 15 years in Hungary would be more or less equivalent to the 2% higher investments required for the transformation to a low-carbon economy over a period of 40 years due to EC policy plans. Therefore, with a lot of caution, one could compare the effort to establish the transformation to the low-carbon economy as being similar to the effort of transforming the new Member States into market economies.

There is one very important difference however. The transition to market economies involved substantial investments to facilitate reallocation of capital in production sectors, machinery and infrastructure. There was no Marshall Plan for these countries and they were primarily assisted by foreign direct investment (FDI) by securities and bank credits (IMF, 2000) that seek a reasonable return on investments. Although the EU did create a program to facilitate the transition through the ‘Program of Community Aid for Central and East European Countries’, it was relatively small. From 1990 to 1999 the Central and Eastern European countries received approximately $ 220 billion (Sarnary, 2002) from public equity. This is approximately 0.1% of their GDP at those times and 1/50 of the total investments that were done. For several reasons one can assume that the input of governmental funds to the transformation to the low-carbon economy must be much more substantial (see also below and Chapters 4-Annex E).

This may have been different in the case of the reunification of Germany as the East-Germans had no possibility of exchange rate adaptations, what made investments in their old infrastructure and economy unprofitable. In 1990 the German reunification started: the German Democratic Republic (East Germany) joined the Federal Republic of Germany (West Germany). Investments were needed to transform former communistic East Germany to a western market economy. Most investments (75-80%) were paid by the federal government and were aimed at infrastructure projects and income maintenance. The exact level of German official investments is difficult to estimate, but would probably be between € 530 and € 600 billion (2015 prices) in the period between 1990 en 1995. This implies a yearly investment of around € 100 billion – equivalent to around 10% of German GDP (Statistisches Bundesambt, 2015).

Except for the military spending and the German unification it is hard to find public spending programs of a size comparable to the transformation to the low-carbon economy. For example, the Netherlands have traditionally invested substantial amounts of money in water management and flood protection.

[15] Own calculations based on data from Eurostat and SIPRI (2015).

The 'Zuiderzeewerken' designed by Cornelis Lely and executed in the period 1921-1975 was budgeted at 200 million guilders, which was as much as the government budget of 1921. Eventually the cumulative final costs were approximately 4 billion guilders, with an annual average of 74 million (Admiraal, 2011). This is equivalent to 0.4% of GDP in the Netherlands over this period. Another large Dutch program was that of the 'Deltawerken', a sea defence construction to prevent against future flooding, executed from 1955 to 1997. The total costs were estimated at 3.3 billion guilders. The final costs were approximately three times higher, covering around 10 billion guilders, which is on average 230 million per year (Admiraal, 2011) – equivalent to 0.2% per year.

We thus conclude that an additional 2% of investments is a very substantial input, but is not impossible given the historical fluctuations in the investment rates and compared to other historic transitions. They are larger than governmental spending on water flood protection in the Netherlands, but smaller than military spending in many countries.

### 3.2.3 Comparing to current market situation

Investment expenditures vary considerably over a business cycle and typically much more than GDP itself. In the last couple of years, investments fell down considerably in the EU. This decline was primarily explained by a fall in returns making investments in the EU unprofitable (EIB, 2013). Reduced bank leverage only played a marginal role and if so, mostly for SMEs. Analysts think that in principle there is no shortage of money for investments (New Climate Economy, 2014). There is evidence that companies have seen their cash positions increase over the last five years (McKinsey, 2013) due to underinvestment. Therefore the low-carbon transformation can, macro-economically, be a right incentive at the right moment to stimulate investments.

## 3.3 Sectoral perspectives on investments and efforts

As stated above we estimate the required investments equivalent to 2% of GDP. Although this is a very conceivable sum for unidirectional investments, the sum is still only 10% of average historic investments. However, the burden is not evenly distributed between all sectors. Based on the calculation and analysis in Annex C-Annex F, we have calculated the relative investment needs compared to the historic averages for the four sectors investigated (power, industry, transport and built environment). Table 4 gives the results of this analysis.[16]

[16] It should be clear that this is an additional effort of this study. Most of the work undertaken by the European Commission does not compare the policy-induced investments to historic investment levels but rather to the Reference Scenario from PRIMES (see also Annex A). As the Reference Scenario already contains quite some policy elements (e.g. an annual reduction in the ETS of 1.74% up to 2050), it is difficult to assess the investments against what is considered as normally in the sectors. Therefore we have attempted to compare the policy-induced investments against the historic investment level.

Table 4 **Comparison of historic investment levels with calculated additional investment levels in the 2°C degree policy scenario**

| | | Additional investments compared to BAU in % of historic level^ | |
|---|---|---|---|
| | Historic investment level (€bn annual)^^ | 2030 | 2050 |
| Power (excl. grid) *** | 40 | 30% | 100% |
| Industry | 350 | 10% | 30% |
| ow energy-intensive industry** | 40 | 70% | 200% |
| Transport*** | 575 | 20% | 50% |
| Built Environment* | 650 | 10% | 20% |

* Historic value lists only investments in commercial property. Investments by households are thus not included and would dwarf the additional investments needed.

** Energy-intensive industry implies all installations in the sectors refineries, basic chemicals, cement, basic metals and paper/pulp.

*** In power and transport all investments have been labelled in the Reference and Policy scenario as 'energy-related'. In Built Environment and Industry this is not the case.

^ Additional investments have been calculated using the GHG40 scenario from the 2030 Framework Impact Assessment (EC, 2014a) and BAU is the estimated extrapolation of historic trend excluding policies in the Reference scenarios. Numbers have been calculated by assuming that the additional investments in the power and transport sectors in EC (2014b) include replacement investments for all machinery/roads and in the industry and built environment are excluding replacement investments in all machinery/buildings.

^^ Historic levels are not taking the same data and time range between sectors. See for more information Annex C-Annex F for calculation.

For the **power sector**, annual investments must double in 2050 compared to the historic investment level (2010-2012). The PRIMES modelling efforts assume that until 2035 primarily investments in renewable energy technologies will take place. After 2035 investments in CCS (both for fossil fuels and biomass-fired stations creating carbon sinks) should become dominant. In the end, about half of the required $CO_2$ reduction will be achieved through deployment of renewables and the other half through the use of CCS.

For **industry** as a whole, the additional investments seem to be small. However, this is different for the energy-intensive industries, where the investment efforts imply a doubling of historical activity level investments. Crowding out may be an issue here as current investments (related to new markets, processes and products) may be jeopardized if such high investment levels are required. Therefore, emission reductions in the industry sector may only be achieved through a combined strategy that includes:

a Gradual improvement of energy efficiency up to 20%.
b Large-scale investments in new break-through technologies (see also below).
c Possibilities to include options in the value chain (with an explicit warning that this may lead to double counting, see Annex D).
d Establishing a route of managed decline for those carbon-intensive industries that have a very substantial overcapacity such as refineries and cement.

There is no choice between these strategies: they must be developed simultaneously.

Also in the **transport** sector various routes are required to achieve a substantial $CO_2$ reduction:

a Technical options (e.g. electrical vehicles) implying investments in engines and infrastructure.
b Modal shift implying a shift to less carbon-intensive modes of transport.
c Behavioural changes such as curbing the demand for transport.

The vast majority of emission reductions will anyway have to be realized through the technological route, as it is much better suited for market economies satisfying consumer demands. The main challenge, from an investment and regulatory perspective, will be to decarbonize road transport. Total investments will be up to 150% of present levels, mainly through infrastructure and more expensive vehicles. In the long run, and especially after 2030, the investment costs are compensated by a decrease in operational costs.

Additional investment levels, in relative terms, seem to be smallest in the **built environment**. The built environment includes both buildings and electrical appliances. Focus of this study will be solely on buildings.[17]
To improve the energy performance of the existing building stock different types of measures are possible. Energy measures can be classified in renewable energy (RE) measures and energy efficiency (EE) measures.
Both groups of measures may be used on an individual (single dwelling) or collective (neighbourhood; apartment block) scale.

For new buildings it is not a problem to construct them in such a way that they have zero carbon emissions. However, the real challenge here is to organize the renovation, as the additional investments are, although small in relative size, very substantial in absolute sizes. Although the numbers vary significantly, deep renovation should entail substantial investment costs and other costs such as discomfort and the temporary closure of buildings for living and other functions. An annual 2-3% deep renovation level is needed to meet the GHG40 targets, while the current practice is slightly above the 1% or shallow renovations (see also Annex F).

## 3.4 Technological and institutional perspectives

### 3.4.1 Technological challenges ahead

The analysis above identified that in most sectors a combination of technological, behavioural and institutional changes must take place in order to meet the challenges of the 2050 targets. Investments will mostly take place in the various technologies and infrastructure. Annex C-Annex F contain a description of the various technologies that can be expected as needed for the low-carbon transformation. Table 5 gives an overview of these technologies and categorises them into technologies that primarily still have technological issues to be resolved, and technologies that have economic issues to be resolved. It is important to notice here that the analysis in Annex C-Annex E shows that the decarbonisation routes without CCS are regarded as being very difficult. In the industry sector, it is not possible to meet the targets without large-scale use of CCS for the most energy-intensive sectors. Also for the power sector, the Impact Assessment of the EC (2014a) assumes that in the

17 The main reason for focussing on buildings is that the decarbonisation mechanism will be different for appliances and that the CAPEX/OPEX shift particularly poses problems in the built environment rather than in the markets for, and use of, appliances. See also Annex F.

policy scenario by 2050 about half of the energy is still produced by fossil fuels. The total reduction of 97% in this sector is only achieved because the produced $CO_2$ is captured and stored underground.

Although all of the individual components in the CCS technology have been proven and commercially applied for over a decade, CCS applied to non-condensed $CO_2$ flows (such as the exhaust from a coal fired power plant) is still under development. Operating and upscaling the integrated CCS chain still requires additional research effort where the main concerns may be related to safety issues rather than costs.

**Table 5 Overview of technologies to be used and their potential barriers (see analysis Annex C-Annex F)**

| Sector | Technological barriers | Economical and institutional barriers |
|---|---|---|
| Power | CCS, tidal, CSP | Solar, wind, biomass |
| Iron and Steel | CCS, Hisarna, electrolysis, top gas recycling | Fastmelt |
| Cement | CCS (oxyfuel), Novacem, input material substitution routes | Biomass/biogas input |
| Petrochemical | CCS | Biomass/biogas feedstocks |
| Paper | CCS (black liquor) | |
| Transport | EV | Biofuels |
| Built Environment | Geothermal | Insulation |

Also other technologies still require substantial additional research. For the transport sector, the low-carbon transformation will have to be achieved by a combination of behavioural and technological changes (see Annex E). In other areas, such as insulation or biomass, there are also institutional hurdles such as improving the chain efficiency of biomass or overcoming principle agent problems. In the Annex C-Annex E more detail is given on these barriers.

### 3.4.2 Regulatory framework and the role of carbon prices

The low-carbon transformation will not take off by itself. Renewable energy technologies are currently more expensive than fossil fuel-based power production and all CCS technologies imply a substantial increase in costs. Therefore, a regulatory framework must be created that gives the right incentives so that market participants are ready to step in.

The basic design choice of this regulatory framework is which instruments are to be used. The current regulatory framework uses a mix of subsidies, carbon prices and technological prescriptions to advance the low-carbon transformation. However, as explained in Chapter 1, the present efforts fall a factor 5 short of what is needed. Therefore, as a rule of thumb, any effort must be increased by a factor 5 if we are to be on the path of the low-carbon transformation. It is clear that some elements are more likely than others. Carbon prices could indeed increase from the present € 6/t$CO_2$ towards € 30/t$CO_2$. Many would say that this is a good price signal in line with what was originally intended when the ETS Phase 3 was designed. It is a bit more difficult to imagine how regulatory efforts can be raised by a factor 5.
This may imply that $CO_2$ standards for cars are increased; electrical appliances face more stringent rules on energy use or will be banned from the EU market; and more strict BAT/REFs energy saving standards for industrial processes will be introduced. However, if we consider the amount of subsidies to be

increased by a factor 5, it becomes clear that this will be very unlikely. Renewable energy subsidies in countries like Spain and Czech Republic were already reduced since they consumed too large share of governmental budgets. Therefore, increasing the present level of subsidies by a factor 5 without problems is difficult to imagine.

Also from a different perspective one could argue that having more subsidies is not the right way forward to the low-carbon transformation. Subsidies assume that the government can assess correctly which techniques have the best potentials to guide the low-carbon transformation. This is rarely the case. Governmental programs involving subsidies tend to misallocate resources and making the total low-carbon transformation much more expensive than anticipated (see Paragraph 5.6.2). If the low-carbon transformation is to be achieved through subsidies, total investment and costs will increase considerably which will introduce new risks of changes in the regulatory regime (which in turn will increase the costs).

Regulation faces the same problem in the sense that governments cannot decide by themselves which technologies are the most cost-effective as they lack inside information from market participants. Therefore, the main mechanism through which the low-carbon economy transformation must be made feasible and profitable is through the carbon price mechanism. This has three distinct advantages:

- carbon prices assist in creating value for low-carbon techniques;
- carbon prices assist in depreciating existing fossil fuel-based assets;
- carbon prices let the market decide which techniques prevail and are more cost effective for stimulating innovation than governmental support schemes.

Only in some areas with high transaction costs, consumer myopia and/or institutional barriers, additional roles for subsidies or regulatory frameworks can be identified. In the specific sectoral chapters (see Annex C-F) it is argued that especially in the built environment and transport sectors regulatory instruments are needed in addition to a high carbon price. For other sectors, a high carbon price, if implemented well, is enough to guide the transformation towards the low-carbon economy.

### 3.4.3 $CO_2$ prices as exchange rate mechanism

Although the existing assets cannot be depreciated through exchange rate modifications, carbon prices can implicitly work as an exchange rate mechanism.

The trajectory towards the low-carbon economy should imply substantial price increases in the price of carbon. The Impact Assessment indicates that the price of $CO_2$ in the ETS under the GHG40 scenario is expected to increase from the present € 7/t$CO_2$ to € 40/t$CO_2$ in 2030 and € 264 in 2050. Especially the large increase after 2030 is remarkable. In practical terms this would imply an annual increase in $CO_2$ prices by more than 10% up to 2050. Every seven years, $CO_2$ prices would have to double.

It is important to recognize that this is not only an outcome of the PRIMES modelling effort. An overview study into the costs of greenhouse gas mitigation policies aiming at the long term stabilisation of these gases in the atmosphere was carried out by Kuik et al. (2009). Based on a meta-analysis of 62 studies they estimated the avoidance costs as functions of target implemented (ranging from 450 to 650 ppm $CO_2$ eq.) for both 2030 and 2050. Both the value of and the uncertainty in the avoidance costs figures increase when the reduction targets are tightened. With regard to a long term target of

450 ppm $CO_2$ eq. (corresponding to a temperature increase of about 2°C) the avoidance cost in 2030 is estimated to be equal to € 129, with a bandwidth of € 69-241. For 2050 the central estimate is € 225, with a bandwidth of € 128-396 per tonne $CO_2$ eq.[18]

Therefore, if the carbon price is settled as the major mechanism through which the low-carbon transformation must take place, one should in the first place accept that a price on carbon must be put in every part of our economic system. In the second place, very substantial increases in the price of $CO_2$ should be realized. This would facilitate the low-carbon transition, as after 2030 the $CO_2$ price mechanism alone could be responsible for making investments in CCS and renewable energy attractive.

### 3.4.4 Towards a new techno-economic paradigm

The transformation into the low-carbon economy can best be described as a radical change in the 'techno-economic paradigm'. This term was used by (Freeman & Perez, 1988) to describe a change in the technology system that has major influences on the behavior of the total economy. A new techno-economic paradigm usually develops within the old economy. The new technique shows its decisive advantages and becomes the dominant technological regime in the long run. This technical change directly or indirectly affects almost every branch of the economy. Due to falling costs and rapidly increasing supply the conditions of production and distribution throughout the system change. The new technology creates a range of investment opportunities and replaces the investment pattern and motive branches of the old system. Technological changes start in times of crisis, create an upswing and end with a new crisis. These cycles are called Kondratieff cycles. Economists recognized five Kondratieff cycles in the past few centuries.

Examples of this type of cycles are the golden age of growth and Keynesian full employment between the 1930s and 1990s driven by oil and other energy sources, and the IT revolution driven by microelectronics since 1980.
Both examples show the upswing of an input factor offering descending prices and abundant supply. This leads to a change in the motive branches and organisational structure of the economy. The low costs for transport in the 20th century changed the whole global production structure. The IT revolution created millions of new jobs in the electronics, software and IT sectors and changed daily work in many other sectors.

Decarbonisation implies a move from fossil energy to higher energy efficiency and the use of renewable energy. This can lead to a change in techno-economic paradigm with far enriching consequences for the whole economy. The conditions are: falling costs, rapidly increasing supply and pervasive applications. For renewable energy, supply of input is in principle unlimited, so no barriers exist for a long term increase in supply. Costs can decrease due to innovation and economies of scale. Decarbonisation leads to higher capital costs, but lower operational costs. Lower total costs and external costs can stimulate an uptake by different branches and replace the current fossil fuel based economy. Decarbonisation can create pervasive business opportunities in renewable energy sectors and indirect jobs for, for example, electric vehicle charging systems and greening of the built environment.

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[18] These values are in 2005 constant euros. Because of inflation, these figures should be increased by 13.2% to arrive constant figures for 2012 euros.

A crisis in the 'old economy' can accelerate a new cycle. Currently investments in oil and gas companies are still profitable, but scarce resources and concerns about climate change can increase risks for those investments. Recently, concerns about the 'carbon bubble' are being vowed that express growing expectations that investments in fossil fuel producing companies may be at risk if the world would adhere to a stringent climate policy. Although the argument is slightly flawed (since CCS would make fossil fuel reserves valuable again), it is true that investors should not expect that burning fossil fuels will be costless in the near future.

## 3.5 Conclusions

The investments for the low-carbon economy will be very substantial and must be taken in a relatively short timeframe. In some ways, the efforts can be compared to the investments that were required after 1990 in the former communist economies that became part of the EU. In a period of 20 years their economies (e.g. infrastructure, industry, consumer durables) have undergone a rapid transformation during which all existing assets (machinery and technologies) became regarded by the general public as obsolete, rapidly depreciated and replaced by more modern technologies. In investment efforts this transformation can be regarded as similar to the transformation to the low-carbon economy.

A very fundamental difference, though, is that the transformation of former communist economies towards the market economy was accompanied with a rapid devaluation of their currencies. This facilitated a rapid depreciation of existing assets. At present, carbon prices can act as an implicit mechanism through which existing assets are being depreciated. Carbon prices need to exceed to values above the € 250/t$CO_2$ in 2050 in order to provide an attractive business case for the new technologies compared to existing polluting technologies of production.

This analysis has indicated that investments needs do not lie outside range of historical differences in investments for most sectors. The electricity market requires substantial investments, higher than currently but not orders of magnitudes higher. Until 2035 primarily investments in renewable energy technologies will take place. After 2035 investments in CCS (both for fossil fuels and biomass-fired stations creating carbon sinks) should become dominant. Therefore an analysis of the electricity market should take into account both the investment climate in conventional generation (including biomass) and renewable generation (see Annex C).

For the industry, total investments seem to be relatively small but not for the most energy-intensive industries that see their investment needs trespass historic levels.

# 4 Capital availability

## 4.1 Introduction

Chapter 3 made clear that the investment challenge is very substantial but not prohibitively high. The investment challenge of the low-carbon economy can best be approximated by reference to the transformation of the former communist economies that had seen their capital rapidly depreciated and replaced by more modern equipment. A similar transformation is awaiting us now.

An often-raised question is whether the substantial amount of investments will not pose problems for the international capital market. Is enough capital available, especially after the economic crisis of 2008-13 has substantially reduced assets and cash position of most economic participants? In this chapter we will investigate this argument in more detail, first from the perspective of the type of capital that is required for the low-carbon transformation (Paragraph 4.2) and then from the perspective of the availability of capital (Paragraph 4.3). While there is in general enough capital available there may be a problem with specific capital provisions that are more risky in nature. Paragraph 4.4 concludes.

## 4.2 Capital requirements

Not only the total amount but also the composition of investments impact on the pace to achieve the low-carbon economy. Various components in the capital market require specific risk/return combinations. The technologies needed for the transformation to the low-carbon economy differ in state of maturity and thus in their perceived risks. Some technologies, like wind and solar-PV are currently reaching their maturity state, while other technologies are still only on the design table.

### 4.2.1 Composition of investments

There are different types of capital that all have a different revenue/risk profile. Some capital sources demand low risk and uncertainties while others are less risk averse and accept larger risks in exchange for (possible) high returns on investments. Projects that are still in the research stage are often associated with a negative risk-revenue composition, large risks about future yield and market breakthrough and often have high transaction and information costs. These projects are therefore dependent on financing by retained earnings with support of the government through for example subsidies (SEO, 2009) or angel investments (Cardullo, 1999). Once risk and transaction costs have declined, a company could try to attract external investors for private equity in the development stage. Private equity is money invested in companies that have not yet gone ‘public’ and are not listed on the stock market (Mishkin, 2007).

The first investment source attracted by such companies will be venture capital (VC), which is provided by venture capitalists such as institutional investors or high net worth individuals who see a high commercial potential in a project and are therefore willing to invest in this project in terms of capital and technical expertise (SEO, 2009). Venture capitalists accept a situation with high risk and a low yield. The scale-up phase is dominated in approximately 80% by venture capital and the remaining part by public stocks (SEO, 2009), which could be attracted when risks are reduced, and transaction and information costs and yields are increasing. Once risks and uncertainties are significantly reduced and the project is in the roll-out phase, public equity (stocks and bonds) may become available as a main capital source accompanied by private bonds and bank assets. First stocks will be available, followed by public and private bonds and bank assets. The maturity phase will be dominated by risk-averse financing sources like bank assets, public equity or even carbon finance (SEO, 2009).

Figure 3 and Table 6 give an overview of the various types of capital in relation to returns and technologies.

**Figure 3** **Type of capital and stages in the technological lifecycle**

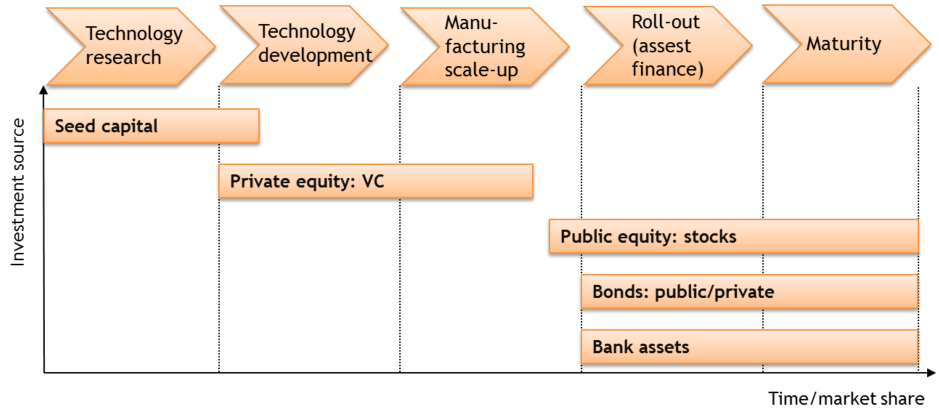



**Table 6** **Main capital sources for sustainable projects and their level of risk and revenue acceptance**

| Main capital source categories | | |
|---|---|---|
| Seed capital | - Retained earnings *<br>- Government support (subsidies)<br>- Angel capital ** | High risk<br>Low revenue |
| Private capital | - Private securities (bonds)<br>- Venture capital (private equity) (VC) | Decreasing risk<br>Low revenue |
| Public equity | - Public securities (bonds)<br>- Stock market | Decreasing risk<br>Increasing revenue |
| Bank assets | - Cash, securities, loans and other assets | Low risk<br>High revenues |

Source: Admiraal, 2011.

The question now is what type of finance would be dominant for the low-carbon economy transition. In an effort to analyse the investment needs for a 450 ppm scenario, Admiraal (2011) calculated which technologies would be required to meet such a scenario and then subsequently analysed the types of capital that would be needed for the transformation. Table 6 shows the relative share of the different capital sources for the different years based on Admiraal (2011). The type of capital needed depends of the development phase of the technique; the more mature the technique is the less seed capital and venture capital is demanded.

Table 7 **Relative annual investment need per capital source**

| | Seed capital* | Private equity: VC | Public equity (stocks/ bonds)/ private bonds/ bank assets) | Total annual capital need |
|---|---|---|---|---|
| 2015-20 | < 1% | 1% | 12% | 14% |
| 2020-25 | < 1% | 2% | 13% | 15% |
| 2025-30 | 0% | 1% | 33% | 34% |
| 2030-35 | 0% | 1% | 36% | 37% |
| **Total share** | **< 1%** | **4%** | **96%** | **100%** |

Source: Own calculations and interpretations based on Admiraal (2011).

Table 7 shows that there is a rough trend in investment needs from the upper left to the lower right corner of the table over the whole period, representing a decrease in seed capital and private capital and an increase in public equity and bank assets. This trend is based on the now available information about emerging technologies. *Ceteris paribus* it can be concluded that the largest share of the capital is needed within the stock, bond and banking sector and especially in the period after 2020. Less than five percent of the investment need is from venture capital. In the first ten years this capital demand will rise, but decreases after 2020 when most investment projects will have arrived in their roll-out and maturity phase, demanding more public equity and bank funding. The investment need for seed capital will be lower and the majority of the investments will be done in more mature technologies.

### 4.2.2 Sectoral perspectives on capital requirements

The composition of capital needed for the low-carbon economy transformation differs between sectors. The industry and transport sectors probably require more seed capital to develop new technologies and improve the economics of existing technologies. For the electricity sector, there is a stronger need for private equity to step in as venture capital– especially for the period after 2030. As explained in Chapter 5, the problem here is that the returns from renewable electricity generation are jeopardized by decreasing marginal costs. Moreover, due to the current economic crisis and uncertain future prospects, investors and especially banks are heavily risk averse and prefer short term loans with low risks and certain revenues. Investments in renewable energy have, because they rely on subsidies, a high risk/revenue composition.
The real challenge here is thus to improve the poor risk-return combination.

Another aspect relates to the investments for energy efficiency that play a role especially in the industrial and built environment sector. From a financing perspective these investments pose specific challenges.
Efficiency measures reduce cash outflow, and therefore they are complex to finance opposed to renewables where there is a cash flow to be reaped.
This means that although energy efficiency measures are profitable and tend to be earned back within a few years, the easy access to financing schemes is more problematic. Energy efficiency is not considered as an established asset by banks on which loans can be funded. Additionally, in the built environment sector, energy savings are about huge volumes of relative small savings, thus standardisation/aggregation of markets to mobilise capital is the key.
The chapters on Transport and Built Environment show that proposals to deal with this issue have been defined in the literature, but progress of this has been very slow up-to-date.

## 4.3 Capital availability

In this paragraph we will discuss whether enough capital is available to finance the low-carbon transition, from the perspective of various categories of capital needed as identified in Paragraph 3.4.

### 4.3.1 Capital availability: seed and venture capital

For the initial stages of technological development and uptake, substantial amount of seed and venture capital is needed. Seed capital is useful for exploring and developing new technologies. This is mostly undertaken by entrepreneurs. Once technologies have proven technological and economic feasibility, subsequent uptake and marketing of these technologies tend to take place in typical small and medium-sized companies. However, since these companies are not listed on the stock exchange, they often find it hard to get mainstream financing via bank loans and they do not have access to capital via stock markets: alternatives like venture capital may help them to grow and develop.

Seed capital includes government support, retained earnings and angel investments. Given the available information, little can be said about the size of retained earnings and angel investments market. Government support includes grants, subsidies and expenditures in research and development (R&D). On EU level firms can attract money from several EU funds to support the research, development and demonstration of innovative projects.
The total average annual budget of these funds was around € 25 billion in the period 2007-2013. This budget is additional to the national support programs of separate Member States, such as R&D expenditures. Total R&D expenditures differ widely across several geographic areas. In the EU almost 2% of GDP is spend on R&D (Eurostat, 2014). This budget is steadily increasing by more than € 8 billion per year. However, from this total R&D expenditure only relative small amounts are currently directed at energy objectives.

A relatively smaller but growing investment source is venture capital (VC), which is part of private equity raised by venture capitalists. They raise capital from high worth individuals and large private sectors, like pension funds and insurance companies. VC is also provided by the European Investment Bank. Europe raised approximately € 10 billion of VC in 2008. VC faced some difficulty through the crisis, but the last few years were marked with an increase in venture investments although VC did not fully recover to values from before 2008. The sector ‘energy and environment’ showed a significant increase in 2008, ending up as the second largest sector. Between 2007 and 2008 the amount spent in the ‘energy and environment’ sector increased by € 1 billion. Nevertheless, the amounts of new funds raised in the past fluctuated a lot over time and even per quarter and therefore the future growth is uncertain. Furthermore there is a trend of increasing foreign investments from outside the EU member states. In 2008 around half of all raised funds were foreign-based.

Private equity not only includes venture capital. Mainly institutional investors also invest in broader private equity funds. These funds not only invest in scale up companies, but also in more mature companies and projects. Sometimes pension funds take a direct stake in a sustainable project, like a windfarm (ECF, 2011). However, more often a more secure portfolio is being aimed at. For the low-carbon economy transformation there is a risk that the technology development and manufacturing scale up will be insufficiently financed by private equity (venture capital) because there is doubt about the perceived risk/return options in the long run, as these are highly dependent on the formed politics. This is in essence true for any sector, but may really become an impediment in the transport sector as the development and scale up of alternative fuel vehicles may be a very challenging task.

### 4.3.2 Capital availability: Stocks, bonds and bank assets

While venture and seed capital are crucial for the development and uptake of new technologies, they are in absolute terms very small. By far the largest part of the capital market is made up from stocks, bonds and bank assets. The total size of the capital market increased in 2013 towards around € 250 trillion on global level (approximately $ 283 trillion) and to around € 75 trillion in the EU (approximately $ 88 trillion) (IMF, 2014). Most capital is public equity. The EU capital market is strongly related to the global market. The economic crisis, beginning in 2008 had a strong negative effect on the size of the capital market. In recent years, the EU capital market is again increasing but it is still below its 2007 levels. Especially public equity suffered from this crisis. The other financial sources of the capital market faced a slowdown, but remained relatively stable.

Table 8 provides an overview of the average percentage growth of the size of different capital market elements in the EU in the period 2003-2007 and the period 2007-2013. This shows a stable growth in capital assets between 2003 and 2007 and a very strong decline in 2008. Afterwards the capital market recovered and showed positive growth numbers again, but the 2013 levels were still smaller than the 2007 values.

**Table 8 Absolute and relative annual change of the EU27 capital market (2003-2007)**

| | 2003-2007 % | 2007-2013 % | Absolute value in 2011 trillion € |
|---|---|---|---|
| Public equity of which | 13.8 | -9.8 | 17.9 |
| - *Stock market* | 17.4 | -2.5 | 7.9 |
| - *Public bonds* | 8.7 | Unknown | 10.0 |
| Private bonds | 16.8 | Unknown | 19.2 |
| Bank assets | 27.8 | -1.3 | 39.1 |
| Total capital market | 21.0 | -0.7 | 76.2 |

Source: IMF (2004; 2008;-2012; 2014).

If the capital market recovers to values and annual increases as in the period 2003-2007, the whole low-carbon economy transformation can easily be financed by the growth in the capital market. In other words: the fear of crowding out existing investments is not supported by our analysis.

Therefore, public equity, private bonds and bank assets do not form a bottleneck in the transformation to the low-carbon economy from the perspective of availability.

### 4.3.3 Future prospects EU capital availability

The capital market declined considerably in 2008 because of the financial crisis, but afterwards the capital market started to grow again and such growth is expected to continue in the future, even though the exact increase will be uncertain. The composition of this capital is also expected to change. For example, the increasing aging of the EU population will probably lead to an increase in savings what will result in a larger capital capacity of banks.

The size of venture capital funds decreased substantially during the crisis and is only recovering slowly. Main drivers for the increase are a growing amount of capital from pension funds and insurance companies. Contrary to these positive indicators are the European capital constraints, and due to low budgets European governments are unable to stimulate VC by means of subsidies or tax benefits. Furthermore, European VC funds have a relatively low track record compared to the USA and have difficulty in raising capital. No reliable predictions could be made for periods even further in the future.

The future EU seed capital capacity depends on the size of future EU government spending and GDP growth. The growth of individual EU member state programs is uncertain, especially due to the economic crisis. Nevertheless, R&D spending is expected to grow in the long run as GDP is expected to increase.

### 4.3.4 Match capital capacity supply and demand

The largest capital can be found within the capital market. Seeds capital takes a second place, followed by venture capital. In terms of an average annual increase, both seed capital and the capital market showed relatively stable increases except for 2008/2009 when the capital was depreciated at an unprecedentedly high rate.

The annual changes in VC are less stable and even vary strongly within each year but there are no accurate measurements that can be provided for this type of capital.

**Table 9 Size and annual increase of EU capitol sources**

| | Capital market | Venture capital | Seed capital* |
|---|---|---|---|
| Size (2008; billion EUR) | 74,000 (2013) | 10 | 280 |
| Average annual increase (2003-2007; billion EUR) | 8,700 | N/A | 28 |

Source: Admiraal (2011).

* Retained earnings and angel capital are not included.

Total demand for capital for the low-carbon economy is less than € 2 trillion up to 2030 and slightly above up to 2050. The demand for capital is therefore less than a quarter of the growth of the capital market. Therefore, capital availability will not be a bottleneck for the low-carbon economy. The entire transformation can be financed from the growth of the capital stock and no crowding out can be expected.

However, the availability of venture capital might be an important bottleneck. Between now and 2025 an estimated amount of around € 30 billion of venture capital may be requested annually if we take the estimate presented in Table 6 into account. That is a very significant amount of VC that will have to be raised within a relatively short timeframe. There will be no lead time to increase this capital; the expansion has to be immediate. The growing demand must be placed against a reduced supply. Venture capital funds have dried out in recent years, and in many countries private equity is nowadays below 50% of the 2007 values. Private equity in energy and environment-related companies declined for every year between 2010 and 2013.

So, although the actual demand for VC is relatively low compared to the demand for stocks, bonds and bank loans, there seems to be no good match with the current and annual capacity. This 'mismatch' might form a bottleneck - especially for projects shifting from research to development, such as tide and wave power and CSP, needing VC as an external investment source. Lack of investments in the development of these technologies and CCS may be regarded as an important bottleneck in the transformation to the low-carbon economy.

## 4.4 Discussion and conclusions

In total quantity the investments for the transformation towards the low-carbon economy will not pose a problem for the capital market, as the entire investments can be financed by the expected growth in the available capital for investments. However, there may be a specific problem for the initial phases. A particular problem exists for the attraction of private equity that would accept a high-risk profile for the scale up phase. This may be a particular problem especially in the transport sector where in a very short time new factories and technologies must be established, and to a lesser extent in the power and industrial sectors. The estimated amount of private equity that would be required, especially in the early years, would surpass the current amount available on the EU market. This may form a hindrance and bottleneck to the low-carbon transformation in the sense that ill-allocated capital in the early years will provide a more costly low-carbon transformation in later years.

The capital for investments has to be attracted mainly from equity in terms of stocks, bonds and bank assets. While capital in the form of public equity (stocks and bonds) is ready to step in, this will crucially hinge on the revenue generating business cases in combination with the perceived risks. As we will discuss in Chapter 5, there are some particular problems related to the CAPEX/OPEX shift, increased systemic risks and institutional risks.

A specific case of capital availability may the government sector.
The government sector is not considered as a separate sector in this study as it is not the actor that needs to undertake the investments. However, the government is important as the regulatory authority creating the (business) environment through which the investments can be stimulated. The capital position of governments in the EU28 has been drastically deteriorating since the start of the economic crisis. Governments of virtually all EU28 MS have now much worse credit status than in 2007. While potentially this may drive up costs for lending capital, these costs have not been experienced so far due to the historically low interest rates. As long as these rates are that low, governments may still expand their budget deficits without huge economic costs. However, if the interest rates start to rise, the position of governmental budgets may become a crucial role in the low-carbon transformation.
This is particularly true for the use of subsidies and other fiscal support measures aiming to stimulate investments in low-carbon technologies.

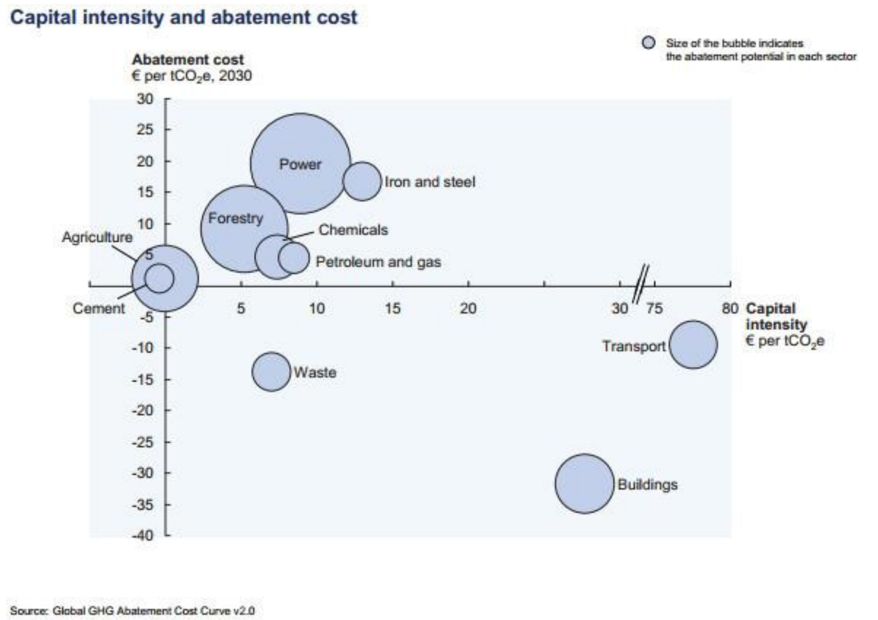
# 5 Risks and returns

## 5.1 Introduction

The transition towards the low-carbon economy implies nothing more than a drastic reduction in the consumption of fossil fuels in a relatively short period of time. At the level of the EU economies, such changes may introduce certain risks. Some of these risks are macro-economic while other risks are sector-specific. In financial economics, risk is the chance that an investment's actual return will be different than expected and measured in the standard deviation of expected returns. Increasing risks would imply that potential returns would have to be higher in order to be attractive for investors. Therefore, the concept of both risk and returns is highly important for the transformation towards the low-carbon economy.

In Chapters 2-4 we have seen that the low-carbon transformation implies that in each of the sectors substantial additional investments compared to BAU have to be taken. However, the total costs increase to a much smaller extent. That is because the most of the investments, except for those that deal with CCS in the electricity generation and industry, will also entail benefits in lower costs of energy use. McKinsey (2009), amongst others, has pointed at the difference between abatement costs and abatement investments for moving to the low-carbon economy. Using their famous abatement cost curve for $CO_2$ emissions, McKinsey (2009) has investigated to what extent different sectors have different capital intensity of the techniques that are required to transform the economy on a low-carbon path. Figure 4 summarizes the differences between sectors.

**Figure 4 Relationship between capital intensity and abatement costs differentiated along sectors**




Source: McKinsey, 2009.

In general, every measure below the horizontal axe is giving a net benefit in the sense that the investment costs will be recuperated by energy savings.

We see here that, in general, measures in the cement and agricultural sectors can be undertaken at low costs and relatively small investments. Measures in the power sector are more costly and require more investments per tonne of $CO_2$ abated and tend to present net costs to society. On the other end, measures in the transport sector, in general, require very high up-front investment costs for each tonne of $CO_2$ abated. However, once these investment costs have been realized, the return on investment is high in the sense that net cost savings would be realized. This is even more applicable for the buildings sector.[19]

Below we will investigate in more detail the impact of the CAPEX/OPEX shift for the sectors (Paragraph 5.2-5.5) and then discuss specific institutional and macro-economic risks in Paragraph 5.6 and 5.7 respectively.

## 5.2 Power

In recent years early signs of the impact of increasing deployment of renewable energy in electricity markets have emerged. Particularly market conditions in the German and neighbouring markets have evolved rapidly since 2010, with the very strong growth of solar-PV. Conventional generation was pushed out of the market, electricity prices declined swiftly, while the need for complementary flexibility for supply, demand or storage emerged in the short term markets. These and other developments have instigated debates on matters of the market design in the face of the energy transition.

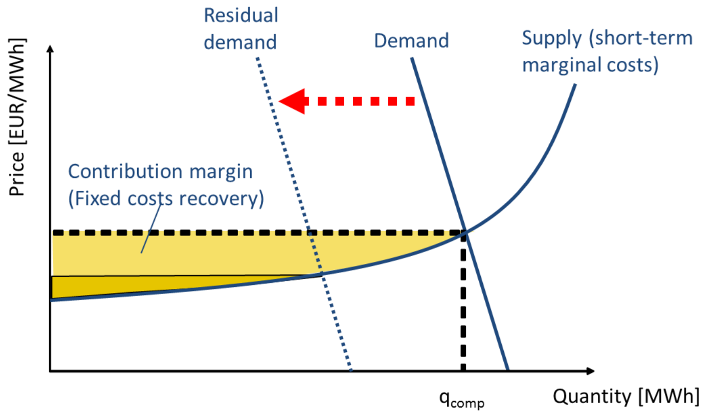
The increasing CAPEX expenditures that arise with the decarbonisation pathways for the European power sector pose a significant challenge for this sector in the energy transition. The increasing needs imply more investment capital will have to be attracted to secure the necessary funds. Such will largely depend on the ability of business model of the generation segment to recover the cost of capital.

Recent developments in the European energy markets, however, have raised questions about the robustness of the classic business model of conventional generation in the electricity markets in this respect. In the case of renewable energy, the current business model largely depends on support schemes.
This is sometimes perceived as a transitional feature. The expectation can be that once the prices are set more rightly (by abandoning fossil fuel support and higher prices for $CO_2$) and the learning effects have been materialized, renewable energy support may be lowered.

19 One should notice that such results are highly dependent on the assumptions underlying fossil fuel price developments and discount rates. McKinsey (2009) assumes an oil price of $ 60/barrel in 2030 and a discount rate of (presumably) 4%. Higher discount rates would especially impact on the sectors being capital intensive in the sense that their costs would rise. As argued in Annex E and F, consumers may have implicitly very high discount rates which actually would explain why investments, despite the substantial net earnings, may not materialize.

However, our analysis in Annex C makes clear that we do not expect that this is a transitional feature. Variable renewable energy, like wind and solar-PV is characterized by very low marginal cost of production, and these technologies are essentially always deployed[20], be it only at times of wind or solar irradiance. This is illustrated in Figure 5 below. As vRES has priority access into the system, remaining residual demand is left for conventional generation to cover. As residual demand declines, sales volumes for conventional generation decline, as well as the remaining contribution margin required for fixed cost recovery. In essence, this happens both for periods of marginal cost pricing and for periods of scarcity pricing (see for example our analysis of Germany in Annex C).

**Figure 5 Modelled impact of growing contributions of vRES on whole sale market conditions**




Source: Hers, 2013.

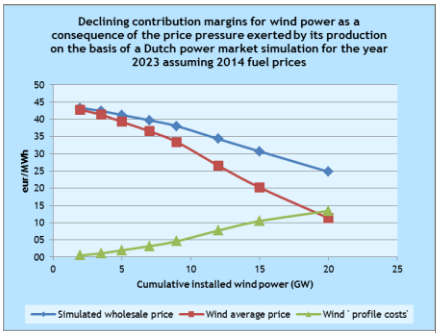
In the longer run, learning effects resulting from increasing renewables deployment may bring down cost of renewables investments. Recent developments in the fabrication of solar-PV panels for example, with cost declines well over 70% since 2006, show that increasing scale of deployment can result in very strong cost reductions. However, such cost reductions may be counterbalanced by prospects of further declining margins in power markets. This is particularly the case for vRES, as these facilities typically generate in conjunction. Upon large-scale deployment one should expect markets to be well supplied when these facilities operate, so that contribution margins (revenues) for these facilities tend to be depressed.[21]
This is illustrated by the modelled example below (see Box 1).

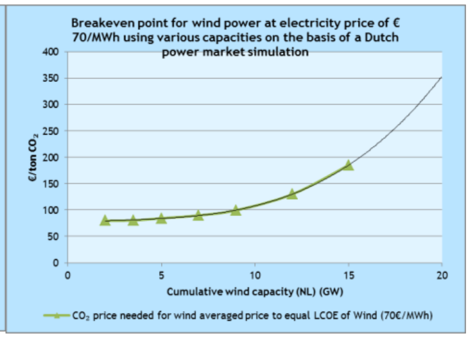
20 As a result of high shares of intermittent power generation in the system wind and solar may occasionally be curtailed for economic reasons (negative power prices). This effect has been recently analysed by the Climate Policy Initiative (CPI) who conclude that curtailment risk will increase the risk and costs of investments in renewable power if not addressed by appropriate policies. Our analysis does not address this specific risk.

21 In addition, scarcity pricing should not be expected to occur when these facilities operate, thereby limiting revenues for conventional units.

**Box 1: An example of high deployment of vRES in the Netherlands**

This example illustrates the case of high deployment of wind power on the basis of model simulations for the Dutch power market under current energy market rules. In Figure 6 below increasing levels of installed capacity of wind are plotted against the yearly average of simulated hourly market prices (blue). In addition the average market price captured by wind power production (red) is plotted, i.e. the hourly market price weighted by the hourly volume of wind power produced. Finally the volume-weighted differential is plotted (green).
This simulation illustrates that both the average market prices and the average returns for wind power production decline upon increasing levels of installed wind turbine capacity.
This decline currently outpaces the projected decline of levelized cost for wind energy. If one would calculate the level of carbon prices required to compensate for the decline in marginal revenues depicted above, the numbers are significant as depicted in the right Figure below




At installed levels of wind capacity up to 20% of total power demand the breakeven point is at € 80/t$CO_2$.When wind capacity reaches 40% of total demand the corresponding carbon price needs to increase to values of € 180/t$CO_2$ in order for wind to be able to compete in the market without subsidies.[22]

This example makes clear that relying on lower technology costs alone is not enough to secure investments in the power sector.  Technology development is needed to bring down costs but these benefits can to be eaten out as more renewables are fed into the grid. This presents a strong case for redesign of the internal energy market to properly price flexibility options such as flexible demand response into the system. Recent conversations on the internal energy market have addressed this issue and various options to counter the effect described above are being discussed.

In addition to market design, carbon pricing can form an important role to mitigate declining margins of renewable energy. Higher shares of renewables should then be accompanied by higher carbon prices. We also note here that at present, in the EU ETS, the price mechanism works exactly the other way round as carbon prices drop if more renewables are employed as a result of a fixed emissions cap based on a projected emissions trajectory.

Furthermore, the above described effect does not only impact larger power producers, but also affects small scale producers (or 'prosumers'; e.g. consumers producing via rooftop solar). The current business model for consumer renewables will be contested as the avoidance of energy taxes and fixed energy costs (including a FiP/FiT component) are implicit support mechanisms. At present, both producers and prosumers receive subsidies (FiP/FiT), but prosumers have an additional profit from avoided energy taxes

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[22] See Annex C for a more detailed assessment.

and a fixed feed-in tariff. Especially this latter mechanism may be untenable in the future and more flexible tariffs will apply making the business case for consumer solar panels more problematic.

## 5.3 Industry

Within the energy-intensive industry sector the additional investments are very substantial and surpass historic investment rates. The investments include a wide range of technologies (see Table 10 and Annex D). In most cases these additional investments do result in significant higher CAPEX but not in lower operational costs, perhaps with exception of some of the technological options in the cement, iron and steel sector. However, these options are at present not yet commercially viable and therefore relatively little information is available on the extent to which the CAPEX/OPEX shift may form a hindrance in these sectors.

**Table 10 Annual investments and options for various energy-intensive sectors**

| | Avg. annual investments | 2050 LCE investments | Short run options | Long run options | CAPEX/ OPEX issues? |
|---|---|---|---|---|---|
| Pulp, paper and paperboard | 3.1 | 3.9 | Energy saving | CCS (black liquor) | No |
| Refined petroleum products | 8.7 | 17.8 | Energy saving | Managed decline | No |
| Basic chemicals | 11 | 19.7 | Energy saving, biomass | Biobased chemical | No |
| Cement, lime and plaster | 1.8 | 20.4 | Biomass, energy saving | Managed decline, CCS (oxyfuel), Novacem, input material substitution routes | Partly |
| Basic metals | 16.9 | 19.7 | Fastmelt | CCS, Hisarna, electrolysis, top gas recycling | Partly |

Investments, however, are jeopardized from two different angles in the industrial sector. First, current production capacity in the EU is exceeding domestic demand in many carbon-intensive sectors, most dominantly in the cement and refineries sectors. This causes prices to stay at a very low level, with evaporating margins to invest in new technologies. Because the EU is a maturing market, the growth in the economy will not result in a situation where the overcapacity is solved. Moreover, the demand for products, especially in the refinery sector, will fall due to climate policies in the transport and built environment sectors. Therefore, a process of 'managed decline' will be needed for some sectors (see Annex D). As noted by ECF (2014), closure of plants is not an easy option for three reasons: (a) most of the assets in the EU industry are already depreciated which implies that the companies operate under reasonable to good profits; (b) there may be substantial exit costs which deal with clean-up of industrial areas; (c) there may be important societal resistance against closures from e.g. trade unions seeking to maintain employment. However, the EU has experienced a similar situation with respect to coal mines, yet coal mining has been abandoned in many countries over the last 30 years and various compensating schemes have been set up. It is wise to start to think of applying such programs to other industries as well.

Second, most of the EU energy-intensive industries (especially in the iron and steel, chemical and refineries sectors) are part of global enterprises with factories in many countries in the world. Investment decisions in such a global context are often based on portfolio decisions taking into account costs and revenues in certain markets, and aiming to maximize the shareholder value of the enterprise. This poses a problem for the EU industry to meet the climate targets. The majority of the energy-intensive installations in the EU have been built, on average, between 1950 and 1980 and are not very efficient against the most modern standards (see also Page 97). In a growing market, installation of the newest technologies would automatically take place and reduce carbon emissions per unit of product. However, the EU can be regarded as a maturing market where such investments cannot be financed through an increased demand for these products.

As most of the EU installations have already been depreciated they are still able to compete on the world market. However, substantial carbon price signals would undermine their competitive advantage. This may partly explain the lobbying for exemptions to climate policies from the involved industries as substantial carbon pricing may undermine their current business case. A move towards carbon policies tackling consumption of energy-intensive products instead of production may mitigate the competitive disadvantages for EU industries.

## 5.4 Built environment

The CAPEX/OPEX shift in the built environment means that high initial investments are needed for e.g. renovations and renewable energy technologies. After the investment phase operational cost i.e. energy costs lower significantly and can even - ideally - reduce to zero. In case of an improvement in energy efficiency, return on investment is a decrease in the energy bill. Moreover, renovations can improve comfort of a building (residential or non-residential) and owners can profit from an increase in asset value.

Although the business case seems to be attractive, even for deep renovations, there are various obstacles:
- The literature shows strong rebound effects in the sense that a relation between certificates and energy consumption in building has not been found. This implies that the expected energy savings often will not materialize.
- Owners are therefore not always sure of an increase in asset value.
- Real estate companies cannot profit from the lower energy bills because of the so-called split incentives (even though the increase in asset value seems to be less of a problem for real estate companies).
- Consumer myopia - as research has indicated, households do not take the energy savings into account when investing. They have very high implicit discount rates implying that in many cases energy savings from insulation are only taken into account for a period of 2-3 years instead of 25 years as usually done in economic calculus.
- Lack of appropriate financial products as financing energy measures can be unattractive for private institutions as the sum per project is relatively limited, and currently there is no good way to bundle projects; Moreover, a reduction in energy consumption cannot be defined as an ‘asset’ that can be sold in case of non-compliance to pay back the mortgage.

In Annex F these risks are being discussed in more detail.

## 5.5 Transport

The European Commission has set an ambitious GHG reduction objective for the transport sector, requiring radical (policy) measures to meet it. A key role is foreseen for technical GHG reduction options, such as more fuel-efficient (conventional) vehicles, alternative fuel vehicles (AFVs, either electrical or hydrogen) and biofuels. The former two options are dealing with a CAPEX/OPEX shift, meaning that they require large (upfront) investments which can be (partly) recovered by operational cost savings (fuel savings).

The CAPEX/OPEX shift may result in several barriers for parties to invest in fuel-efficient and alternative fuel vehicles and related infrastructure.
The main barriers (identified in Annex E) are related to:
- Consumer myopia. Consumers do not fully account for future operating cost savings in their purchases of vehicle and hence OPEX play a smaller role in the purchase decision than economically rational. This phenomenon is referred to as consumer myopia[23].
- Uncertainty on future cash flows (e.g. actual fuel savings to be realised are uncertain and dependent not only on fossil fuel prices, charge prices of electricity, but also on the expected use of the vehicle).
- Expected market shares (will the market for AFVs really become mature?).
- Split incentives (fuel savings are not gained by owner of the vehicle – typical for lease cars).

It should be noted that just solving the CAPEX/OPEX issue is not enough to enhance market shares for electric and hydrogen vehicles. Costs per unit of reduced $CO_2$ are currently rather high. Although these costs are expected to decrease in the next years, investments in these vehicles will not become cost effective in the period up to 2020 (CE Delft and TNO, 2011) and probably not before 2030. Therefore, an overall decrease of the total cost of ownership of these vehicles is required to realise a cost effective large-scale market penetration.

Investments in AFVs and related infrastructure often require external sources. Consequently, banks and/or other private financers have to be willing to provide the required capital. When an actor fails to arrange funding, this will impede the investments in fuel-efficient vehicles and AFVs. Therefore, next to the barriers on the markets for these vehicles and related infrastructure, also barriers on the financial market should be considered. Dougherthy and Nigro (2014) distinguish four types of barriers:
- information and uncertainty related barriers;
- legal and regulatory barriers;
- liquidity risks;
- scale barriers.

These barriers apply largely to both the investments for new production technologies and for the investments by consumers in new vehicle types. Such barriers can be characterized as a 'chicken-egg' situation. Manufacturers need to develop and invest in new fuel-saving technologies, while consumers and (transport) companies benefit from the reduced fuel consumption (CE Delft, 2012b; Greene, 2010). As R&D is highly expensive and risky, manufacturers may be reluctant to do so, especially if they are not certain to

[23] The term is slightly confusing as it does not only apply to consumers, as also business may demand unrealistically short payback periods.

earn back their investments from charging a premium price or from increased sales. Annex F discusses these barriers in more detail.

## 5.6 Institutional risks

Next to the financial risks, there also exist important institutional risks which may hamper investments in the low-carbon technologies. These risks may result in a lower level of investment than required. Such risks typically arise because of the lack of stable policies. Due to changing economic circumstances, governmental budget deficits or the pressure of lobby groups, politicians may change the conditions and policy instruments that are being used to stimulate the low-carbon technologies.

The recent (2013) abrupt changes in the stimulation of renewable energy in Spain and the Czech Republic (EEA, 2014) have made investors cautious. Every investor takes the stability of the political regime into account when weighting the expected returns on their investments. That is why investments in politically instable countries require returns more than five times higher than an average investor would ask. For the low-carbon transformation this would imply that the investments would not materialize.

We will discuss here the risk of governmental failure from thee particular angles:
a The $CO_2$ price risk in the ETS.
b The risk of subsidy disruptions.
c The risk of policy competition and overly focus on costs of policies and pressure from lobby groups.

### 5.6.1 $CO_2$ price risks

In Chapter 3 we have argued that carbon prices, both in the ETS and non-ETS sectors, should double every seven years to reach values of above € 250/t$CO_2$ in 2050. However, the $CO_2$ price is in the end a political construct where scarcity is created by limiting the issuing of $CO_2$ allowances on the market. It is very likely that high $CO_2$ prices will cause political pressure for issuing more allowances on the ETS market jeopardizing price developments exceeding € 50-80/t$CO_2$. CDP (2014) discloses that many international companies use internal carbon prices for investment decisions but these rarely exceed € 50/t$CO_2$. Higher prices may be perceived by participants in the EU ETS as unrealistic in a world with uneven carbon prices because of distortion of international competition and carbon leakage.

In practical terms this implies that there is a risk for investments in the low-carbon technologies, that the $CO_2$ price savings as depicted by the EC (2014a) and Kuik et al. (2009) will not be realized. It increases the risk premium that investors will ask on their investments.

### 5.6.2 Risks of subsidy disruptions

If $CO_2$ prices would rise up to € 250/t$CO_2$, the $CO_2$ price will be the main vehicle through which investments to a low-carbon economy are attracted. However, until that time, climate policies must use a mix of subsidies and price instruments (taxes, ETS). There is a substantial risk that on such a path of using various policy instruments substantial costs are involved and associated with suboptimal formulation of climate policies. These, in turn, can have political repercussions such as a sudden change in subsidy regimes.

It is useful to remind that such suboptimal outcomes have no place in the Impact Assessment of the 2030 Policy Framework. The total costs of the low-carbon transformation are very small according to this analysis on the basis of the economic models employed (see Chapter 2). The key driver in these models is the carbon target. In order to meet this target, economic agents are seeking the most optimal solution where they minimize their costs while meeting their constraints (e.g. their targets).[24] These economic models do not prescribe policy packages. Instead, they assume that all economic decisions will be subject to a carbon price which will equalize among the various sectors in order to minimize costs.[25]

However, policy formulation will not work according to the simplified assumptions of an economic model. Governmental policies are formed through a complicated process of social interaction with little knowledge of, or consideration for, economic efficiency. Pressure from lobby groups and other considerations than economic efficiency (e.g. maintaining full employment even though it is not efficient) often play a large role in political decision making. This undermines the efficiency of environmental policies. Such inefficiencies, which have been reported in ex-post research (CE Delft, 2005), can inflate the total costs of meeting the targets with a factor 1.5 to 4.[26]

An additional problem is that stimulating these investments through subsidies requires very detailed information on costs and benefits. The chances are high that subsidies are either too low (see e.g. the case of renewable energy stimulation in the Netherlands and Switzerland, EEA 2014) resulting in under-stimulation or too high resulting in a run-down of the governmental budgets. If the demand for subsidies trespasses certain political thresholds, subsidy schemes will be suddenly abolished. The failure of governments to provide a stable price mechanism through either subsidies or carbon prices creates additional risk for investors for which they need to be compensated. This drives up the total costs of the low-carbon economy considerably.

### 5.6.3 Risk of policy competition between member states

Government failure may not only exist within one, but also between Member States. Financiers are free to "shop" in the Member State with the most favourable energy policy. This option leads to competition between Member States to attract capital. This may result in inefficient, unsustainable policies in the longer run (ECF, 2011).

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24 In an economic model one can either optimise using an overall target or set targets for specific groups.

25 Carbon prices can be explicit or implicit. An explicit carbon price is the price for an EU emission allowance (EUA) in the EU ETS. However, also regulation, such as vehicle standards, have a carbon price: the vehicle standard is then translated to the costs that must be made to meet this target and these costs can then subsequently be translated (through a discount rate) to an implicit price of $CO_2$ to meet the targets. In the rationale of the economic models, all carbon prices (explicit or implicit) will equalise among sectors and countries. This is needed to obtain economic efficiency: it would not be efficient to have e.g. carbon prices in transport higher than those in the built environment. In that case, lowering the targets in transport and increasing them in the built environment could increase economic welfare.

26 In an effort to analyse ex-post the efficiency of Dutch climate policies, we concluded in 2005 that the policies were formulated sub-optimal thereby increasing the costs of compliance to a factor 1.5 to almost 4 (CE Delft, 2005). This was mostly due to the myriad of policies which often were overlapping and focus on more expensive 'fancy' options, such as subsidizing renewable energy and neglecting the more cost-effective energy saving options.

Policy competition may become fiercer if it is believed, a-priori, that the costs of the low-carbon transformation are too high. There is quite some evidence, by comparing ex-ante and ex-post cost assessments, that the ex-ante perceived costs are often much higher than the ex-post realized costs (see for example IVM, 2006). However, from this study it becomes apparent that this applies primarily to air quality policies. Climate policies tend to be more costly than ex-ante anticipated. This result was also presented in the abovementioned research of CE Delft (2005) on the ex-post cost effectiveness of Dutch climate policies.

Lobbying may be an important cause of policy competition resulting in exemptions for the lobby groups. In general these drive up the total costs of the low-carbon transformation. Politicians and society should be more aware of the fact that exemptions for one group imply costs for another group. There is no free lunch in the low-carbon economy transformation.

## 5.7 Macro-economic price risks

In addition to the availability of capital (see Chapter 3), there are a few specific market risks associated with the transformation to a low-carbon economy. They mostly relate to 'rebound' effects on other markets due to the investment in low-carbon technologies. Such price risks may undermine the availability of capital for the low-carbon economy transformation resulting in underinvestment relative to what is required for an 80-95% reduction in 2050.

We observe here three types of risks:
a Fossil fuel price risks.
b Exchange rate risks.
c Interest rate risks.

$CO_2$ price risks, as fourth price risk, have already been elaborated under the institutional risks above.

### 5.7.1 Fossil fuel price risks

The first obvious risk is that if we encounter a global transformation to the low-carbon economy, fossil fuel prices will seriously fall. This deteriorates the business case for both energy saving and renewable energy investments.
It leads to the paradox that the more successful international climate policy is, the less attractive investments in mitigation measures are.

A few years ago, many analysts predicted ever-growing energy prices due to the growing scarcity formulated in the so-called 'peak oil' hypothesis. In this hypothesis it was suggested that oil reserves were virtually exhausted due to the geological characteristics of oil fields and that oil companies were inflating their reserves in order to fake assets. This hypothesis has been overtaken more recently by the carbon bubble hypothesis (McGlade and Ekins, 2015) which states that 1/3 of all known oil reserves (and 1/2 of natural gas reserves and 4/5 of all coal reserves) must stay in the ground if we are to prevent global warming below the 2°C degrees threshold. Interesting is that also the proponents of this hypothesis claim that the assets of oil companies have been inflated because they are worthless if the world is to adhere to limit global warming.

It is always interesting to see how modern beliefs influence financial institutions, even when having an indisputable reputation like IMF. In a working paper of 2012, IMF staff stated that they would predict "*a near doubling of the real price of oil over the coming decade*" (IMF, 2012). This would imply that the price of a barrel of Brent would increase from around $ 100 in 2011 to nearly $ 180 in 2021.[27] We all know that after 2012 oil prices collapses and decreased from around $ 100/barrel in 2012 to below the $ 50/barrel in 2015. Therefore, in 2015, IMF staff stated in an article that "*Fossil fuel prices are likely to stay low for long*" *(*IMF, 2015).[28] In this 2015 article, the authors argue that the low fossil fuel prices impede investments in the low-carbon technologies.

For these reasons, any investment related to energy use bears the risk of price fluctuations on the energy markets. The question is therefore not what the future price will be but to which extent climate policies influence these prices and risks. The extent to which climate change policies influence the price formation of fossil fuels has been, amongst others, investigated in IEA (2013). They conclude that the influence in the end is rather limited. Stronger climate policies do not cause any currently producing oil and gas fields to shut down early but rather limit exploration of new fields. This may mitigate possible negative price effects.

Moreover, the use of CCS in both the power and industrial sector implies that there will be still a vast demand for fossil fuels. It cannot be expected, therefore, that the prices will decrease much further than the present levels in the long run. Also policies can help to de-risk fossil fuel price impacts by, for example, transferring this risk to the government or by introducing energy taxes that are made flexible on the energy price development: if prices are high, the tax rates are lowered and if prices are low, tax rates are increased. In this way the risk of fossil fuel price developments is in essence transferred to the state budgets.

However, the current low price levels do constitute one particular problem with respect to the costs, as assessed in the IA of the 2030 framework. The 2030 framework assessed the costs and benefits against expected fossil fuel import prices of € 110/barrel in 2015 rising towards over € 140/barrel in 2050. This oil price determines to a large extent the expected benefits from any technology saving on fossil fuels. It can therefore be argued that the IA of the 2030 framework most likely has overestimated benefits from the low-carbon transition and that in the end the expected benefits are smaller than anticipated. The lower fossil fuel prices thus necessitate even stronger carbon prices to step in, in order to make the low-carbon transformation financially attractive.

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27 With a 90% confidence interval laying between $ 125 and $ 240 in 2021.

28 To be fair: in both articles it is explicitly stated that the views expressed in the paper are those of the authors, not of the IMF.

### 5.7.2 Exchange rate risks

Within the EU, more than 55% of fossil fuels consumption is imported from countries outside the EU (EEA, 2012). Moreover, fossil fuels constitute the largest import category of the EU trade with the rest of the world.[29] Since the majority of EU's fossil fuels are imported from other countries, there is a chance that if the EU is reducing its fossil fuel imports, the balance of trade will improve and exchange rates will rise. However, this may hamper exports in the long run.

There is no good study, to our knowledge, that has investigated this issue. We suspect, however, that the impact in the long run will be relatively limited. A possible appreciation of the euro due to limited fossil fuel imports will be dampened by secondary reactions on markets. Higher efficiency and lower salary demands due to lower inflation will stimulate export and the demand for euros. Moreover, for private investors these risks are not relevant since their investments in themselves are not causing this risk. Therefore we conclude that this risk is not hampering the transformation towards the low-carbon economy from an investor's perspective. Moreover, we expect that this is not in the long run a major risk in the transition towards a low-carbon economy.

### 5.7.3 Capital market risks

Some economists have been arguing that the capital needs for transition may result in a 'crowding out' effect: due to investments in environmental policies, other effective investments are not undertaken.[30] This may drive up interest rates and reduce the profitability of all other investments and thus reduce prosperity.

However, there are some compelling arguments why this may not be an important risk. First, the analysis in Chapter 4 has witnessed that there is no shortage of money for investments. The total investments in the low-carbon economy transformation can easily be found from the growth of the capital market. Second, the investments in the low-carbon economy may not necessarily limit other investments, but rather limit present consumption. So we believe that there is not a risk of crowding out and raising interest rates due to increased demand for capital.

A special issue of 'crowding out' may arise in the context of 'stranded assets'. The global low-carbon transition will lead to a decline in value of some fossil fuel assets as these will no longer be used ('stranded'). If the current policies do not adhere strongly enough to the rigour of future climate policies, investments may still take place in coal fired power stations and refinery capacities. This will drive up total investments and make the transition towards the low-carbon economy needlessly more expensive.

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[29] In 2014 almost 30% of total EU28 extra imports came from fossil fuel imports. If one would extract the exports, a net import position of 23% would remain.

[30] This is the argument that Lomborg (2000) implicitly makes.

## 5.8 Conclusions

The substantial investments towards the low-carbon economy up to 2050 imply certain risks for investors and the economic climate in the EU28. These risks are often sector-specific. In the power sector the reduction of infra-marginal rents (both through lower OPEX and reduced scarcity pricing) seems to be a major risk to investments. In the industry sector the maturing EU market in combination with the global concern about investment policies seem to be major risks while in the transport and built environment sectors consumer myopia, where future reduced energy costs are not fully taken into account, seem to form a major obstacle.

In addition to these sectoral obstacles, we have investigated macro-economic risks. Price risks (exchange rates, fossil fuel prices) are probably not very important and can normally be hedged in financial markets. Institutional risks seem to be much more important. Lobbying and badly-informed policy decisions may be important risks on the low-carbon economy path. In order to make private capital available, $CO_2$ prices should rise substantially towards € 250/t$CO_2$ in 2050. However, there are quite some political lobbying goings-on to keep prices at very low levels. Some frontrunner companies do include implicit carbon costs in their investments but virtually no company takes into account that carbon prices need to reach levels above the € 50/t$CO_2$.
In the absence of a high $CO_2$ price, a myriad of subsidies and price instruments must guide the transition towards the low-carbon economy. In this path, suboptimal policy choices are likely. Recent examples of drastic changes in support schemes in Spain and Czech Republic have shown that governments will cut down support schemes if deficits on state budgets emerge.
These experiences drive up the risks for investors, making investments more expensive.

# 6 Conclusions and policy recommendations

## 6.1 General conclusions

This study has investigated investment barriers for the low-carbon transformation towards 2050. The following conclusions can be taken from this study:

- The investments for the low-carbon economy have to be very substantial and mount to 2% of GDP annually. Moreover, these investments must be taken in a relatively short period of 35 years (e.g. an average value of 18 years). This is a very short cycle exceeding historic capital replacement rates in e.g. buildings and industrial machinery.
- Although the investment efforts need to be high, similar investment efforts have been observed in history. The current investment efforts can be compared to the investments that were required after 1990 in the former communist economies that became part of the EU. In a period of 20 years their economies (e.g. infrastructure, industry, consumer durables) have undergone a rapid transformation during which all existing assets (machinery and technologies) were rapidly depreciated and replaced by more modern technologies.
- The transformation of the former communist economies towards a market economy was accompanied with a rapid devaluation of their currencies, which helped to depreciate quickly the existing assets and to make an attractive business case for investors to step in. The low-carbon transformation, if successful, should develop a similar mechanism through a rapid increase in the carbon prices.
- The main conclusion of this study is therefore that **carbon prices must be raised very considerably in order to provide attractive business models for the low-carbon economy transformation.** Carbon prices would ideally be raised up to € 30/t$CO_2$ now and gradually increase to over € 100/t$CO_2$ in 2030 and € 250/t$CO_2$ in 2050.[31] Without very high $CO_2$ prices, the whole low-carbon economy transformation must be achieved through a mix of subsidies and regulation which is very costly, opens the floor for lobbying and consequent misallocation of resources and is likely to be untenable because of public concerns over worn-out governmental budgets.
- Despite the substantial investments and high carbon prices, total system costs to deliver energy functions to end users are comparable to the present situation. The higher CAPEX is thus earned back through a lower OPEX. Therefore, there are virtually no negative impacts to be expected in the long run on our level of welfare or affluence.
- Understanding capital flows and technology development helps to manage transition. Capital availability is in general not a problem. The entire transformation to the low-carbon economy can be financed from the growth of the capital market so that crowding out will not occur. However, there may be a specific problem with respect to the availability of private equity for innovative SMEs required for the scale-up phase in the technology life cycle. This may hamper a cost-effective transformation to

[31] CE Delft assessment based on EC (2011b) and CPB/PBL (2016).

a low-carbon economy especially since many of the required technologies still need additional research and experiments to improve both the technologies and its economics.

- The majority of capital requirements can be financed from public equity (stocks, bonds) provided that revenue/risk combinations are acceptable for investors. Due to globalisation and good investment opportunities in other parts of the world, public equity nowadays requires higher revenues than in the past. In general we observe that most private investors in e.g. companies would expect minimum rate of returns between 12-14% on investments. This is substantially higher than most of the discount rates that have been used in Impact Assessments and in abatement cost curves like the McKinsey curves. The fact, that the expected return on investments is higher than the social discount rate, implies that it will be more difficult to formulate attractive business cases for private investors. In order to formulate attractive business cases carbon prices may have to rise even further than the suggested € 250/t$CO_2$ in 2050.
- Not only revenues are falling short of expected returns, also risks tend to increase. The major component of higher risk is the higher upfront investments vs. lower OPEX. Especially in the power sector this would require different revenue and risk models from reference cases. Moreover, there is a considerable regulatory risk in the sense that public concern over governmental budget deficits may lead to ceasing subsidy programs, and intensive lobbying from special interest groups may limit carbon pricing so that the price incentives for the low-carbon economy are too poorly implemented. Special attention should be paid to possibilities to bring down these risks, for example by providing stable institutional frameworks.

## 6.2 Generalised policy recommendations

There are five distinct policy recommendations applicable at a general level that stem from this study:[32]

1. Make much more use of the carbon price mechanism to create value and increase these carbon prices.
2. Make specific provisions for capital markets.
3. Develop an active policy of de-risking.
4. Provide managed decline for those carbon-intensive assets that are still profitable.

These four components will be described below in more detail. Specific sectoral policy recommendations will be discussed in Paragraph 6.3.

### 6.2.1 Recommendation 1: Make much more use of carbon price mechanism to create value and accept steeply increasing carbon prices

The upshot of this study is that without high $CO_2$ prices, investments in low-carbon technologies cannot be made profitable. Carbon prices generate value for low-carbon investments through which markets can actively engage in investing in technologies. Without high carbon prices, the low-carbon transformation must be stimulated by a mix of subsidies and regulatory instruments. This puts a heavy burden on governments for obtaining the right information and choices on the development of technologies. Furthermore,

[32] In addition to these, some sector-specific policy recommendations, that follow from the analysis in the Annexes, are listed in Paragraph 6.3.

advancing the low-carbon transformation through subsidies and regulations opens the floor for lobbying and consequent misallocation of resources and is likely to be untenable because of public concerns over worn-out governmental budgets. Moreover, if the low-carbon transformation is to be achieved through subsidies, total investment and costs will increase considerably which will introduce new risks of changes in the regulatory regime (which in turn will increase the costs). Therefore our first recommendation is that there should be an explicit carbon price established in every sector of the economy.

Carbon prices assist in creating value for the low-carbon techniques so that revenue generating business cases more easily can be defined. Moreover, carbon prices assist in depreciating existing fossil fuel-based assets, which is an important characteristic of the low-carbon transformation. Finally, carbon prices let the market decide which techniques prevail and are more cost effective for stimulating innovation than governments.

However, present level of carbon prices is way too low. Carbon prices would have to double every seven years in order to stimulate low-carbon investments. Ideally carbon prices would be raised to € 30/t$CO_2$ now and gradually increased to over € 100/t$CO_2$ in 2030 and € 250/t$CO_2$ in 2050. These are very substantial increases from present levels and policymakers should start to make clear to the society that we can expect such prices in the near future.

Companies are slowly getting used to the idea that emitting carbon costs money. CDP (2014) has surveyed that many companies already use an internal $CO_2$ price for evaluating investments. Although CDP does not calculate an average shadow price of $CO_2$, their examples show that most companies in the industrial sector use carbon prices between € 20-50/t$CO_2$.[33] However, this study has indicated that in order for carbon price mechanisms to work, much higher shadow prices are needed, between € 100/t$CO_2$ in 2030 towards € 250 and higher in 2050. It is therefore crucial that the EU starts to communicate clearly towards all stakeholders that carbon prices will start to increase every seven years. Moreover, it can be a very prudent strategy to try to bring carbon prices today even much higher and in the range of € 30-40 that the frontrunner companies currently use.

Higher carbon prices may not necessarily be enforced through the ETS alone. It is very clear that this will cause problems with competiveness in the long run. Free allocation is an insufficient mechanism to tackle competitive issues because carbon costs are implicitly passed forward in product prices (CE Delft & Öko-Institut , 2015). If carbon costs reach € 250/t$CO_2$, the iron and steel sector runs the risk that by 2050 over 40% of the cost price of e.g. hot rolled coil is explained by carbon costs which cannot be sustained if non-EU countries do not adhere to carbon pricing. However, if the focus of taxation is shifted from the production of steel towards the consumption of steel, such high carbon prices may not lead to adverse competitive impacts, especially if the taxation is coupled with a system of monitoring and reporting like in a system of carbon added taxes.

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[33] Power companies use higher prices of € 70/t$CO_2$. According to the surveys in CDP (2014) there is one power company (Pennon Group in the UK) that has indicated that it calculates investments also with a $CO_2$ price of € 250/t$CO_2$, next to the more commonly used € 70/t$CO_2$.

For other sectors, like the power sector, a steep increase in $CO_2$ price will offset the decreasing marginal revenues from renewables and thus form an important component in the business case and constitute a mechanism to counterbalance the perceived CAPEX/OPEX shift. In addition, it may stimulate the development of CCS in the power sector indicating that much of the current discussion on system imbalances with a high share of renewables could be partly mitigated by serving a larger share of the market by fossil fuels, as has been assumed in the PRIMES analysis of the policy scenario in the Impact Assessments.

High $CO_2$ prices also work on depreciating current assets. The low-carbon economy transformation will not materialise if currently sweating assets are not heavily depreciated. If markets do not value the current assets as stranded, they will continue to be used in production and remain attractive investment objects. High $CO_2$ prices may act like the exchange rate depreciations in the former communist economies devaluating the value of the existing capital stock.

### 6.2.2 Recommendation 2: Make provisions for venture capitalists and Green Funds

Capital availability is not a problem for the low-carbon transformation. However, there are two specific bottlenecks in the capital market which relate to the availability of venture capital and the large amount of capital needed in very small shares for the built environment. For these cases, governments could formulate alternative policies:

*Ad 1: Stimulate venture capital*

Many of the technologies needed for the low-carbon transformation have already been developed. In terms of capital, there seems to be no shortage of capital for research and development, but rather for the next stage which should lead to commercially attractive options. Policy support for the low-carbon transformation is currently available in both the beginning (innovation, but perhaps not enough) and towards the end (ETS) of the cycle, but mostly lacking in between – where is the deployment support for low-carbon technologies that are close to maturing and are facing now a matured (and often oversupplied) demand market. Governments could factually subsidise venture capitalist participations in low-carbon technologies by taking away potential risks. There exist a few such initiatives (e.g. the SEED regulation in the Netherlands). Another opportunity would be to construct public-private partnerships where governments take over part of the risks that are involved in new ventures by constructing a Green Fund that would lend money itself for projects to private venture capitalist funds and share the risks. This so-called Fund of Funds mechanism can reduce the risks by spreading them over a larger group of participants (Admiraal, 2011).

*Ad 2: Bundling of projects*

Large investors tend to have a preference for large projects. However, at the level of households, both with respect to transport and built environment, most of the investments must be undertaken by millions of individuals. Especially in the built environment there does not, at this moment, exist a financing scheme that is capable of serving the investment need. Bank loans are difficult to obtain since the energy savings seem not to be passed through in an equiproporionate increase in asset values. Large investors, like pension funds, often demand projects of minimal € 100 million in order to keep overhead costs low. Especially in the built environment sector it is therefore important to find ways to bundle projects. This can be done through the use of a Green Fund that would act as public or quasi-public financing institution that provide low-cost, long term financing support to low-carbon project by leveraging public funds through the use of various financial mechanisms to attract private investments. They can have two roles: (a) by lowering the costs of capital since governments can borrow capital at more favourable conditions than private investors; (b) by bundling small-scale investments into one larger financial bundle that can be traded on financial markets and used by investors. In this way Green Banks can overcome the substantial transaction costs that are especially relevant for the small-scale investments by households in the built environment and transport sectors.

### 6.2.3 Recommendations 3: Bring down regulatory risks

Reducing risks is another important feature from the investor perspective to stimulate investments in low-carbon technologies. This especially applies to technologies that are in a more mature state, like some renewable energy technologies. Innovation may not bring down costs considerably and the uptake of these technologies in the markets can be stimulated better by reducing the risks.

Within this study we have identified regulatory risks and fossil fuel price risks as the most important risk components. Regulatory risks are very important both in the power and industry sectors. At present, the first and most important barriers in **the power sector** seems to be the lack of a stable policy framework, and the lack of a shared long term outlook for RES and fossil demand, both at the EU and at Member State levels. Stable policies and stable and reliable demand outlooks will reduce risks to investors as well as the cost of financing (see, for example IEA RE Medium term market outlook report, 2014; EWEA, 2013). In the absence of stable policies, the risk premium on investments is simply increasing. At present, the relevant EU directives additional to the ETS (namely the RED and related policies such as the EED and EPBD) are limited to 2020, while MS policies are quite volatile in many countries and have failed to create a stable regulatory framework.
This situation is likely to continue in the years to come, since a decision regarding the 2030 RES-related EU governance is not expected before 2018 and many MS policies for 2030 will not be decided on before the EU framework is in place. As the current policy of binding targets for 2020 at Member State level (defined in the Renewable Energy Directive) will not be continued after 2020, the future of RES development in the EU after 2020 will remain uncertain.

But also for the prospects of EU **industry,** a long term oriented policy perspective is needed. There is lack of recognition that free allowances can only be a temporal solution to the risk of carbon leakage. At present, with a very low-carbon price, the risk of carbon leakage is indeed quite minimal.
But in the longer run, with prices required to be 30-50 times higher than observed today, free allocation will no longer be able to safeguard companies from competitive disadvantages (see also Annex D). The 2030 framework does not address this issue and put its hopes rather on a weak carbon price signal to continue up to 2030. This, in itself, already creates a lock-in in which industrial installations in Europe are not being modernised, with strong industrial lobbying regarded as more effective than investing in low-carbon measures.

Chapter 4 identified that some price risks may be involved, especially with respect to the energy price. The decrease of fossil fuel prices since 2014 have made investments in renewable energy, which already were not profitable, even less attractive. In this situation these projects are often dependent on subsidies, what decreases the change of attracting capital. Therefore governments should try to stimulate the investments by taxing fossil energy more heavily. Taxes can be made fluctuating on the energy price level in which a higher share of the energy is being taxed when prices fall. This would make the economics of renewable energy projects more predictable.

### 6.2.4 Recommendation 4: Provide a system of managed decline for those fossil fuel assets that are still sweating

The crucial element in the low-carbon transformation is a rapid depreciation of current assets. The economy of the EU must undergo a structural transformation towards the low-carbon economy. There are two problems with these. First, there may be a risk that the incentive system (e.g. carbon prices and subsidies) introduces feedback loops that undermine the effectiveness of the price mechanism. In that case there are not enough signals generated to depreciate current assets and make them unprofitable. This is especially the case for the oil price development and the decreasing marginal returns for renewables. Such feedback loops could be, in theory, compensated by increasing subsidies and/or carbon prices, but this may be difficult to implement. Therefore, a system of managed decline of (industrial) assets may be required to assure that the transformation towards the low-carbon economy is not endangered by fossil fuel assets that are still profitable.

Second, transformation processes have proven to be difficult in the past because they are accompanied with a structural shift in the distribution of incomes. Even though the net impact on our welfare seems to be minimal, there are winners and losers and the net impact for losers may be very substantial. Therefore a process of managed decline will be required to mitigate eventual negative social consequences.

Some experience with managed decline has been gained in the transformation of European coal industry. In Germany, Poland and Czech Republic, special programs have been developed to aid the transformation of local communities towards different forms of employment, for example by educational programs and preferable loans for other investors to invest in the regions. At present, no such programs exist for the low-carbon transformation, but it would be good to start to consider if such programs could be developed for regions that will be adversely affected by the low-carbon transformation. Aid through such programs should be oriented towards finding more productive activities under the new cost structure. This may be accompanied with a search for ‘better jobs’ where less harsh labour conditions prevail than in some parts of the energy-intensive industries.

## 6.3 Specific sectoral conclusions and recommendations

This study has investigated the transformation towards the low-carbon economy both from the perspective of the whole economy and from the perspective of individual sectors. The sectoral analysis has entirely been shifted to the Annexes in this study while the main results from the sectoral analysis have been integrated with the macro-economic analysis throughout Chapters 2-5. Below we present the main conclusions from the sectoral perspectives.

### 6.3.1 Power sector

The cost-effective transformation towards an 80% emission reduction in 2050 foresees an almost complete decarbonisation of the power sector. To achieve this, substantial additional investments must be made, but not order of magnitudes higher than today. Until 2035 primarily investments in renewable energy technologies will take place. After 2035 investments in CCS (both for fossil fuels and biomass-fired stations creating carbon sinks) would become dominant in official European Commission scenarios, although progress on CCS has been much slower than expected for various reasons. Therefore both the investment climate in conventional generation (including biomass) and renewable generation is relevant for the future of the power sector.[34]

The investment climate is seriously hampered by three mechanisms: (i) lower returns due to lower marginal costs of production due to increased electricity from renewables (lower OPEX) which is enhanced by the fact that there is currently overcapacity in many EU MS electricity markets; (ii) higher price risks due to higher price volatility of renewable electricity revenues; (iii) more uncertainty because of the growing dependency on support mechanisms for a larger share of the electricity market and the uncertainty whether politicians are willing to accommodate these. Rising carbon prices, managed retirement (see below) and better integration of flexibility pricing of demand response can mitigate some of the problems of providing attractive business cases for renewables. Moreover, rising carbon prices are also a prerequisite for the economic business case for CCS, alongside increased government support and broader public acceptance.

However, in the short run, the importance of subsidy schemes is likely to be more pressing. Here, subsidies must compete in a market that is oversaturated with production capacity so that the price mechanism is currently destroyed. Moreover, the current outlook on RES targets beyond 2020 foresees only the EU wide target to 2030, while current policy of binding targets for 2020 at Member State level will not be continued after 2020. For RES investments the questions of how to relate to the binding EU 2030 RES target at national level may become a barrier for further deployments of renewable energy if the new governance regime is not sufficiently robust.[35] While Member States have started to implement short term mitigating measures, they have so far failed to create a stable policy framework. In this context, attention should also be paid to managing price formation by e.g. a managed decline of certain fossil fuel based assets that could assist in reducing overcapacity and bringing prices more in line with what is needed.

Problems are not limited to power companies only. The current business model for consumer renewables will be contested as the avoidance of energy taxes and fixed energy costs (including a FiP/FiT component) are implicit support mechanisms. Especially the differences between the avoided tariff costs and the factual spot market price can become very substantial in the future and is likely to be untenable, as someone needs to bear these costs. Thus the envisaged internal energy market and the EU ETS reforms at EU level will need to take these considerations into account.

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[34] It should be noted that the Commission is also looking at biomass sustainability and this is also a factor in future assumptions on biomass.

[35] The IEA Technology Roadmaps assess in detail the barriers to further deployment of the various RES technologies. Regarding financing of wind energy, for example, the IEA confirms the value of binding deployment targets with near-term milestones as it encourages private sector investments.

### 6.3.2 Industry

While the emission reduction efforts in the industrial sector may be not as ambitious as in other sectors, the investment challenges may be more substantial. Energy-intensive industries may see the requested investments surpass the historically known investment levels. In addition, demand in the EU market for energy-intensive products is lagging and EU industries use relatively old installations which, to some extent, have been depreciated already. This makes continuation of production using the current technologies profitable and investments in low-carbon technologies unlikely.

Most of the EU energy-intensive industry is part of the global concerns that do not consider investments in the EU as profitable. Therefore, capital availability is a bottleneck. Moreover, rising carbon prices would render EU industries in a competitive disadvantage vice versa producers from regions where carbon has a lower price. Therefore, policy options need to be developed that cope with this issue. These would consist of shifting a larger share of climate policies for energy-intensive industries from the production *within the EU* towards the consumption of their products, irrespective of whether they are produced in the EU or elsewhere. This would bring the competitive position of EU firms on par with competitors from countries where carbon has no or a lower price. A carbon added tax (see also Annex D) can provide a better guidance for EU manufacturers than the present policy package of the EU ETS.

It is important to recognise that not only large-scale investments are needed but that substantial improvements can already be realised by relatively small energy efficiency investments. It is clear that the ETS price signal is too weak to stimulate these. At present, in many Member States, companies participating in the ETS are exempt from additional policies. This practice effectively limits the uptake of efficiency improvements as has been demonstrated, for example, in the case of the Netherlands (CE Delft, 2011). EU policy could address this, for example, by enforcing energy improvements via the BAT-Refs and environmental inspections.

Refineries and cement manufacturing are faced with a situation of severe overcapacity, especially when interpreted in the light of the 2050 framework. Therefore a process of managed decline will be required. Some experience with managed decline has been gained in the transformation of European coal industry. In Germany, Poland and Czech Republic, special programs have been developed to aid the transformation of local communities towards different forms of employment, for example by educational programs and preferable loans for other investors to invest in the regions. Such programs are lacking in general when it comes to industrial transformation. It would be wise to consider if provisions can be made in the European Structural Fund to guide the industrial transformation towards a less carbon future explicitly.

### 6.3.3 Built environment

To meet the GHG40 emission targets the built environment has to reduce its emissions by 82%. The main challenge to achieve this target is how to accelerate the annual rate of deep renovations of existing buildings.
These types of renovations ask for a high initial level of investments and have long payback times. Current (deep) renovation levels are way too low to achieve the targets. Problems that hinder the pace are first of all a lack of demand from owner-occupiers and problems with intangible revenue streams and reluctance from the investor's side, because of a lack of solid cash flows and high perceived risks. To overcome those hurdles a stable regulatory framework is needed. Demand can be increased by price incentives or mandatory requirements. Leverage is an important solution to attract more private capital. The problem of intangible revenue streams can be solved by focusing on collective heat solutions or by creating new financing models, like ESCOs.

Large investors tend to have a preference for large projects. As discussed in Annex F, large investors often demand projects of minimal € 100 million. Otherwise overhead costs will become higher than preferred. Therefore scale of the projects is important for several investors, disadvantaging smaller projects. Especially in the built environment sector it is therefore important to find ways to bundle projects. This can be done through the use of a Green Funds or Green Banks. They are public or quasi-public financing institutions that provide low-cost, long term financing support to low-carbon project by leveraging public funds through the use of various financial mechanisms to attract private investments.

### 6.3.4 Transport

The European Commission has set the ambitious GHG reduction objective for the transport sector, requiring radical (policy) measures to meet them. A key role is foreseen for technical GHG reduction options, such as more fuel-efficient (conventional) vehicles, AFVs and biofuels. The former two options are dealing with a CAPEX/OPEX shift, meaning that they require large (upfront) investments which can be (partly) recovered by operational cost savings (fuel savings).

The CAPEX/OPEX issue do result in several barriers for parties to invest in fuel-efficient and alternative fuel vehicles and related infrastructure. The main barriers are related to consumer myopia (the future fuel savings are not fully considered when buying a vehicle), uncertainty on future cash flows (e.g. actual fuel savings to be realised are uncertain) and market shares (will the market for AFVs really become mature?), and split incentives (fuel savings are not gained by owner of the vehicle). Additionally, there may be barriers on the financial markets that hamper financing investments in these vehicles/infrastructure, such as regulatory, liquidity and scale barriers.

Several measures can be implemented to address the barriers resulting from the CAPEX/OPEX shift. Private/semi-public financial tools that can be used are leasing models, ESCOs and energy savings performance contracts and Green Banks. These measures are mainly focused on addressing the barriers on the financial markets, although they may also address the barriers of consumer myopia and uncertainty on future cash flows.
With respect to the low-carbon transformation, the most important obstacles that policy measures should address are consumer myopia and the development of low-carbon infrastructure. For the transport sector, high $CO_2$ prices may not be enough to stimulate the transition as the very high personal discount rates make the use of financial instruments useless.

Therefore, governmental regulation in the form of product norms and providing information may be more effective. Product norms can be used in e.g. drastically lowering the maximum $CO_2$ exhaust gasses for new vehicles reducing this from the present 95 $gCO_2$/km to zero in 2040. In addition, providing information about lifetime costs and/or labelling can be alternative means towards changing consumer preferences. Also reducing long term risks (e.g. providing guarantees for batteries) can be a good strategy to enhance the uptake of AFVs.

In the short run, the negative revenue case of AFVs can also be addressed by means of subsidies and fiscal incentives.

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# Annex A PRIMES Reference Scenario

## A.1 The PRIMES reference

The Reference Scenario is described in detail in Chapter 7.1 of the IA of the 2030 Framework (EC, 2014a) and in the PRIMES background documentation (EC, 2013a). This scenario is based on the binding RES and GHG targets that were agreed in the 2020 energy and climate package combined with the assumption that the annual EU ETS linear reduction factor of 1.74% will continue after 2020. In the Reference Scenario, GDP grows by 1.5% per year between 2010 and 2030 and decreases to 1.4% after 2030 (due to assumptions regarding the ageing of the population). In the Reference Scenario, no enabling policies are assumed.

The Reference Scenario in the IA is therefore, in terms of policy content, comparable to the reference scenario in the 2050 Low-carbon Roadmap. However, the Reference Scenario in the 2030 IA has been based on new PRIMES forecasts while the reference scenario in the 2050 Low-carbon Roadmap was based on the PRIMES forecasts from 2009. Primarily because economic growth was much lower than anticipated between 2009-2012, the new PRIMES reference scenario will result in higher reductions in 2030. In the Reference Scenario, GHG emissions will be reduced in 2030 by 32.4% compared to 1990. It is, in this light, important to notice that these reductions will not be achieved 'automatically' but already contain various environmental policy instruments that need to be implemented and maintained (an issue further elaborated in Paragraph 2.2.1).

However, the analysis of the 2011 IA Roadmap was based on the PRIMES 2009 baseline scenarios in which the impact of the economic crisis was not fully reflected. The PRIMES 2009 Reference Scenario assumed that, after the downturn of 2008, sustained economic growth would prevail after 2010, resulting in average EU27 growth rates of 1% in 2011 and 2012 with full recovery afterwards resulting in a growth forecast of, on average, 2.2% of GDP between 2010 and 2020 and 1.7% between 2020 and 2030 (see EC, 2010). However, the 2013 PRIMES Reference Scenario, which was used in the IA currently under review, assumes a much lower GDP growth forecast at about 1.45% per annum between 2010-2030. As a consequence, GHG emissions are lower in the in the Reference Scenario in the present IA compared to the IA of the Low-carbon Roadmap. Table 11 shows the different development of GDP and emissions in both Reference Scenarios.

**Table 11 Overview of developments in GDP and $CO_2$ emissions according to PRIMES Reference Scenario 2009 and 2013**

| | 2005 | 2010 | 2015 | 2020 | 2025 | 2030 |
|---|---|---|---|---|---|---|
| GDP PRIMES Ref 2013 | 100 | 105 | 112 | 121 | 131 | 142 |
| GDP PRIMES Ref 2009 | 100 | 103 | 115 | 128 | 140 | 152 |
| $CO_2$ PRIMES Ref 2013 | 100 | 91 | 87 | 79 | 75 | 69 |
| $CO_2$ PRIMES Ref 2009 | 100 | 95 | 93 | 87 | 86 | 83 |

Source: Own calculations based on EC, 2014a and EC, 2011b. The Primes Reference Scenario 2013 has been based on EU27, not EU28 as in the PRIMES documentation, in order to make it comparable to the 2009 PRIMES Scenario.

$CO_2$ emissions in the new PRIMES Reference Scenario are 14% lower compared to the old PRIMES Reference Scenario because of lower GDP growth and a more policy-intensive formulation of energy efficiency measures in the Reference Scenario.

Oil prices in the PRIMES Reference scenario start from € 110/barrel in 2010 and slowly increase to € 140/barrel in 2050.

# Annex B Additional information scenarios

## B.1 Targets scenarios of the Low-carbon Roadmap (2011)

In 2011 the European Commission made an assessment of a set of possible 'decarbonisation' scenarios leading to a 80% domestic (i.e. EU) reduction of 2050 GHG emissions below 1990 and compared the impacts of the decarbonisation scenarios with a reference scenario.[36]

In the reference scenario, EU and national policies implemented in March 2010, including the EU 2020 energy and climate policy package, are considered. The developments in the decarbonisation scenarios to meet the -80% constraint are driven by carbon prices relating to $CO_2$ and non-$CO_2$ emissions whereby a common carbon price across all sectors and gases is assumed. Since the so-called Delayed Climate Action Scenario is the decarbonisation scenario that is the closest to the GHG40 Scenario of the 2030 energy and climate package, we will focus in the following on the investment requirements and energy costs in the Delayed Climate Action Scenario.

The Delayed Climate Action Scenario is characterised by a fragmented action in the sense that no global action in line with the 2°C target is taken, leading to world energy prices that are higher than in the case of global action. In fact fossil fuel prices are assumed to be increasing and to be the same as in the reference scenario. The scenario further assumes the achievement of the climate change and energy package by 2020 (the 20% GHG reduction target and the 20% renewables targets by 2020). Between 2020 and 2030 action is no more ambitious than for the reference scenario, with carbon prices equal to the reference scenario. Action is resumed in 2030, after 10 years of delay, with increasing carbon prices at levels that would cause the cumulative EU carbon emissions over the full period 2010 to 2050 to equalise with those of the 'Effective and widely accepted technology' scenario. Technological change for electrification is assumed to come at a higher cost than in the 'Effective and widely accepted technology' scenario due to a corresponding delay in development and deployment, but other technologies are for simplicity assumed to come at same cost.

## B.2 Investment and costs of the Low-carbon Roadmap (2011)

The average annual total energy investments in the period 2011-2050 are, for all sectors, estimated to amount to approximately € 930 billion in the reference scenario and around € 1,200 billion in the Delayed Climate Action Scenario (see Table 12).

[36] All scenarios lead to a 80% domestic reduction of 2050 GHG emissions except one scenario in which additional measures are taken to protect the international competitiveness of Europe's energy-intensive industries.

Table 12 **Average annual total energy investments (all sectors; billion €)**

| | 2011-2030 | 2031-2050 | Average |
|---|---|---|---|
| Reference Scenario | 866 | 992 | 929 |
| Delayed Climate Action | 928 | 1,541 | 1,234 |

This table also shows that the Delayed Climate Action scenario is typically having much larger investments in 2030-2050 than in the earlier years. Between 2031-50 the additional annual investments compared to the Reference Scenario accrue to over € 550 billion, which would be equivalent to 3% of GDP in this period.

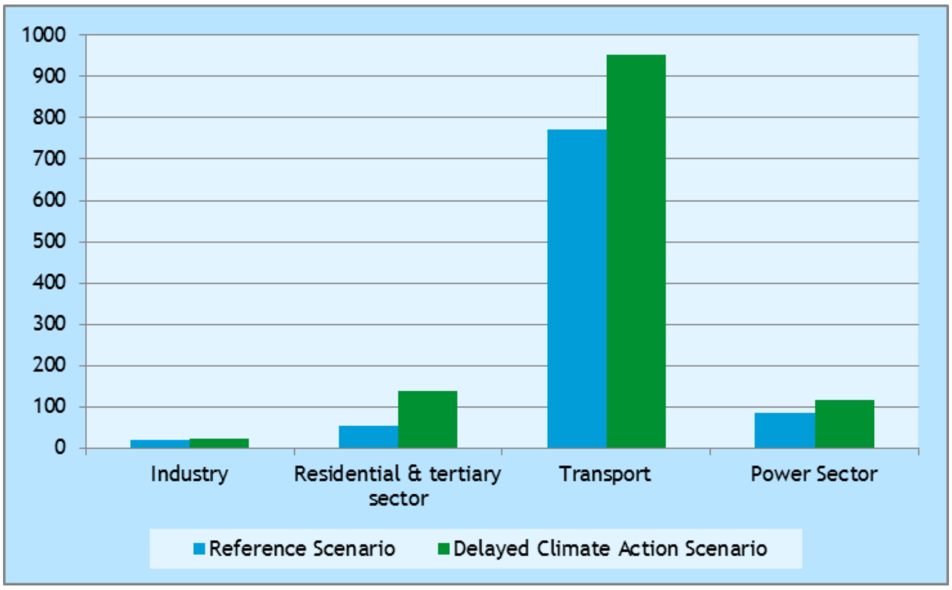
A look at the annual average energy investments per sector (Table 13 and Figure 6) reveals a similar pattern as presented in the Impact Assessment of the 2030 energy and climate package, however, investment levels are, especially for the transport sector, estimated to be higher.

Table 13 **Average annual energy investments per sector for the periods 2011-2030 and 2031-2050 (billion €)**

| | Reference Scenario | | Delayed Climate Action | |
|---|---|---|---|---|
| | 2011-2030 | 2031-2050 | 2011-2030 | 2031-2050 |
| Industry | 19 | 20 | 18,5 | 29 |
| Residential & tertiary sector | 48 | 57 | 49 | 227 |
| Transport | 722 | 825 | 768 | 1,139 |
| Power sector | 78 | 92 | 93 | 138 |

Source: Based on EC (2011).

Figure 6 **Average annual investments per sector for the periods 2011-2050 (billion €)**




Source: Based on EC (2011).

Regarding the average annual fuel expenses (Table 14), these are, just as in the Impact Assessment of the 2030 energy and climate package, estimated to decline for each sector if you compare the reference and the policy scenario.

Table 14 **Average annual fuel expenses per sector for the period 2011-2050 (billion €)**

| | Reference Scenario | Delayed Climate Action |
|---|---|---|
| **Industry** | | |
| Fuel and electricity expenses | 288 | 275 |
| CCS expenses | 0 | 5 |
| **Residential & tertiary sector** | | |
| Fuel and electricity expenses | 270 | 236 |
| CCS expenses | 388 | 352 |
| **Transport** | | |
| Fuel expenses | 628 | 509 |
| Electricity expenses | 10 | 74 |
| **Power Sector** | | |
| Fuel expenses | 167 | 153 |
| **Total** | **1,751** | **1,605** |

Source: EC (2011).

## B.3 Macro-economic Impacts of the Low-carbon Roadmap (2011)

In the Impact Assessment of the Low-carbon Roadmap (EC, 2011b), the impacts are determined, on the one hand by using global models (POLES, GEM E3), and on the other hand by using EU models (Primes, GAINS for EU non-$CO_2$ emissions, CAPRI for agricultural production). The employment and GDP effects of the Delayed Climate Action Scenario as such are not derived in the Impact Assessment.

The employment and GDP effects of a fragmented action scenario (NB: the Delayed Climate Action Scenario is a fragmented action scenario too) are determined using the global GEM E3 model. In this fragmented action scenario it is assumed that the EU achieves internally a 25% GHG reduction by 2020, increasing to a 40% reduction by 2030, whereas other regions only fulfil their low end of the Copenhagen Pledges up to 2020, and after 2020 these pledges are assumed to stay constant. In addition four scenario variants are considered where the non-ETS sectors are/aren't subject to a carbon tax and where the ETS sectors that receive free allowances (all but power sector) do/do not pass on the opportunity costs of using free allowances.

In Table 15 the 2020 and 2030 GDP and employment impacts are summarised for the different variants, given as the percentage change as compared to the reference scenario. The 2050 impacts are not determined.

Table 15 **GDP and employment in fragmented action scenario compared to reference scenario**

| Non-ETS tax | Pass through of ETS sectors' opportunity costs of free allowances | GDP effect | | Employment effect | |
|---|---|---|---|---|---|
| | | 2020 | 2030 | 2020 | 2030 |
| YES | YES | -0.18 % | -0.89 % | +0.57 % | +0.22 % |
| | NO | -0.09 % | -0.74 % | +0.68 % | +0.38 % |
| NO | YES | -0.97 % | -1.95 % | -0.11 % | -0.62 % |
| | NO | -0.93 % | -1.86 % | -0.04 % | -0.49 % |

Source: EC, 2011b.

The effect on GDP is negative and ranges from -0.1% to -1% in 2020 and from -1 to -2% in 2030. The GDP effect is less negative if the ETS sectors do not pass on the opportunity costs of using the allowances that they have received for free and if the non-ETS sectors are subject to a carbon tax.

The impact on the energy-intensive sectors in terms of the production (not given in Table 15) is, at least in 2030, more outspoken. In the worst case, production decreases with 4.3%.

Employment effects can be positive in the scenario where the non-ETS sectors are taxed. This is due to revenue recycling. Just as for the GDP effect it holds that the effect is more favourable if the ETS sectors do not pass on the opportunity costs of using the allowances that they have received for free. The employment effect ranges from -0.0 to +0.7% in 2020 and from -0.5 to +0.4% in 2030 if compared to the reference scenario.

Regarding sector-specific employment effects, results from the literature are mentioned in the Impact Assessment.
Regarding the built environment sector, it is estimated that an additional annual € 20 billion investment in green or energy saving buildings would lead to annually 150,000 to 500,000 direct construction jobs being created or maintained in the coming decade, and to 250,000 to 750,000 jobs if also indirect employment effects in other sectors would be taken into account. The upper range estimates come from studies on investments taking place in new Member States due to their significantly higher labour intensity.

Regarding the power sector, the results of E3ME model runs carried out for the European Commission (EC, 2010) are given in the Impact Assessment. Here it has been estimated that an additional € 50 billion investment in the power sector would cumulatively lead to around 400,000 additional jobs over the coming decade, if indirect and induced effects are included.

It is stressed that even if the employment effects are positive, significant shifts in the employment among sectors can be expected to take place.

## B.4 Prices and assumptions in the IA of the 2030 Framework (2014)

The estimated impacts are contingent on the assumptions regarding energy and $CO_2$ prices. International fossil fuel prices are set exogenous to the macro-economic models. Electricity and $CO_2$ prices are then endogenously derived from the modelling efforts.

The international fossil fuel price developments in the calculations for the 2030 Framework are similar across all scenarios and are given in Table 16.

**Table 16 International fossil fuel price developments in all scenarios (€ 2010 per boe)**

| | 2010 | 2020 | 2030 | 2050 |
|---|---|---|---|---|
| Oil | 60 | 89 | 93 | 110 |
| Gas | 38 | 62 | 65 | 63 |
| Coal | 16 | 23 | 24 | 31 |

Source: EC, 2014a.

The electricity price differs between the scenarios: it increases already significantly in the Reference scenario (31% in real terms until 2030 compared to 2010) and will increase even more in the policy scenario:
- 2030: € 176/MWh in reference and € 179/MWh in GHG40 policy scenario;
- 2050: € 175/MWh in reference and € 183/MWh in GHG40 policy scenario.

The electricity price increases due to a rise of gas and coal import prices and due to increased power generation investments (old capital stock has to be replaced, back-up capacity is needed due to more renewable sources, etc.).

Under the EU Reference Scenario 2013, the carbon price in the ETS sectors is expected to reach 35 €/t$CO_2$ in 2030 and 100 €/t$CO_2$ in 2050. In the GHG40 policy scenarios, it is expected to reach 40 €/t$CO_2$ in 2030 and 264 €/t$CO_2$ in 2050. In the GHG40 scenario it is assumed that a similar (implicit) carbon price prevails in the non-ETS sectors as well.

## B.5 Prices and assumptions in the Low-carbon Roadmap (2011)

### Fuel and carbon prices

The impacts (emissions, etc.) of the Delayed Climate Action Scenario are determined using the EU models; here fuel prices are taken to be exogenous but the assumed fuel prices are based on the outcomes of the global modelling (POLES).

The impacts of the Delayed Climate Action Scenario as such are thereby not determined with POLES, however, a scenario that is also characterised by fragmented action[37] has been analysed.

For the Delayed Climate Action Scenario, the fossil fuel prices are assumed to be the same as in the reference scenario. The fossil fuel prices increase over time and are higher than in a global action scenario. In 2050 the energy import prices amount to 127 $(08)/barrel of oil, 98 $(08)/boe of gas, whereas the coal price remains much lower at 30 $(08)/boe.

Regarding the carbon prices, these, by definition, deviate in the Delayed Climate Action Scenario only after 2030 from the carbon prices in the reference scenario. In order to reach the 80% reduction in 2050 the prices, carbon prices after 2030 have to rise significantly, leading to a 2050 carbon price that is five times higher than in the reference scenario.

**Table 17 Carbon prices (€/t$CO_2$eq)**

| | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| Reference Scenario* | 16.5 | 20 | 36 | 50 | 52 | 51 | 50 |
| Delayed Climate Action | 16.5 | 20 | 36 | 65 | 131 | 207 | 250 |

Source: EC, 2011b; *ETS carbon prices.

37 In this fragmented action scenario it is assumed that the EU pursues an ambitious reduction strategy (represented by the same carbon price signal as in the Global action scenario up to 2050), but that other countries only comply with the lower end of the Copenhagen Accord pledges until 2020. After 2020 these countries are assumed not to increase their effort (represented by assuming constant a carbon price signal after 2020 in line with the required carbon price that achieves their Copenhagen pledge in 2020). Countries with no Copenhagen pledge are assumed to follow baseline.

# Annex C Power sector

## C.1 Introduction

Given its significant contribution to the overall $CO_2$ emissions, the power sector is set to play a central role in EU's efforts to enhance decarbonisation of the European economy. For the near term the decarbonisation process is mainly driven by the renewable energy commitments for 2020, targeting increasing contributions of renewable electricity production, combined with the EU ETS to incur $CO_2$ emission reductions.

In recent years early signs of the impact of increasing deployment of renewable energy in the electricity markets have emerged. Particularly market conditions in the German and neighbouring markets have evolved rapidly since 2010, with an unexpectedly strong growth of solar-PV. Conventional generation was pushed out from the market, electricity prices declined swiftly, while the need for complementary flexibility in supply, demand or storage emerged in the short term markets. These and other developments have instigated debates on matters of market design in the face of the energy transition.

In this chapter the expected developments in the power sector in its transformation to the low-carbon economy are reviewed in Paragraph C.2, while implications for the development of the cost structures of generation are evaluated in Paragraph C.3. Challenges in generation investment are discussed in Paragraph C.4, followed by barriers to financing in Paragraph C.5. Policy options from this analysis have been presented in Chapter 6. The cost components in this chapter refer to energy system costs, not to societal costs, unless otherwise stated (see also Paragraph 1.2.4).

## C.2 Power Decarbonisation towards 2050

An overview of the GHG emission reductions achieved by the power sector in 2030 and 2050, according to the 2013 reference pathway for 2030/2050 as well as under the GHG40 scenario provides a more detailed view on decarbonisation pathways towards 2050.

From Table 18 it can be derived that up to 2030 the differences between the GHG40 scenario and the reference scenario are limited. After 2030, however, the scenarios diverge significantly. By 2050, a 73% emission reduction is realised in the reference scenario, while the power sector achieves almost complete decarbonisation in the GHG40 scenario. This decarbonisation does not entail a fully *renewable* electricity supply, the share of renewables stands at 54% in the GHG scenario at a level only slightly above that of the reference scenario. The majority of the additional emission reductions rely on nuclear and biomass/fossil fuels with CCS.

An important difference between the reference and the GHG40 scenario is that in the latter the total volume (TWh) markedly increases due to increased demand from transport and built environment after 2030. Given a slightly higher share of renewables, in the GHG40 scenario the renewable installed capacities (e.g. wind/solar) are significantly higher due to the increased volumes.

Table 18 GHG emission reduction and Power Sector details from the 2014 Impact assessment

| | 2030 | | 2050 | |
|---|---|---|---|---|
| | 2030 Reference | Scenario GHG 40 | 2050 Reference | Scenario GHG 40 |
| **GHG emission reduction in power generation** | -47% | -57% | -73% | -98% |
| **Gross Electricity Generation (TWh)** | 3664 | 3532 | 4339 | 5040 |
| Solids share | 13% | 12% | 8% | 10% |
| Oil Share | 1% | 1% | 1% | 0% |
| Gas share | 20% | 15% | 17% | 13% |
| Nuclear share | 22% | 23% | 21% | 22% |
| **Renewables share** | **45%** | **49%** | **52%** | **54%** |
| of which hydro share | 11% | 11% | 10% | 9% |
| of which wind share | 21% | 24% | 25% | 27% |
| of which solar, tidal etc. share | 6% | 6% | 8% | 10% |
| of which biomass and waste share | 7% | 8% | 8% | 9% |
| **Share electricity from CCS** | **0,5%** | **0,8%** | **7%** | **15%** |
| **CHP indicator (share electricity from CHP)** | **16%** | **16%** | **16%** | **14%** |
| Carbon intensity Power Gen (per MWhe+MWhth | 17.8 | 15.1 | 7.9 | 0.7 |

Source: EC (2014a).

## C.3 CAPEX and OPEX towards 2050

The reference and GHG40 scenarios from the IA result in rather different investment expenditures. Table 19 depicts the CAPEX required for power generation and boilers of the various scenarios that meet the 2050 GHG objectives, along with several scenarios with additional energy efficiency measures as described in the IA. All of these show an increase of energy system costs compared to this reference scenario. The expenditures are given as annual averages without precise placement in time.

The composition of system costs varies from scenario to scenario, but all show more pronounced capital costs than the reference scenario. This can be explained from the different impacts of the various RES and supply technologies. The generation costs of many conventional technologies are for a large share dominated by variable costs whereas the renewable technologies entail low variable costs but high capital costs (with the exception of bioenergy). The scenarios mostly require a lot of investments in wind and solar-PV.

Table 19 Average annual investment expenditures, as annuity (€bn/a), given for reference scenario and scenarios that are compatible with 2050 GHG objectives excluding investments in grids

| Timeframe | Reference 2013 | Scenario with “carbon values” | Scenarios with “concrete energy efficiency measures” | | |
|---|---|---|---|---|---|
| | Reference scenario | GHG40 | GHG40EE | GHG40EERES30 | GHG45EERES35 |
| 2011-2030 | 50 | 53 | 48 | 55 | 68 |
| 2031-2050 | 59 | 85 | 66 | 72 | 67 |

Source: PRIMES/EC (2014a).

Note: Capital costs are expressed in annuity payments.

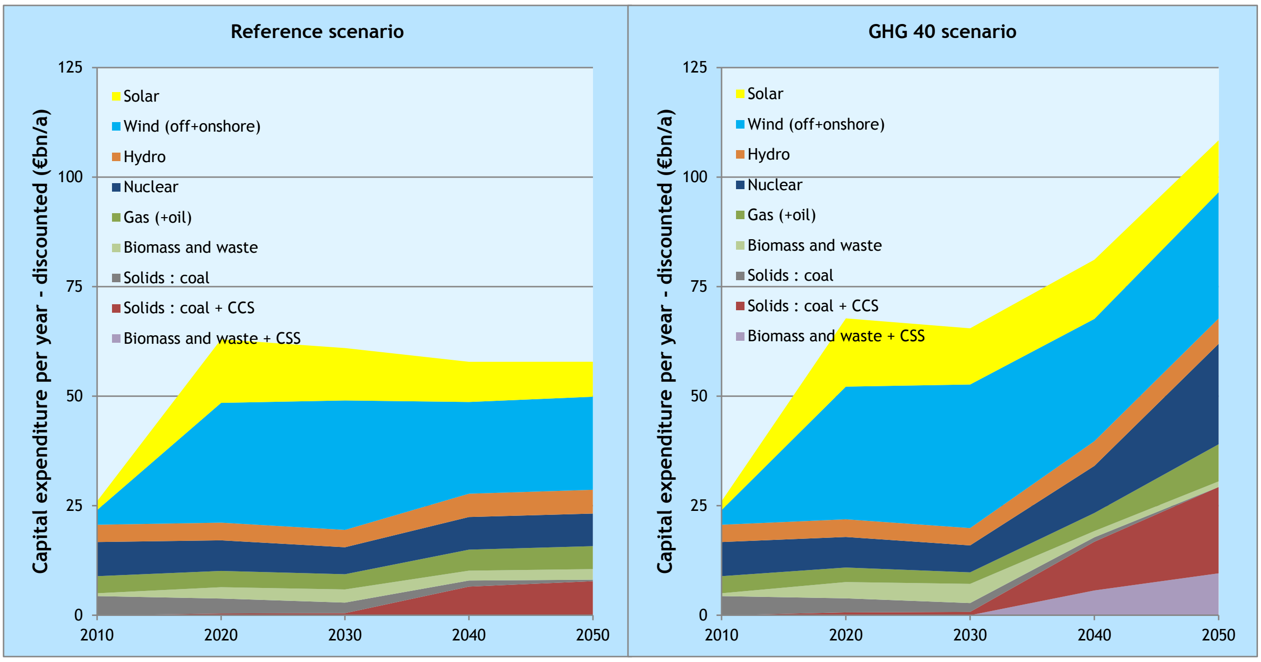
The following can be observed from the EC IA figures:
- the investments needed until 2030 in the reference case and the GHG40 scenarios are comparable;
- after 2030 expenditures increase significantly in the GHG40 scenarios, as these scenarios assume much more carbon reduction and higher electricity demand (see Figure 16) than in the reference scenario;
- the difference between the GHG40 and GHG40EE* scenarios demonstrate that energy efficiency investments can have a sizeable impact on investments needed in the power sector.

## C.3.1 CAPEX trends toward 2050

Cumulatively over the period to 2050, the total investment expenditure facing the power sector can be approximated by summing the annual CAPEX figures over the years in timeframe. This yields approximately the following amounts:
- € 2,071 bn for the reference scenario;
- € 2,622 bn for the GHG40 scenario (a 27% increase compared to reference).

Figure 7 shows how, to our interpretation, these investments are allocated over time by translating the volumes in TWh per fuel source of Table 18 into indicative time series that depict the CAPEX consequences.

**Figure 7 Indicative CAPEX pathways derived from EC IA scenarios excluding grid**




Source: CE Delft calculations based on PRIMES simulation outputs.[38]

Figure 7 shows that, despite the small differences in the share of renewables between the reference and GHG40 scenario (see Table 19), the CAPEX differs substantially between both scenarios. This is primarily because of the increase

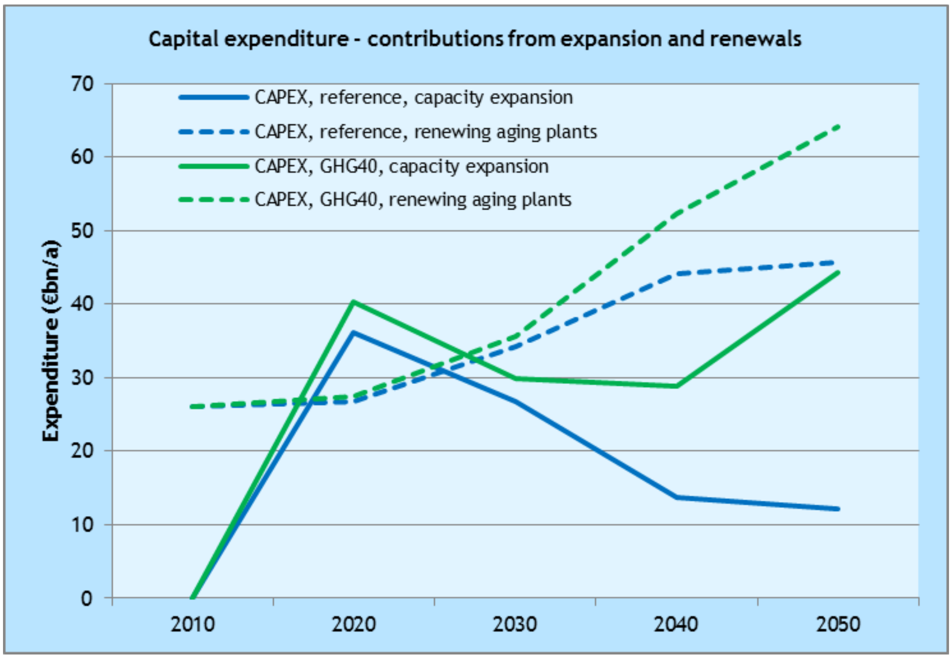
[38] The CE Delft model contains cost figures and technical properties (conversion efficiencies, carbon intensities and so on) of the indicated generation technologies. Of these parameters, also future developments of these parameters are incorporated. The model has been tuned to the PRIMES simulation outputs.

of CCS in the GHG40 scenario. In addition, nuclear investments are more pronounced in the GHG40 scenario. With respect to renewables, the reference and policy scenario contain similar investment patterns. Over the entire time frame investment in renewables makes up for around 2/3 of total investments.[39]

The volume of electricity production differs between the two scenarios; therefore it is useful to look at the CAPEX per unit of volume (MWh). In the reference scenario, the CAPEX is expected to increase from 7.7 to 13.6 €/MWh (a 75% increase), whereas in the GHG40 scenario they are expected to rise from 7.7 to 22 €/MWh (a 185% increase).

The main drivers of the CAPEX are capacity expansions to meet the new volumes as well as the recurring investments to renew power plants that have reached the end of their lifetime. These trends are depicted in Figure 8.
It shows that in both scenarios, replacement investments tend to outweigh the investments due to capacity expansion (growth in demand).

**Figure 8 Trend in renewal in investments and capacity expansion**




Source: CE Delft calculations based on PRIMES simulation outputs.
Note: 2010 not included for additional expansion, it is the starting year in the calculations.

The figures presented in the IA are in general higher than historically observed, but not by orders of magnitude. Based on the historic trend of energy capital investment in the IEA World Energy Investment Outlook (2014), investments in power plants have steadily risen from 60 in 2000 to 210 bln US$ in 2012, for the OECD member countries. If we scale this figure for the EU28

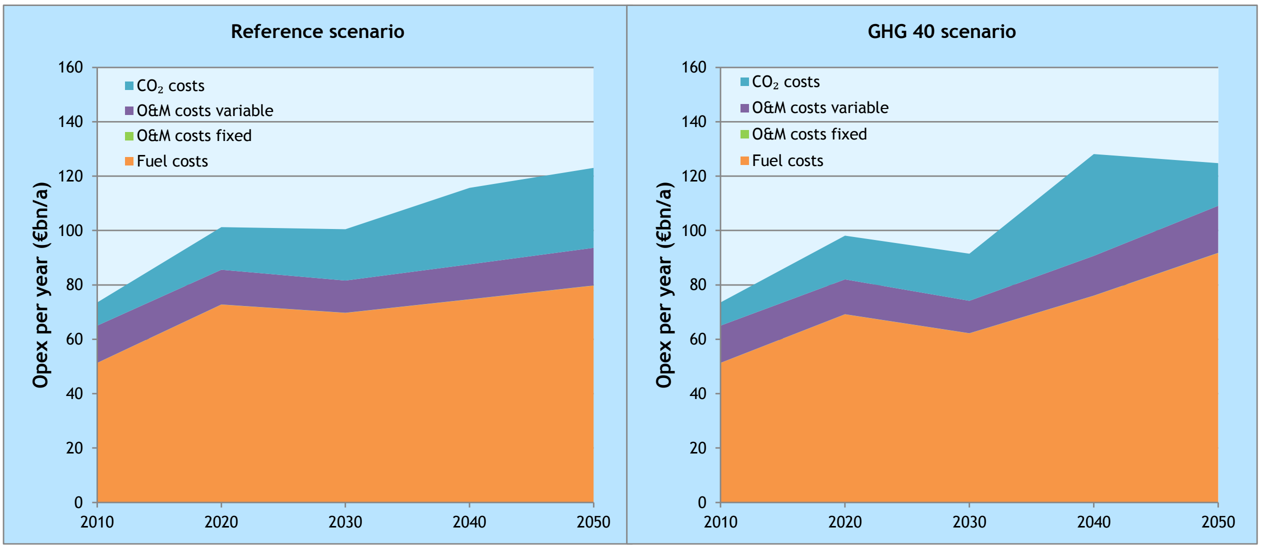
[39] One should interpret the quantitative numbers in such figures with some caution. There are profound uncertainties in looking at supply technologies where a lot of innovations materialise, such as solar-PV. Developments, price decline, may or may not occur.

based on the ratio of 2012 GDP between the OECD and EU28, an energy capital investment increase from € 18.5 (in 2000) to 65 bln in 2012 results. [40]

A tentative conclusion is that, while we will see higher investment levels than historically, they are fully in line with a trend that has been going on for a number of years now.

### C.3.2 OPEX shifts OPEX trends toward 2050

**Figure 9 OPEX pathways derived from EC IA scenarios, showing OPEX contributions by generation technologies (top) and composition of OPEX cost drivers (bottom) excluding grid investments**



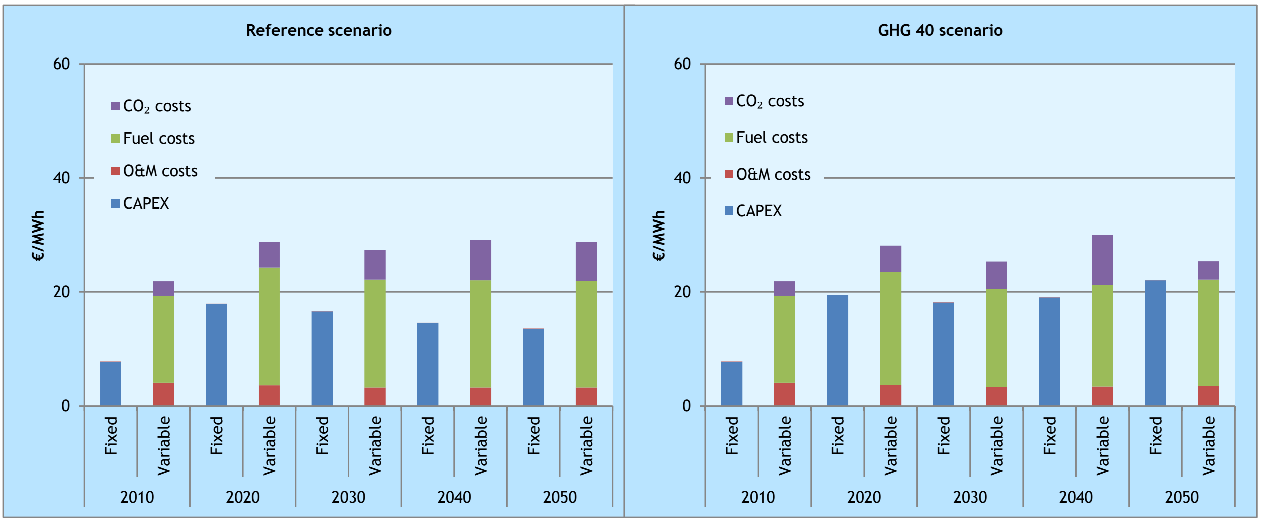

Source: CE Delft calculations based on PRIMES simulation outputs, using fuel cost developments from the EC's IA. After 2030 total CO2 costs are suppressed in the GHG 40 scenario because of lower emissions of CO2, not because of lower carbon prices. Fuel costs after 2030 increase due to the use of large-scale CCS (which requires more fuel).

Figure 9 presents the OPEX associated with the reference scenario and the GHG40 scenario. The OPEX include the cost of fuel, fixed and variable O&M and $CO_2$. The figures show that in both scenarios, OPEX remain a sizeable part of power generation costs. This can be understood if it is observed that, whilst the volume of power produced from solids and natural gas declines over the time span 2010-2050, the fuel and $CO_2$ costs assumed in the scenarios also increase markedly. After 2030, both scenarios assume a shift towards CCS, rather than a further decline in volumes produced from fossil fuels.

Complementing the absolute values, Figure 10 shows the OPEX costs expressed per MWh. From the figure may be observed that under the reference scenario, OPEX costs are expected to rise 31% by 2050 compared to 2010, whereas under the GHG40 scenario they are modelled to rise more limited 16%.

[40] The EU28's GDP is approximately 37% of the OECD's (2014). Exchange rate used: € 1.00 = $ 1.20.

Figure 10 Fixed and variable costs for OPEX and CAPEX, expressed per MWh, under the scenarios

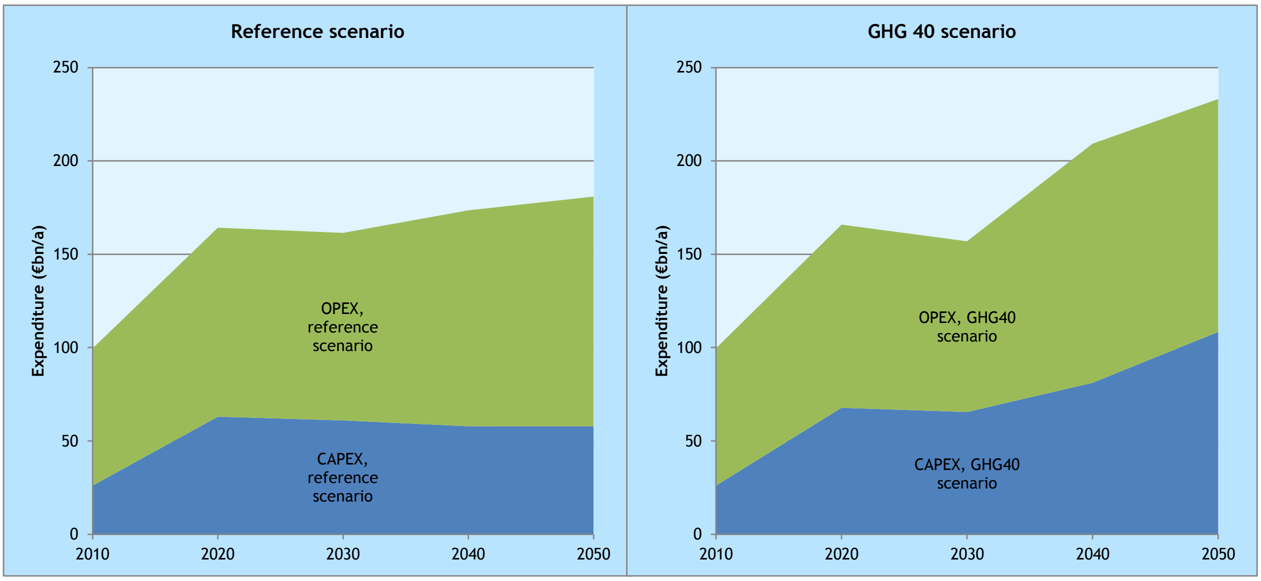



Source: CE Delft calculations based on PRIMES simulation outputs.

## C.3.3 The OPEX/CAPEX shift

Figure 10 shows that both the reference scenario and the GHG40 scenario entail a significant growth of annual investments in electricity generation assets, doubling these expenditures in the years up to 2030. Beyond 2030 the required annual investment in the reference scenario remains fairly stable, while in the GHG40 scenario yet another 30% growth of annual investments is required. OPEX expenditures tend to increase in the short run (up to 2020) and remain then fairly stable per unit of MWh. In the GHG 40 scenario OPEX expenditures per MWh are expected to decrease after 2040. Figure 10 shows the costs components expressed per MWh. Figure 11 shows the absolute CAPEX and OPEX trends. Again it is important to note that these analyses are inherent in the PRIMES modelling scenarios in which fossil fuel-generated electricity combined with CCS plays an important role in the transition towards the low-carbon economy.

Figure 11 Absolute OPEX and CAPES trends in power generation excluding grid investments




Source: CE Delft calculations based on PRIMES simulation outputs.

So far the investments have been analysed excluding grid investments. If investments in grid are included, CAPEX figures will be higher and roughly double compared to Figure 11 above. In the reference scenario, the share of CAPEX (capital costs and direct efficiency investments) in total system costs increases over time from 24% in 2010 to 40% in 2050. In the GHG40 policy scenario CAPEX will further increase to over 55%.

## C.4 Challenges in Generation Investment

The increasing CAPEX expenditures that arise with the decarbonisation pathways for the European electricity sector pose a significant challenge for the sector in the energy transition. The increasing needs imply more investment capital will have to be attracted to secure the necessary funds. Such will largely depend on the ability of business model of the generation segment to recover the cost of capital.

Recent developments in the European energy markets, however, have raised questions about the robustness of the classic business model of conventional generation in the electricity markets in this respect. In case of renewable energy, the current business model largely depends on support schemes. This is sometimes perceived as a transitional feature. The expectation can be that once the prices are set more rightly (by abandoning fossil fuel support and higher prices for $CO_2$) and the learning effects have been materialised, renewable energy support may be lowered.

However, this may be a too shallow way of thinking given the CAPEX/OPEX shift and the problems it may deliver to provide a stable earning model in a market dominated by high shares of renewables. This may impact both renewables and conventional generation that will be more often used as a capacity mechanism (to assure that the demand can be satisfied with adequate supply).

In the following, the concerns regarding the business model for conventional generation in relation to the CAPEX/OPEX shift will be discussed in more detail, as well as perspectives on future development of the business model for renewable energy. This will be done against the description of the current market situation below.

### C.4.1 Current market situation

Due to the non-storable nature of electricity, it is required that demand and supply are balanced at all times. This poses some particularities with respect to the revenues and risks in the electricity sector, which will alter in the low-carbon economy.

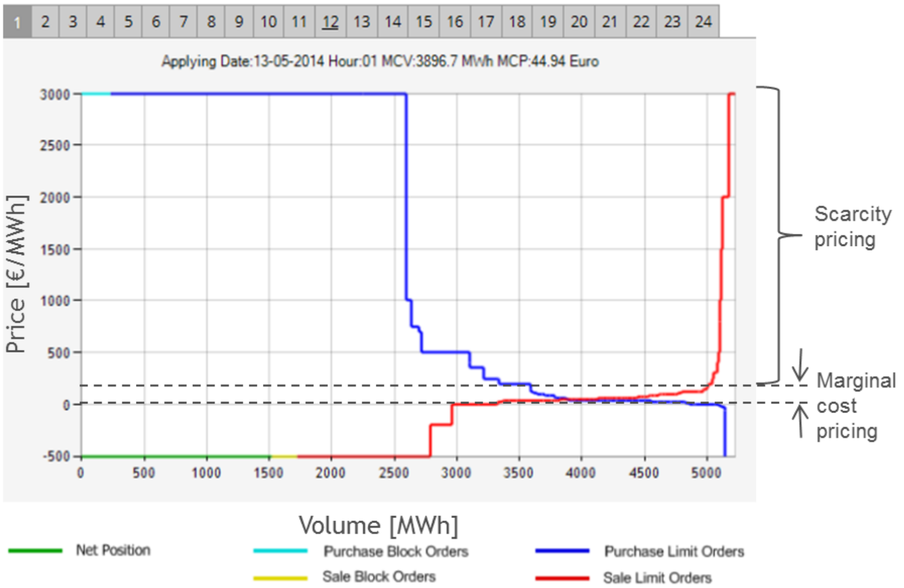
Since the liberalisation of the electricity sector in Europe, the earning model for conventional generation in the power sector is driven by the earnings generated by sales in the wholesale electricity market, spanned by forward markets, spot markets, intraday markets and balancing markets. The most important price benchmark in this respect is the (day-ahead) spot market. Forward markets typically serve risk management purposes (hedging) and are driven by the expectation value of the spot market, while intraday and balancing markets serve the purpose of adjustment of the day-ahead positions resulting from the spot market.

In the spot market for electricity, prices and volumes are set by levels where supply equals demand. Demand for electricity in the spot market is however largely inelastic, as few parties respond to short term electricity prices. As such prices tend to depend at the price of supply required to meet demand. Price of supply can be characterised by two differing pricing regimes: marginal cost pricing and scarcity pricing.

Under competitive conditions, marginal cost pricing prevails. In this case supply is priced at the short run marginal cost of production.[41] This price level represents the minimum revenue required to cover the short run (e.g. fuel, maintenance) cost of an additional unit of production. If some facility is the last facility required fulfilling demand (the marginal unit), it will set the price and only recover these short run costs of production. The facilities with lower short run costs of production than the marginal unit (the inframarginal units) will then earn a margin (inframarginal rents) that serves to recover the fixed cost, including CAPEX.

For the offerings at the far end of the supply curve however, with the highest short run marginal cost of production, the situation is somewhat different. These facilities are only rarely deployed, only at times when demand reaches up to very high levels. In these instances, these facilities result to be the marginal unit and set the price. As no higher demand levels occur, these facilities are never in the position to capture inframarginal rents.

**Figure 12** **Illustration of marginal cost pricing and scarcity pricing in the supply curve on the APX spot market in the Netherlands**

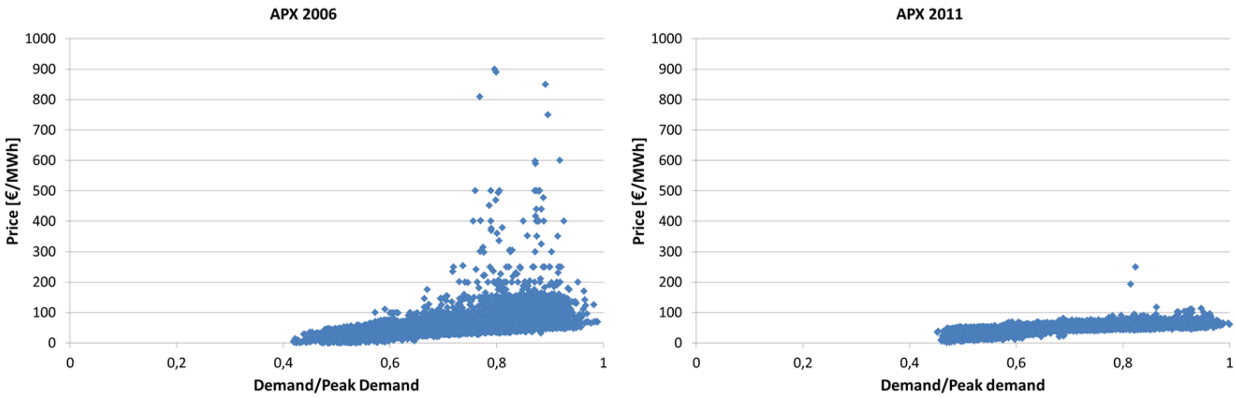



Hence, such facilities are bid into the market at marginal cost of production with an additional premium in order to recover fixed cost. Given that such peak facilities run only rarely, these fixed cost can be recovered in only a

41 Marginal cost of production is defined as the change in total cost of production resulting from an additional unit of production. In terms of dispatch, it is the cost to run the unit on a €/MWh basis, which includes fuel (if any), variable operations and maintenance (VOM), and any environmental costs (e.g., EU ETS allowances).

limited number of hours per year. Finally, the expected number of running hours is highly uncertain, and may easily vary from tens to hundreds of hours year-on-year. Hence, the hourly premium required can be quite high as well. Since these facilities don't risk to be outbid by competitors, these may even be bid in to the market at the highest price level allowed, the market cap[42]. Such bids essentially seek to capture the rents associated with rare events of extreme scarcity. Such scarcity pricing is represented by the far end of the bid curves in spot markets, with bids well above any known level of marginal cost of production, and often at the level of the price cap (see Figure 12).

**Figure 13 Price dynamics on the Dutch day-ahead market for electricity in 2006 and 2011**




The two price regimes, marginal cost pricing and scarcity pricing drive the price dynamics in spot markets. When ample supply is present, prices are largely set by the marginal cost of production of the marginal unit. However, when supply conditions are tightening, the price dynamics may significantly diverge from marginal cost and may even reach up to the market cap. These price hikes typically occur only for a limited number of hours, at instances of high demand and/or low supply (due to plant or line failures for example).
Figure 13 illustrates such price dynamics for the Dutch APX market in 2006 and 2011 where each dot represents an hourly clearing price. In both years, prices for demand below 80% of peak demand show relatively stable price levels, representing marginal cost pricing results. Here, prices steadily increase with demand as facilities with higher marginal cost of production are deployed. In case of 2006 however, prices for demand levels above 80% of peak demand show frequent price hikes. At these demand levels, market tightness resulting from maintenance, plant - and line failures occasionally induced prices well above marginal cost of production as a consequence of scarcity pricing.
The price hikes in 2006 (and preceding years) implied revenues were relatively high in these years, so that investments were induced. The new investments resulted in an oversupply situation in 2011, explaining absence of price hikes in that year.

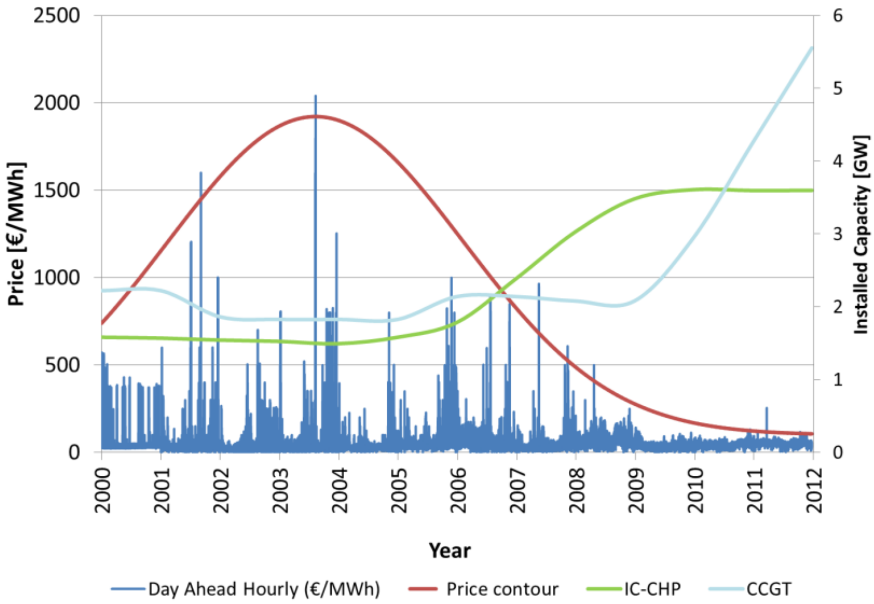
The relationship between scarcity pricing and investment dynamics is illustrated in Figure 14. Here, hourly day-ahead prices for the Dutch market are presented over the 2000-2012 timeframe. It may be observed that scarcity

42 Spot exchanges impose a market cap for administrative reasons, but market caps may also be set by the regulator in order to limit market power risks.

pricing occurred frequently in the years 2000 to 2006, peaking in 2004. Following the year 2004, in 2005, a significant amount of new investments in production capacity was announced. The first investments to come on-line were investments in small and modular internal combustion combined heat and power facilities in horticulture (IC-CHP). By 2009 also new CCGT facilities came on-line, after a four-year lead-time for development. For 2015/2016 an additional 3 GW of coal-fired facilities will be realized.

With the installation of the IC-CHP in the years 2006 to 2009, scarcity was reduced and the occurrence of scarcity pricing in the spot market declined steadily. From 2009 onward, the additional CCGT capacity rendered the market well-supplied at all times and scarcity pricing was virtually absent. In conclusion, investments in generation capacity are induced by both inframarginal rents as well as scarcity rents, jointly called the contribution margin. Particularly scarcity rents have provided for a strong investment incentive in the past. It is these rents that will be required to cover the increasing CAPEX expenditures in the future energy markets. As scarcity prices tended to fall, there may be a particular problem relating to recover CAPEX expenditures for any unit in the electricity market.

**Figure 14 Hourly day-ahead prices at the Dutch spot market APX, and indicative spot price contour and investments in IC-CHP and CCGT**



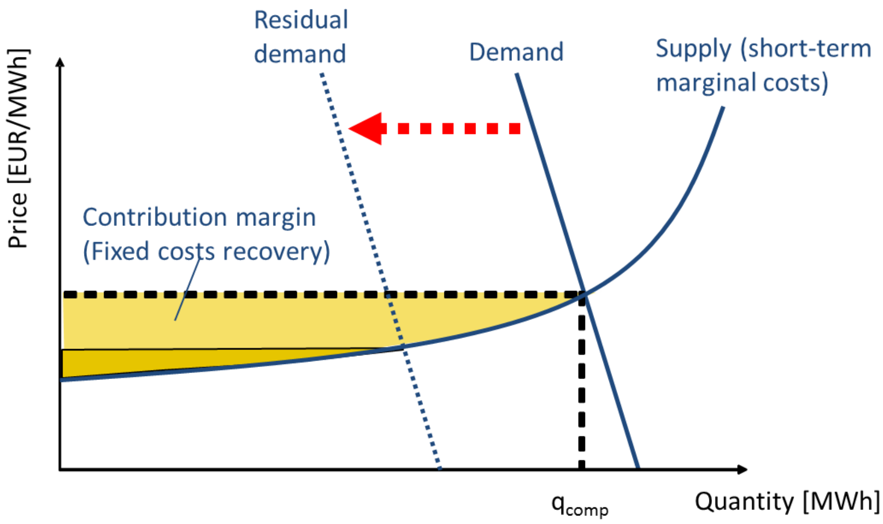

## C.4.2 Investment climate for conventional generation

For the current and future investment outlook one should distinguish between investments in conventional generation and investments in renewable energy generation, as the business model for the two differs substantially. In this section, first the outlook for conventional generation is discussed, followed by a discussion on the outlook for renewable energy generation in Paragraph C.4.3).

In recent years, strong expansion of variable renewable energy (vRES) has significantly altered the market conditions in North-West Europe for conventional generation. Notably solar-PV expanded rapidly in Germany, as

the declining cost figures for Chinese panels combined with the stable support mechanism drove payback time down to some five years only.
As a result, 30 GW of solar-PV was installed in Germany's 80 GW market over a timespan of about three years. Of course this can safely be called a supply shock that had a severe impact on both the German market as well as the other markets in North-West Europe.

**Figure 15 The impacts of growing contributions of vRES on whole sale market conditions**

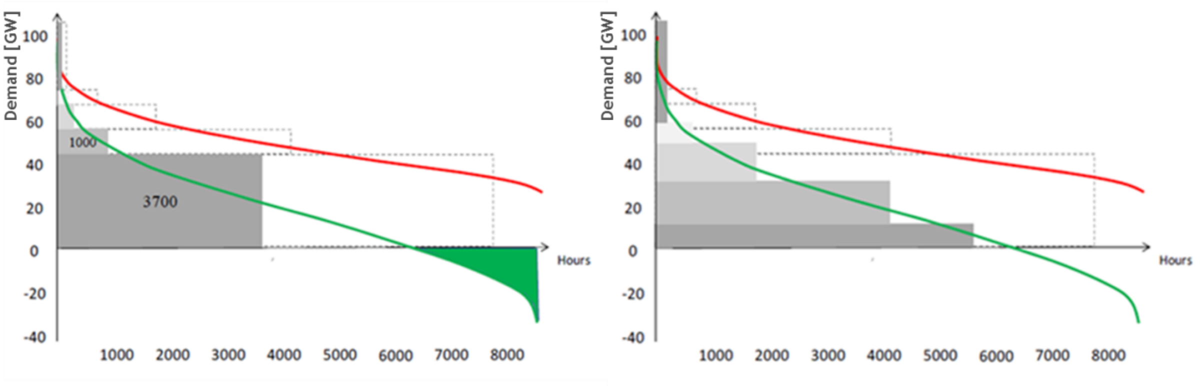



Source: Hers, 2013.

Variable renewable energy, like wind and solar-PV is characterised by very low marginal cost of production, so these technologies are essentially always deployed, be it only at times of wind or solar irradiance. As vRES is always fed in to the system, remaining residual demand is left for conventional generation to cover (see Figure 15). As residual demand declines, sales volumes for conventional generation decline, as well as the remaining contribution margin required for fixed cost recovery.

Here, particularly the mid-merit and peak facilities suffer a strong loss of volume, as residual demand during peak hours declined heavily due to the strong impact of solar-PV during these hours. Base load plants like coal-fired facilities are compelled to become the marginal unit both during the off-peak hours as well as during peak, evaporating essentially their entire contribution margin that was historically gained during peak when higher cost gas-fired facilities used to set the prices. Here, essentially declining OPEX results in declining inframarginal rents, that or part of the driver for new investments.

**Figure 16** **Short run (left) and long run (right) optimal response to increasing vRES contributions to electricity supply**




Source: Baritaud, 2012.

This short term impact is illustrated in the left-hand graph in Figure 16. Here the red curve illustrates the load duration curve, i.e. all hourly load values over the course of a year in declining order. This demand is served by a stack of supply facilities (indicated by dotted blocks), with base load facilities running some 8,000 hours a year and setting the price for some 4,000 hours a year. Mid-merit facilities are deployed some 1,000 to 4,000 hours a year in this graph, hence, setting the price some 3,000 hours yearly. Finally peak facilities serve load only 1,000 hours a year or less, setting the highest prices for these hours as well. When residual load, resulting from increasing wind and solar-PV, reduces to the green curve, one may observe a strong reduction of base–load output, still setting prices from hour 1,000 to hour 6,000 (in part load), i.e. setting prices some 5,000 hours a year. Mid-merit and peak facilities, being pushed out of the market, serve and set prices only for the last 1000 hours. The remainder of the year, this figure illustrates oversupply from vRES, presumably setting prices at zero or below, providing for incentives for new electricity usage, like power-to-heat[43] or storage.

In the longer run, the loss of volume and contribution margin will induce divestures in conventional generation. In a first response mid-merit and peak facilities are mothballed or closed as these are pushed out of the market. Base-load facilities will face the need for investments over years to come, either for lifetime extension or replacement investments. Due to the loss of contribution margin, however, such investments will prove to be no longer justified. The resulting base-load foreclosures will imply new opportunities for mid-merit facilities, so that mothballed facilities will come on-line again and scarcity will result in new investments. The right-hand side in Figure 16 illustrates such adjustments, with a strong decline in base-load capacity and a recovery of the contributions from mid-merit and peak facilities.

Clearly, these dynamics suggest that today's price signals are much like they should be, inducing adjustment of the production park as it should. However these new market conditions coincided with an impending need for replacement investments relating to regulatory imposed phase-outs in

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43 Power-to-Heat refers to practice of generating heat with power, which becomes increasingly attractive when power prices decline. Particularly generation of low-temperature heat in industrial context, through use of relatively low-cost industrial boilers shows significant potential (see also Agora, 2014).

North-West Europe (older coal facilities in United Kingdom and France due the Large Combustion Plant Directive LCPD, nuclear installations in Belgium and Germany due to the nuclear phase-out). This has sparked the debate on the need for additional investment stimuli in the various European power markets and in particular the need for capacity remuneration mechanisms.

In addition it is worth to note that the investment climate for conventional generation is severely affected by the development of vRES. The deployment of vRES is largely driven by support schemes and politically set targets, which are both typically subject to strong and continuous debate. Accordingly, this induces significant uncertainty with regard to future market developments and thus the business case for investment in conventional generation.

### C.4.3 Investment climate for renewables

With the exception of biomass, the costs of renewable energy generation are largely determined by CAPEX. Technologies like wind, solar-PV show relatively high investment costs, while OPEX is low or virtually zero. Given the high CAPEX, these technologies require such high contribution margins that until today the investment in renewable energy generation has not become profitable. Therefore, given the policy targets for decarbonisation of the electricity system in the EU, support mechanisms have been put into practice across the EU.

A variety of instruments have been deployed over the years, ranging from tax incentives and investment grants, to more market-based schemes like the feed-in premiums (FIP) and (renewable) quota obligations. Where FIP currently typically involves remuneration on the basis of the market price and a premium associated with volume, quota obligation systems typically induce secondary markets for renewable energy quota.
Current outlooks suggest feed-in premiums (FIP) and (renewable) quota obligation systems remain the dominant systems in the near future.

In the longer run, learning effects resulting from increasing deployment may bring down the cost of investment associated with renewable energy generation. Recent developments in the fabrication of solar-PV panels for example, with cost declines well over 70% since 2006, show that increasing scale of deployment can result in very strong cost reductions.

On the other hand, the longer-term perspectives on declining margins in power markets may compromise a future perspective on market-based return on investment. This is particularly the case for vRES, as these facilities typically generate in conjunction. Upon large-scale deployment one should expect markets to be well supplied when these facilities operate and, as a result, contribution margins for these facilities are always depressed. In addition, scarcity pricing should not be expected to occur, when these facilities operate.

Figure 17 **Declining contribution margins for wind power as a consequence of the price pressure exerted by its production on the basis of a Dutch power market simulation for the situation in 2023 assuming 2014 fuel prices**

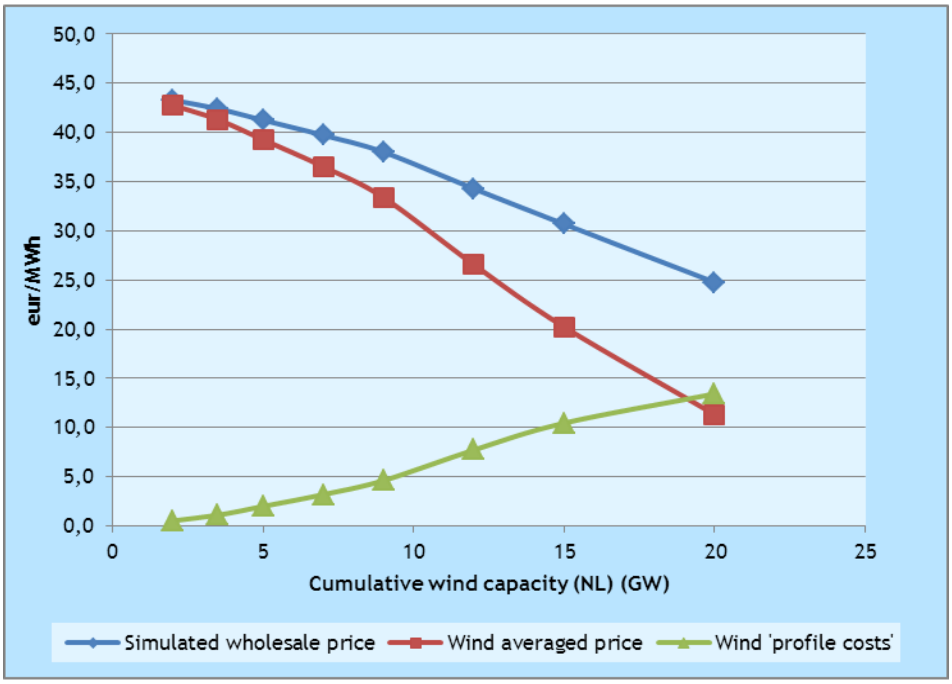



Figure 17 illustrates such a situation for the case of wind power on the basis of simulations the Dutch power market. Here, increasing levels of installed capacity of wind including targets for 2023 are plotted against the yearly average of simulated hourly market prices (blue). In addition the average market price captured by wind power production (red), i.e. the hourly market price weighted by the hourly volume of wind power produced is plotted. Finally the volume-weighted differential is plotted (green). Clearly, both the average market prices, as well as average returns for wind power production decline upon increasing levels of installed wind turbine capacity. The decline outpaces the currently projected decline of levelised cost for wind energy due to learning effects.

This clearly indicates the major problem in the renewable energy market. Large-scale deployment of vRES lowers their profitability at a higher rate than the decrease in costs due to learning effects, implying that an ever-growing level of support is needed to deploy renewable energy technologies. Mechanism that in part rely on market-based returns, like the FIP system would then see these returns decline, so that the compensating premia would need to increase accordingly. In this sense, FIP would essentially be moving to a feed-in tariff system, where fixed remuneration for vRES production is commissioned. The quota obligation system with a secondary market for quota, on the other hand, effectively comes down to a capacity remuneration system for vRES, and will therefore be insensitive to these price dynamics.

At present, costs are shifted differently between consumers (as owners of solar panels) and producers (of e.g. large-scale windmill farms). Both receive subsidies (FiP/FiT), but consumers have an additional profit from avoided energy taxes and a fixed feed-in tariff. Especially this latter mechanism may be changed in the future and more flexible tariffs will apply making the business case for solar panels more problematic.

### C.4.4 Outlook on Investment to 2050

Summarizing the findings in the previous sections, investments in conventional generation are largely driven by scarcity pricing, rather than the OPEX-driven inframarginal rents. The dynamics of scarcity and scarcity pricing may well offer the required incentives for investment decisions in response to market developments in the electricity market. An impending shortage of conventional generation capacity, for example, should eventually generate increasingly strong price signals. In comparison to normal market conditions where only inframarginal rents are captured, scarcity prices have the potential to induce margin increases by a hundredfold on an hourly basis hour.
Such margin increases easily outstrip the foreseen increasing CAPEX requirements in generation investments.

On the other hand the incentive does not assure timely investments that would resolve the scarcity signalled. Further, given the nature of the impact vRES, the dynamics of scarcity pricing may become even more volatile over the course of the energy transition as it will increasingly be driven by weather conditions.
It should therefore be acknowledged that increasing contributions of vRES will deteriorate the market share and increase investment risk for conventional generation. The increasing need for scarcity rents may therefore delay investments in new conventional generation. Such developments will only reinforce ongoing debates on capacity remuneration mechanism.

The fact that timely investments are not assured will probably continue to contribute to the debate whether one can rely on the markets to offer supply at all times. Recent moves of several EU Member States to introduce capacity markets, like France and Belgium, seek to address such fears. With such markets, performance will depend largely on the design and implementation, as the structure can and does vary widely across the EU Member States. Depending on the design, such a mechanism would imply CAPEX to be recovered fully or partially through a capacity market mechanism. Of course such mechanisms can induce strong incentives for investment.

In case of vRES, i.e. renewable energy from wind and solar-PV, scarcity rents can generally not be captured, as this production is unable to respond to prices. Instead, the market prices at times when these resources operate should be expected to decline significantly so that market-based returns are likely to decline upon large-scale deployment. Hence, these technologies are likely to rely on support mechanisms well into the future.

## C.5 Barriers to financing

A number of barriers to financing investments in generation can be identified, based on the evidence from the previous sections, experiences in the past and a range of literature on the subject.

The first and most important barriers seem to be lack of a stable policy framework and lack of a shared long term outlook for RES and fossil demand, both at the EU and at Member State level. Stable policies and stable and reliable demand outlooks will reduce risks to investors as well as reduce cost of financing (see, for example IEA RE Medium term market outlook report, 2014; EWEA, 2013). In the absence of stable policies, the risk premium on investments is simply increasing.

The relevant EU directives, namely the RED and ETS, but also related policies such as the EED and EPBD, are currently limited to 2020 and national policies are quite dynamic in many Member States. This situation is likely to continue in the years to come, since a decision regarding the 2030 RES-related EU governance is not expected before 2018 and many MS policies for 2030 will not be decided on before the EU framework is in place. As the current policy of binding targets for 2020 at Member State level (defined in the Renewable Energy Directive) will not be continued after 2020, the future of RES development in the EU after 2020 will remain uncertain. Since vRES deployment has a significant impact on market conditions for conventional generation this also raises risks for conventional generation. RES development therefore may depend strongly on the actual policies that will be implemented in the Member States and the EU governance that will be agreed on in the coming years.

In recent years, in a number of Member States (e.g. Czech Republic, Spain), RES policy has changed at short notice and retroactive changes were implemented. This not only impacts ongoing projects, but also increases uncertainty and risks for future project, and thus deter future investment climate as well.
This would in itself imply a strong plea for leaving the subsidised deployment path and rather use à quota system with fines for non-compliance.

When looking at the different types of investments to be made, which may differ significantly between different types of renewable and fossil energy generation, more specific barriers to financing can be identified.

### Barriers to investments in conventional power generation

Regarding investments in fossil fuel plants, the key issue will be the risk of less attractive business cases as the share of vRES generation increases due to **reduced load factors**. As long as vRES is set to grow, residual demand and thus the market for conventional generation is essentially contracting and new investments are not warranted.

A general overcapacity in the market may further affect profitability and thus return on investment. In a market that remains to face increasing contributions from vRES, a continuous risk of oversupply seems eminent.

The increasing contributions of vRES also have a significant impact on the **stability of cash flows** for conventional generation. With increasing contributions from vRES, residual demand becomes increasingly volatile. Since residual demand spans the market for conventional generation, the demand for conventional generation will be increasingly driven by vRES. Rather than a relatively stable and predictable demand pattern, with high peak- and lower off peak demand, weekend- and weekday patterns and additional seasonal pattern, a conventional generator faces significant weather-driven risk that its bid ends up to set the price or that there is no market for its production altogether. Hence, increasing vRES contributions induce a significant weather-driven price risk as well as volume risk, and an increasingly volatile cash flow.

Another risk that conventional generation faces results from the fact that existing markets provide **inadequate price signals** to reward conventional against its true value to system allocation. Particularly the short term markets that follow after the spot market, especially the balancing market, shows a wide range of designs between countries with many differences in market access, market pricing, market completeness and the like. This may compromise the potential to find the marginal value to the system, and hence the value of potential contributions from conventional generation and better harmonise electricity markets in the EU through, e.g., better intermittence.

The past years have shown ongoing efforts for further **market integration** and harmonisation in the EU, both on the EU level, regulatory level through ACER, as well as on the level ENTSO-E. While market integration in the short term markets originally focused on the integration of spot markets for electricity, efforts over the past years have expanded to the intraday market and balancing markets. These markets play a crucial role in the integration of vRES. The intraday market typically allows to trade products required to cover for production planning adjustments, as required in response to updated forecasts of renewable energy. Any remaining mismatches end up in the balancing market, inducing the required response in production or offtake. Hence, these markets play an important role in the remuneration of conventional capacity offering the flexibility to respond efficiently to vRES. Another example is provided by the recent achievement of the implementation of flow-based market coupling, enhancing the allocation of transmission capacity such that this capacity is deployed more efficiently, so that overall system allocation can be more efficient as well. Efforts like these entail a piecewise further improvement of the market integration and with that price signalling and remuneration.

As discussed above, a pivotal driver for investments in (conventional) generation is found in the scarcity of available capacity in comparison with the inelastic segments of demand. During such periods, the steep segments of supply and demand in the day-ahead markets are matched, and prices start to exhibit strong fly-ups. Generally a **price cap** applies to these markets, so that fly-ups at times of scarcity are capped. Such caps are required for administrative reasons in market operations, but are often also incurred to mitigate market power risks. As a side effect, these price caps will however also reduce the scarcity value signalled at times of scarcity, and, hence, limit the incentive for new investments. Many energy economists argue that such price caps should in principle be removed altogether, and regulation should resort to alternative means to mitigate market power. A second best option suggested is to set the price cap at levels higher than the value of lost load.

With regard to capacity **remuneration mechanisms,** recently several Member States have implemented capacity mechanisms in different forms and to a differing extent. Where France installed a decentralised capacity remuneration mechanism, Belgium installed a strategic reserve market to assure generation adequacy and the United Kingdom resorted to auctions of reliability options. Germany on the other hand is in the process of evaluating the need. The European Commission has so far mainly expressed concern about these developments regarding unilateral actions as well as the impact on competition. It also emphasized the need for regional approaches and recently launched a sector inquiry into capacity mechanisms.

### Barriers to investments in RES

It is unlikely that RES will become competitive without very high $CO_2$ prices. As long as RES is not competitive, **insufficient incentives** to ensure that investments are financially attractive may clearly create a barrier to investment in new RES capacity. Different types of RES policy measures, such as feed-in tariffs or premiums, a tendering system or RES quota, possibly in combination with internalisation of external cost of non-RES electricity production, can be effective means to promote investments, if implemented well and continuity is ensured. As such, it is important that the domestic policy frameworks are responsive to evaluation of risk and return profiles on which the private sector makes investment decisions (IEA Roadmap Wind Energy, 2013).

State aid rules aim to prevent financial overcompensation. However, any subsidy runs the risk of overcompensating. Since the marginal unit must be stimulated, other units that can deliver electricity at lower costs may encounter a profit additional to their costs. Combined with the falling revenues from renewable energy generation and the substantial amount of RES that needs to be deployed, the amount of subsidies required can become very substantial. This in itself will make them more uncertain as it can be questioned to what extent governments are willing to increase and sustain renewable energy support for such a long period of time.

Other issues determine the investment climate as well. IEA (IEA RE Medium term market outlook report, 2014) finds that market conditions in which renewables operate can have a significant impact on their bankability. In markets with good resources, good financing conditions and rising demand, it is much easier for renewables to compete than in other markets. The value of the electricity produced, which depends on the time and location of production, the **market frameworks** under which different technologies compete, or the recovery of fixed network costs all come into play.

The same IEA study also concludes that the current market design does not effectively **price the value that RES** can bring to energy systems, nor does it increase **power system flexibility** to ensure system adequacy with higher levels of variable renewables (IEA RE Medium term market outlook report, 2014).

# Annex D Industry

## D.1 Introduction

The EU energy-intensive industries can be regarded as world players. The European Competitiveness Report (version 2012) concludes that EU multinational enterprises seem to be more globally competitive in manufacturing industries (e.g. chemicals, machinery and vehicles) than in service industries. At global level, the EU is the largest direct investor in the manufacturing sector, typically accounting for more than half of global FDI outflows (intra-EU flows included). If one thing becomes clear that there is absolutely no shortage of money for investments in the industrial sector.

However, there is another coin to this story which makes the prospects for investments in low-carbon technologies rather bleak in the European Union. Maturing markets and stranded assets make the prospect of investing *in* the European Union looking dim. This chapter will discuss the potential challenges in the industrial sector. In Paragraph D.2 we will outline the $CO_2$ targets and discuss the potential routes to realise these targets. Then in Paragraph D.3 we will discuss the investments that are required to realise those targets and discuss to what extent these can be regarded as feasible taking into account the various barriers. Paragraph D.4 discusses options to overcome these barriers and Paragraph D.5 concludes.

## D.2 $CO_2$ targets

### D.2.1 Overview of $CO_2$ targets for the industry sector

Industrial emissions are, together with emissions from electricity generation, primarily regulated through the EU ETS although important initiatives for industry exist under the Effort Sharing Decision as well. At present, around 75% of industrial emissions are regulated through the EU ETS, whereas 25% of industrial emissions are regulated through the Effort Sharing Decision.[44]

The IA of the EU of the 2030 framework (EC, 2014a) indicates that up to 2050, under the GHG40 scenario, industry will have to reduce their $CO_2$ emissions by 78% compared to 2005. Such targets have been embraced by various industries, like e.g. the pulp and paper industry that has investigated the options of the -80% target in 2050 (CEPI, 2011).

When one takes a closer look at the assumptions underlying the PRIMES modelling from the IA, it becomes evident that PRIMES factually would assume targets less ambitious than the -80% overall reduction – especially for the energy-intensive industry falling under the ETS. First, the ETS itself will reduce their GHG emissions by 87% compared to 2005. However, the majority of the emission reductions come from the power sector that is almost completely decarbonised by 2050. Whereas currently power & heat generation constitutes 2/3 of total emissions under the EU ETS, this would be reduced to 12% in 2050,

[44] Although three-quarters of industry thus can be classified as ‘energy-intensive industry regulated through the EU ETS’, the share of value added and employment in these industries is much smaller. To our knowledge, no study has yet tried to take into account the share of industry that falls under the ETS in terms of employment or value added, but it would definitely be smaller than 50%.

leaving 88% of emissions under the ETS to industrial sources. The factual emission reduction of industry in the ETS would then be less than 70% compared to 2005.

Second, such reductions will be realised by other policy domains as well. Transport policies (see Annex F) will have a repressing demand for products from refineries. This will reduce industrial $CO_2$ emissions by an additional 10-15% so that the 'own effort' from the ETS companies will be more closely related to a -60% reduction in 2050 compared to 2005.

This 60% reduction is an absolute reduction and must be interpreted with the likely increase in industrial production over the next 35 years. According to PRIMES, industrial production will grow with 1.3%/year until 2030 and with 0.9% per year between 2030-2050. In 2050 industrial production will be more than 50% higher than in 2010. This implies that the relative target (e.g. GHG emission per unit industrial production) would be in the range of -75%.

In terms of industrial composition, cement and steel are the main sectors in the ETS from which this 75% reduction should come as they are responsible (together) for almost 40% of industrial emissions in the EU ETS. Other important sectors include the petrochemicals and pulp/paper. Together with refineries these sectors make up 75% of current emissions in the EU ETS. For that reason we will focus in this chapter particular on the options in these five sectors (refineries, cement, iron and steel, petrochemicals and pulp/paper) to drastically reduce emissions in 2050 compared to 2005.

### D.2.2 Strategies to realise the $CO_2$ targets

In general four types of strategies towards a substantial $CO_2$ reduction in the industry can be distinguished:

a Gradual improvement.
b Large-scale renewed investments.
c Improved value chain (differentiated accounts).
d Managed decline.

There is no choice between these strategies: they must be developed simultaneously. However, the efforts required for each of these strategies differ substantially and each of these routes require a different policy mix that would enable them. Below they will be explained in more detail.

#### Gradual improvement

In the literature there is consensus that there is a substantial part of GHG emission reductions in industry that can be achieved at zero or negative costs (McKinsey, 2009). These could yield a reduction of about 10-20% of energy consumption in 2030 (CE Delft, 2014b) and relate to measures concerning heating, cooling and lightning. However, uptake of such measures has been cumbersome so far. Recent research (Ecofys, 2012) on the potential savings from insulation measures in the European industry shows that a possible reason for the slow uptake is that the above measures are all measures that relate to the periphery of the process and therefore do not have the attention of management.

Since the costs are relatively small, these measures can be stimulated by a mix of regulation and price mechanisms. The advantage of regulating such emissions, for example through expanding the IPPC-BAT Refs, is that they can be better tailored towards the specific circumstances in each of the industries. The EU ETS benchmarking has a similar status of stimulating companies to undertake such measures to avoid unduly auctioning of emission allowances. These will become more important when $CO_2$ prices are going to rise.

### Large-scale investments

Measures that would yield more than 20% reduction in the industry are available for all sectors but would require substantial investments. In general two type of deep emission reductions can be identified: (i) options that use CCS to capture and store the $CO_2$ emissions; (ii) new production technologies that would imply a complete overhaul of the production facility which goes far beyond retrofitting existing installations. In the latter case, such installations would use new technologies which would, for example, enable the use of recycled materials to a much larger extent than currently possible.

The technological options, both with respect to CCS and new production technologies, would be capable of realizing over 80% reductions. In some cases (e.g. cement) even carbon sinks could be created by industry.
In Paragraph D.3.2 these options are described in more detail.

Despite the fact that such measures have been designed and in most cases pilot projects have been started, uptake of such investments can be hampered by a few factors: (a) lack of funds for pilot projects at a larger scale; (b) unfavourable market conditions due to maturing EU market and growing markets in other regions (Asia, America); (c) carbon leakage and the use of the carbon leakage argument in the political framing of the ETS. In Paragraph D.4 these will be discussed.

### Extending the scope of emission coverage (value chain options)

Environmental policies primarily target the emissions that come from the production of goods and services. In the context of the EU ETS, these are labelled as 'direct emissions'. In the context of the accounting and reporting requirements under the UNFCC these are labelled as scope 1 emissions.

Companies, however, are not only producers, but also consumers of materials and electricity. Moreover, their products can be used in applications that aim to reduce GHG emissions. Most industrial sector reports identify substantial potentials for emission reductions up and down the chain (see e.g. CEPI, 2011 for the paper sector; ECF, 2014, for the chemical sector; Eurofer, 2013 for the iron and steel sector and Cembureau, 2009 for the cement sector). For the industrial sectors they form an important strategy to contribute to the 80-95% reduction in 2050. They are often labelled as 'options during the value chain'.

It is without doubts that companies can and should take up their social responsibility regarding their purchases of materials and intermediate products and the use of their products. However, there is an important issue with these 'emissions reductions' and that relates to double counting in the international climate context. If a company, for example, purchases green energy for its production processes, it is a great evidence of a company with good manners when it comes to social responsibility. However, under current accounting and policy regulations, this does not reduce overall $CO_2$ emissions. Since the electricity sector is regulated by the EU ETS, the reduction of $CO_2$ emissions through the purchase of electricity does not reduce the cap directly.

Therefore, under current accounting and policy regimes, such emissions reductions should not be accountable for the enterprises. The same applies to the use of products of the sector in e.g. transport or insulation. Manufacturers of aluminium and chemicals have pointed out that the use of their products would make transport vehicles lighter reducing energy consumption for motion. However, counting this as an emission reduction that would accrue to the sector implies taking away this emission reduction from the transport sector and allocating this to the industry sector. If this does not result in an augmentation of the targets for the industrial sector, this would imply double counting.

We fully agree that this is quite counterintuitive, difficult to explain to business leaders and opposite to the current trend of corporate social responsibility. Therefore, it would be a true value if such emissions were to be included in the efforts requested from multinational enterprises.[45] However, it is important to notice that these reductions would *not be instead* of the above-identified 75% emission reductions, but rather *in addition* to these. Because if they would come *instead* of these emission reductions, the total EU28-wide 80% emission reduction in 2050 will not be achieved. Therefore, the target for the companies must rather be read as: 60% direct emission reduction *plus* 80% emission reduction of indirect emissions.

In Paragraph D.4 we will discuss in more detail the political options to include reductions across the value chain and how these can enhance the level playing field across industries that operate in a global economy.

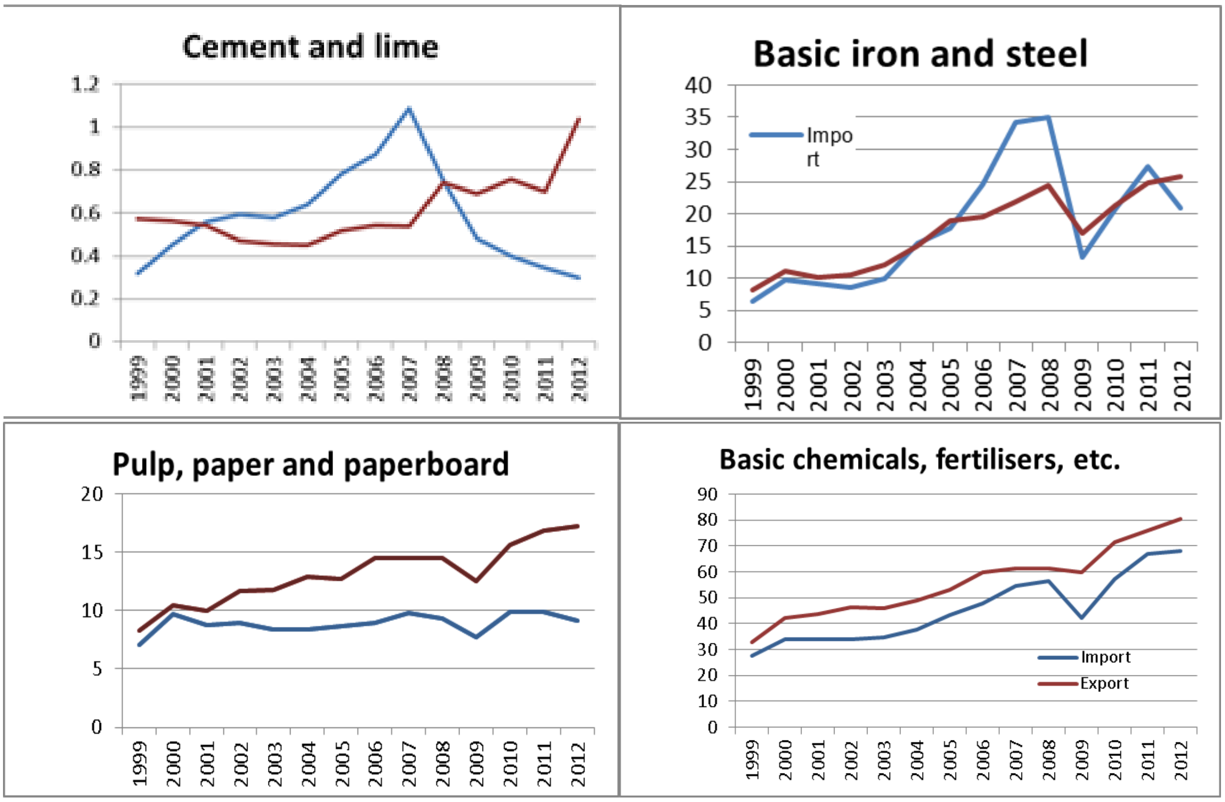
### Managed decline

In the transition towards the low-carbon economy, carbon emissions will also be limited by limiting consumption of carbon-intensive products. This is most evident in the refinery sector. By 2050, demand for refined oil products will be largely phased out in the passenger transport sector. Biomass will preferably be used to reduce the emissions from freight transport and full electrification of automotive transport is foreseen. This will drastically reduce demand from the refineries sector.

However, not only the refineries sector will see their demand decline. The EU is a net exporter of energy-intensive products (see Figure 18). Therefore the carbon footprint of EU consumption is most likely lower than the factual $CO_2$ emissions. Since new industrial facilities are rapidly opening in Asia and Arabic countries, export possibilities of EU energy-intensive industries will become smaller, so that the total production capacity will be more in line with domestic EU demand. It is therefore logical that in some sectors, especially refineries and cement, a process of 'managed decline' will be needed.
As noted by ECF (2014), closure of plants is not an easy option for three reasons: (a) most of the assets in the EU industry are already depreciated which implies that the companies operate under reasonable to good profits; (b) there may be substantial exit costs which deal with clean-up of industrial areas; (c) there may be important societal resistance against closures from e.g. trade unions seeking to maintain employment. Therefore, to some extent, subsidies for closure of installations may be helpful (see also Paragraph D.4).

[45] See also e.g. KPMG's True Value project in which CE Delft is cooperating.

**Figure 18 Import and export (in billion Euros) for EU energy-intensive industries, 1999-2012**




Notes: own calculations based on Eurostat. Blue lines refer to imports, red lines to exports.

Closures of installations do imply a loss of employment. However, there is an important caveat to make here. It is important to realise that climate policies are much more of a benefit to industry than a threat. Overall, EU firms are world leaders in the increasing cross-border 'eco-investments' in clean and more energy-efficient technologies. EU companies account for almost two thirds of the FDI by multinational enterprises worldwide in renewable energy in the period 2007-2011 (EC, 2012b). They are also global frontrunners in other eco-technologies (such as engines and turbines) used to provide environmental goods and services. Also macro-economically there is some evidence that total employment may rise due to the transformation to the low-carbon economy - although the evidence is mixed and dependent on how governmental policies are being designed.[46]

## D.3 Investment challenges

In Paragraph D.2 we have identified the options for the industrial sector. When it comes to investments, the routes 'managed decline' and 'gradual improvement' do not necessarily result in large investment claims. They would require targeted policy responses (see Paragraph D.5) but not necessarily policies that would facilitate investments. The 'renewal' route, however, would entail very substantial investments. These investments are discussed in this paragraph. First, in Paragraph D.3.1 we will discuss the size of

[46] If, e.g., carbon taxes are applied (or 100% auctioning under ETS) and the revenues are recycled back to lower labor taxes more substantial benefits to employment can be seen than in scenarios where this does not take place.

investments and compare these with the ongoing investments in the industrial sector in Paragraph D.3.2. Then, in Paragraph D.3.3 we will identify for each of the involved sectors the technical measures that need to be taken in order to drastically reduce emissions.

### D.3.1 Investments needed

The reference scenario in the IA of the 2030 Framework assumes that investments in the industry sector may go up from € 19 billion annually in 2011-2030 to € 30 billion annually in 2030-2050 due to investments in energy saving measures and renewables. In the GHG 40 scenario the investments increase substantially, especially in the period after 2030 when they mount to a total of € 88 billion annually.

**Table 20 Overview of efforts and investments in the industry sector**

| | 2030 | | 2050 | |
|---|---|---|---|---|
| | Reference | GHG40 | Reference | GHG40 |
| GHG Emission reduction (2005) | -22% | -27% | -44% | -78% |
| Investment (bn€/an) | 19 | 24 | 30 | 88 |

### D.3.2 Comparing with historical investments

There are no Eurostat data available from which precisely the level of investments in the industrial sector can be discerned. While the data on foreign direct investments (inflow and outflow) are available, data on domestic direct investments are lacking.[47] Based on OECD data from France and Germany on gross capital formation and the analysis in EC (2014c), one can discern that, on average, industry in the EU should have a (domestic) investment level of between 20-24% of its value added. This would imply that total investments in the industrial sector are equivalent of € 320-380 billion annually. This would imply that the investments in the industry sector in the reference scenario would mount to 10% of current investments. In the GHG40 scenario this would increase to almost 30% in 2050. Therefore, the investments for the industrial sector can be considered as very substantial.

This is even more pressing for certain industrial sectors since the investment challenge will not be evenly distributed among industries. Table 21 gives an estimated investment level of the most energy-intensive industrial sectors and compares this with the required investments in 2050 under the assumption that the investments per $CO_2$ reduction are similar for all the sectors. The data in the table show that in 2050 the total required investments for the energy-intensive industrial sectors may easily outweigh the current investment level.

[47] Gross capital formation, as a proxy for investments, is not distributed among sectors in the Eurostat data.

Table 21 **Comparing annual investment according to PRIMES for a low-carbon economy with historical annual investments in energy-intensive sectors (bv€ annually)**

| | NACE code | 2050 LCE investments | Average 2007-2011 |
|---|---|---|---|
| Total Industry | | 88 | 356.9 |
| Pulp, paper and paperboard | 171 | 3.9 | 3.1 |
| Refined petroleum products | 192 | 17.8 | 8.7 |
| Basic chemicals | 241 | 19.7 | 11.0 |
| Cement, lime and plaster | 235 | 20.4 | 1.8 |
| Basic metals | 24 | 19.7 | 16.9 |

Note: Own calculations based on Eurostat, EC (2014b) and EUTL. Assumptions: all sectors have to reduce equally $CO_2$ and investments per Euro $CO_2$ reductions are equal for the whole industry.

It should be emphasized that Table 21 is only a hypothetical illustrative calculation to indicate that there may be a problem with financing the investments in the energy-intensive industries.[48] This has also to be interpreted in the light of the recent fall in investments in the EU. After the economic crisis, investments in the EU industry have fallen substantially. Analysts (EIB, 2013; EC, 2014c) have concluded that primarily weak demand lowered return on investments, which suppressed these investments.[49] This may hamper the energy-intensive industries in particular because the demand for their products should remain weak as the low-carbon economy transformation must, in the end, also steer consumer decisions away from carbon-intensive products.

## D.3.3 Estimation of break through technologies needed

To what extent are 75% reductions feasible given the available technologies? In general there is a common feeling that over 75% emission reductions are feasible in all sectors, but that it may require very substantial investments. In this section we will discuss the technological options that exist for the various sectors.

### Steel sector

Broadly two types of steel production can be identified. The first involves melting of primary materials as iron ore and coal coke in large scale integrated facilities (3-15 Mt) using the basic oxygen furnace (BOF) technique (Hatch Beddows, 2007). The majority of the final products that emerge from this production process are so called flat products[50]. These are often specialties with a relative high value, especially used in the automotive industry (Climate Strategies, 2007). This route is highly carbon-intensive. Second, there is the creation of steel by remelting secondary scrap that arises from downstream manufacturing processes and consumer goods.
It is performed in relatively smaller mills, generally involving electric arc furnaces (EAF) (Hatch Beddows, 2007). The largest part of the production is

48 It is only illustrative as it is assumed that across the sectors the investments costs per ton $CO_2$ reduction are similar. More analysis will be needed to determine the investment costs of the options listed in Paragraph D3.3.3 as this falls outside the scope of the present study.

49 Reduced banking leverage may have played a (small) role especially for SMEs. EC (2014c) concludes that there is evidence that the banking sector does not work efficiently when it comes to lending to SMEs.

50 In the EU, 75% of the steel products from BOF plants are flat end-products, 25% are long end-products (McKinsey, 2006).

focused on long products[51]. These are mostly commodities, used for example in the housing sector (Climate Strategies, 2007).

The BOF route is, on average, about 4-5 times more energy-intensive than the EAF route. The challenge is therefore what opportunities the BOF route can provide for reducing the $CO_2$ emissions.
For the steel sector, Hisarna coke free steelmaking appears to be the most promising in the medium term (2020-2030).The main features of the technology are that coke is no longer input for the steel process and $CO_2$ is captured and stored (CCS). 80% reduction can be reached compared to an average blast furnace. In addition, investment and operational costs lie below average, the latter due to a wider range of (cheaper) inputs that can be used.

In the short run, the Fastmelt process is a valuable option. It is already available on the market and also yields a significant $CO_2$ reduction compared to the average blast furnace in Europe. Although initial investments costs are relatively high, a main advantage of the technology is that a broader range of inputs can be used for steelmaking, thereby lowering the operational costs.

Finally, top gas recycling is a technological route which has been explored at a LKAB pilot plant (Sweden). It will shortly be demonstrated on a commercial-scale. The technology is more $CO_2$ efficient than the average blast furnace in Europe. New plants are expected to be built using this configuration.

In the longer run, electrolysis could be a promising option. It means that electricity is used for the reduction process similar to the EAF production route. This would allow for carbon-neutral steel production if the electricity used in the process is produced without $CO_2$ emissions. The industrial process no longer requires carbon but electrolysis is still in the early stages of development. Without further R&D stimulation, it might, according to some, take over 20 years before the first commercial scale production facility could become operational.

Eurofer (2014) indicates that the ambitious objectives proposed in the Commission's Low-carbon Roadmap for the ETS is technically and economically unachievable for the steel industry unless alternative innovative steelmaking technologies combined with CCS are deployed at industrial scale and at the same time steps are taken to shield the sector's competitiveness.

### Cement Sector
In the cement sector different alternative cements are in development, some promising examples are:
- Novacem route;
- CSA-Belite cement;
- geopolymers.

The Novacem route of producing magnesium clinker-based cement offers lower energy consumption and a huge $CO_2$ reduction, if not a carbon sink.
Process emissions and carbonisation of product during production are avoided, so no CCS would be needed. At the same time cost figures are similar to the existing cement kilns. However, efforts need to be undertaken to make it

[51] About 85% of the products from EAF plants are long end-products, 15% are flat end-products (McKinsey, 2006).

ready for market introduction and for the products to (better) meet market standards.

Lafarge and HeidelbergCement work independently on the development of calcium sulpho-aluminate belite cements, Lafarge calls it BCT Technology and HeidelbergCement BCSAF cements. These cements are produced from similar stock material as ordinary Portland cement (OPC) and can be produced in regular Portland cement kilns and mills, but produce 20-30% less $CO_2$ compared to OPC. Lafarge has carried out full-scale tests in three of its existing mills proving that they are capable of CSA-Belite production. The preliminary reports on the outcomes of these tests are positive. The only step that has to be taken on the production side are duration tests, however, before that full-scale product tests are required to convince potential buyers.

Furthermore there is the group of so-called geopolymers, these are alkali activated materials that are supposed to replace OPC in the role of binder in concrete. Compared to OPC innovative geopolymers are capable of $CO_2$ reductions of 70-80%. Geopolymers come in a wide range of stock materials and production processes, strongly varying in properties per combination of stock material and production process. Because of this the prices may vary from 20% less than OPC to 20% more than OPC.
The strong difference in production methods and stock materials means that the current quality and safety tests for OPC do not apply to geopolymers. Before geopolymers can be applied in weight baring structures, development of new types of tests is required. Until then only application in non-constructive applications like paving stones is possible.

Additional to the above developments a more circular approach to concrete use is under development. Part of this approach is the development of a new generation of concrete crushers aiming to separate the concrete in different fractions instead of reducing the concrete to a predefined size. In tests using concrete from an actual demolished building the gravel and sand fractions have proven to perform as well or slightly better than virgin sand or gravel. Ways to separate and functionally apply the cement stone fraction are at an earlier stage of development. The $CO_2$ reduction that can be realised by reuse of the concrete strongly depends on the potential for reuse of the cement stone as a binding material in the concrete.

In the meantime, the use of oxyfuel would be possible in the medium term. It is an oxygen fired, limestone based clinker production process. This technology might yield up to 90% $CO_2$ abatement as it requires CCS. Both investment and operational cost figures are above average though. Cembureau would rather suggest using CCS to reduce emissions. According to their Roadmap (Cembureau, 2014), CCS is a particularly important technology for the cement sector, required to deliver up to half of the emissions reductions needed by 2050.

Biomass/natural gas utilisation can be an option for companies to enhance their $CO_2$ efficiency somewhat (35% emission reduction expected). However, operational costs will be rather higher compared to the current average costs.

### Petrochemicals and fertilizer

There exist many smaller options for the petrochemical and fertilizer sector. However, when it comes to substantial emission reductions two options seem to be the most promising:

a Biobased chemical routes. And
b CCS.

For the petrochemical sector, the first one seems to be most logical.
ECF (2014) has indicated that a shift to renewable feedstocks could entail important competitive advantages for the chemical sector in Europe. However, in some chemical routes the technological and economics of the techniques would still have to be improved. Bio-ethylene seems to be the most promising route here replacing ordinary ethylene in, for example, PVC production.

For fertilizers, the use of Carbon Capture and Storage (CCS) has already been established and proven to be successful since the 1980s when in the US carbon was captured to be used for enhanced oil recovery. Even without beneficial use, costs are about half of other industrial processes as $CO_2$ is available in concentrated streams with higher purity than e.g. exhaust from coal fired power plants. In Canada, an Agrium-owned fertilizer plant is preparing to capture and store the $CO_2$ from its ammonia production.

### Paper sector

For the paper sector, CEPI (2011) has listed various measures including the increased use of recycled papers. For large-scale investments, the black liquor[52] gasification with subsequent CCS has been identified by CE Delft (2010) as a technology that could be implemented in a relatively short term and would allow for significant $CO_2$ reductions. This option has been developed by Chemrec (Sweden).

## D.4 Financing measures and their barriers

The analysis in Paragraph D.3 showed that while for industry as a whole the investment challenge seems possible, for individual industrial sectors this may not be the case. From a technical perspective, there are promising measures available in each of the sectors. In various sectors more research and development is needed before the options can really materialise.
However, the investments required would extend the current investment level. To what extent can the sectors attract additional capital is a question we will address in this paragraph.

### D.4.1 Investment barriers categorised to capital needs

Based on the above technical descriptions one can state that three types of capital investments are needed:

a Seed capital for the development and application of low-carbon technologies. Although some technologies have already been run in pilot projects, more research must be done on technologies in e.g. the cement and iron and steel sector.
b Private capital for market uptake of the new technologies.

[52] Black liquor is a major residue of chemical pulping.

c Governmental capital which would imply that a CCS infrastructure is developed, to which companies can link to absorb there $CO_2$ gasses, especially in the iron and steel, fertilizer and pulp and paper industries as there seem to be no other opportunities for extensive GHG reduction.

### Seed capital
Seed capital can come from government support, retained earnings and angel investments. It is difficult to assess if currently enough of these capital funds are available to companies as no data exist on retained earnings and angel capital. There is some data available on governmental support for R&D and these data show that, on average, EU spendings on R&D tend to be lower than in the US and Japan. In the EU, the support is provided on both EU and individual member States. On EU level there exist three main funds which firms can attract to support their projects, based on three large themes: research (FP7/Horizon2020), innovation (CIP en EIP)[53] and regional development (Structural Funds). These programs have provided support in the period 2007-2013 of about € 22 billion annually (Admiraal, 2011). It is unclear how much of this support finally went to companies.

### Private capital for market uptake
The EU energy-intensive installations, especially in the iron and steel, chemical and refineries sector, are part of multinational enterprises with factories in many countries in the world. EC (2012b) indicates that the manufacturing sector, particularly in the refineries, basic metals and machinery have a revealed comparative advantage in foreign direct investments in the sense that these sectors are more active in investing in other countries than an average multinational[54]. Investment decisions in such global context are often based on portfolio decisions taking into account costs and revenues in certain markets aiming to maximise the shareholder value of the enterprise. New installations typically are introduced in the growing markets rather than in mature markets.

This poses a problem for the EU industry to meet the climate targets. Growing markets tend to attract a larger share of investments than maturing markets and new installations. In a growing market, innovation in low-carbon installations would be stimulated by the market which could realise new plants that are much less energy-intensive. However, the EU can be regarded as a maturing market where such investments cannot be financed through an increased demand for these products.

The majority of the energy-intensive installations in the EU were built, on average, between 1950-1980. Such installations are typically less energy efficient than the most modern installations. Data on refineries, for example, show that EU installations may be 1.5-2 times less efficient than the most modern plants that are installed today. Such data also reveal that most installations constructed during the 1950s have meanwhile been retrofitted so that their energy efficiency improved. This is not the case for installations built in the early 1970s.[55]

[53] EIP = Entrepreneurship and Innovation Programme. CIP= Competitiveness and Innovation Framework.

[54] EC (2012b, 2014c) also show that the chemical sector has a comparative advantage in selling relatively more export products outside the EU compared to reference countries.

[55] Personal communication, Hans Keuken, PDC.

Such developments are, at a macro-scale, backed up by statistical data. The EU's share of world (inward) FDI flows declined substantially, from 45% in 2001 to 23% in 2010 implying that the EU has become less attractive to foreign investors. In outward FDI there has been a shift from intra-EU to extra-EU flows. Low growth in the EU as a whole during the economic crisis may lead many European multinationals to seek investment opportunities in fast-growing emerging markets outside the EU. This is backed up by sectoral studies, such as ECF (2014) which makes clear that the investment direction in the chemical industries was after 2008 primarily oriented outside the EU.

#### Infrastructural support for CCS

The iron and steel, fertilizer and paper/pulp industries probably have to rely on CCS options to drastically reduce their emissions. Costs for these options can be drastically reduced if the government would take up the task of realizing the necessary infrastructure for CCS. This would most likely make the $CO_2$ reductions for industrial sources attractive with $CO_2$ prices above € 40-60/t$CO_2$ depending on the concentration of $CO_2$ in the industrial flows.

### D.4.2 Return barriers

EIB (2013, chapter 5) indicates that manufacturing industry experienced a nominal rate of return on investment of 13.5% between 2005-2007, which fell to 8.8% between 2008-2011.[56] EIB (2013) makes clear that the reduced return was the major reason for the drastic reduction in investments. So an *average rate of return* of 8.8% is considered to be too low by many commercial market participants because elsewhere (e.g. China, India) more profitable options are available. This is backed up by the evidence (EC, 2012b) that the total shareholder value of globally operating firms seem to have increased in the last couple of years - much more than the shareholder value of the domestically oriented companies.[57]

Therefore one could consider this 13.5% as a minimum return which is requested on investments. Moreover, the above-identified rate of return gives an average of *realised profitability* on investments taken. It is important to understand that this average is a mix of successful and unsuccessful investments. Probably the 'threshold level' for investment decisions at the boardroom level lies even above these – of course pending on the perceived risks.

## D.5 Policy options

Low growth, low demand, major investments needed elsewhere in the world: this is the financial situation of the EU industry. Due to maturing stage of industry lifecycle, the EU industry may be soon even facing competitive disadvantage over $CO_2$ costs (= lock-in or pollution haven). This will aggravate lobbying for exemptions.

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[56] It should be noted that the EIB calculates the internal rate of return including the change in market values of companies which may be influenced by e.g. bubbles. If financial markets are misleadingly believing that the firms are profitable while they are not, the internal rate of return may not reflect the factual rate of return.

[57] We have undertaken some own research into the use of shareholder value. The average long term shareholder value seems to lie between the 10-15 percent from information as Shell, Exxon Mobile, Holcim. However, there are considerable short term fluctuations in the shareholder value of companies.

The question is whether a governmental policy can steer ways to overcome this unattractive foresight for the industrial sector and steer investments in the right direction. We notice that at present there is lack of an overarching policy framework. There is such a program for renewables, but not for the industry. In the absence of a clear sustainable industrial policy framework, vested interests may inhibit the political debates on the future of industry in the EU.
This paragraph contains elements through which such an overarching policy framework could be established.

A policy framework should recognise the four areas of action that were identified in Paragraph D.2:
- efficiency improvements;
- managed decline;
- large-scale investments and renewal;
- options along the value chain.

In order to realise these four areas of action, a broad policy perspective can be sketched for governments to change the landscape for industries in such a way that the 75% reductions per unit of product can be realised. This policy perspective should rest on four pillars:
a Increasing the support for small-scale efficiency improvements.
b Organizing a managed decline in, especially, the refinery sectors.
c Shifting the locus of climate policies from production towards consumption.
d Organizing leverage and capex in industrial clusters.

While each of these options can and should be described in a high level of detail, they will be briefly introduced here. Future research should in more detail elaborate on the potential of these options in transforming the industrial sector towards the low-carbon one.

### D.5.1 Support for small-scale efficiency improvements

At present there are many smaller efficiency investments that are not undertaken because companies lack incentives to pay attention to these. However, in general, the costs can be earned back in a few years. Therefore, paying attention to those investments can stimulate the EU industry and should be part of an active Green Industrial Policy. This policy should acknowledge that the large-scale investments are probably taking place after 2030 and that until that time, emissions can substantially be reduced by 20-40% with measures that are profitable even if, after 2030, alternative production routes may have to be chosen.
At present such short term investments are primarily stimulated through the EU ETS. While the EU ETS can have a stimulus for companies to invest in efficiency measures, present prices have been too low to provide an incentive according to a pan-European survey for the European Commission (ICF *et al.*, 2015). Therefore, support for measures that would increase the price of $CO_2$ will enhance efficiency improvements as well.

However, this may be a very cumbersome route given the political difficulties in reducing the current oversupply in the ETS. Therefore, additional policies should be formulated that would reap these benefits. These can be a combination of regulation and subsidies/awareness programs. At present, in many Member States, companies participating in the ETS are exempt from additional policies. This practice effectively limits the uptake of efficiency improvements as has been demonstrated, for example, in the case of the

Netherlands (CE Delft, 2010). EU policy could lift this, for example, by bringing energy improvements under the BAT-Refs and environmental inspectors.

Subsidies may help in this respect, not only because of the financial motive, but also because subsidies using a list of potential measures, which can be used for subsidisation help to raise awareness. However, the general environmental effectiveness of subsidies can be limited if not costs and revenues are the primary obstacle for investments. In that case, the subsidy would merely stimulate free riders and allocate money to investors that already have decided to take the investment.

### D.5.2 Support for managed decline

Especially the refineries sector is expected to be faced with the problem that demand for their products will fall. However, since the assets have been depreciated already and the sector is profitable, there will be a pressure both from industrial and labour organisations to keep the production facilities open, for example by enlarging the share of exports.

Some experience with managed decline has been collected in the transformation of the European coal industry. In Germany, Poland and Czech Republic, special programs have been developed to aid the transformation of local communities towards different forms of employment, for example by educational programs and preferable loans for other investors to invest in the regions. Such programs are in general missing when it comes to industrial transformation. Nevertheless, we know in which areas refineries are dominant and where problems in the future can be expected. It would be good if provisions can be made in the European Structural Fund to guide industrial transformation towards a less carbon future explicitly. This would start by investigating the regions that may be most affected.

### D.5.3 Shifting policy from production towards consumption through product norms and green procurement

The large-scale investments are very substantial for the energy-intensive industries compared to their historic investment level. In a world with even carbon prices this may not pose a problem as the costs were simply passed through to the consumers. However, a world of uniform carbon prices is unlikely given the fact that the UNFCC has embraced the principle of ‘common but differentiated responsibilities’. Given competition from regions where $CO_2$ is priced lower or not at all, companies may opt not to pass on the costs of $CO_2$ abatement in their prices reducing their profitability and leverage for new investments.

This could be overcome if EU climate policies were less focused on the production of carbon-intensive goods but rather focused on the consumption of these goods. This can be done by, *inter alia*, introducing product norms, green procurement or the introduction of a specific consumer tax (e.g. for the consumption of steel, see Climate Strategies, 2014) or a ‘carbon added tax’. This would ensure that the level playing field between the EU and non-EU industries is maintained while at the same time assuring that the revenues for low-carbon investments are more certain.

Product norms could be extended to not only include prescriptions for energy consumption during the use phase (such as with electrical appliances) but also containing material composition so that the most GHG-unfriendly materials are being banned, such as in refrigerants in cars, etc. Introducing such measures can also help EU industry to create a competitive edge. For example, there is some evidence that the low-sulphur norms for gasoline, gasoil and kerosene have helped refineries to keep out non-European competition (McKinsey, 2006).

Product norms could also be of help when it comes to reduce potential liability risks associated with new products. From a jurisdictional perspective this risk would most likely be shifted from the manufacturers of low-carbon products towards the government that has established the product norms.

Norms that arrive through green procurement can be another important vehicle for the low-carbon products. Not in all areas of governmental spending there is enough attention nowadays for achieving zero carbon footprint through the purchases of services and goods. Especially military spendings can be important here as they constitute a large part of governmental budgets with relatively little attention for carbon footprinting so far.

One step further would be to completely take out a certain sector from the ETS and regulate it through consumer taxes based on the relative performance of the manufacturer. This could perhaps be a feasible model for the steel sector, although it needs to be investigated in more detail. Introducing a carbon tax explicitly at the consumer level would be a more drastic shift. A Carbon Added Tax (CAT) on 'gross added carbon' could be designed analogously to today's VAT and form an instrument that could, with time, even replace it. In a very recent research paper CE Delft (2015) elaborated this instrument and investigated the impacts on the price level of products and the potential competitive impacts on industry. As this instrument would tax products from the EU industry similar to the non-EU industry it could provide an important vehicle for increasing revenues from low-carbon investments as the costs for these investments can then be passed through to the consumers without a loss in market share. If well designed, such a system of CAT could even benefit EU producers by taking a competitive edge in carbon reduction and lower their sales prices by lowering the tax paid.

### D.5.4 Leverage and sharing CAPEX in industrial clusters

CCS and the biobased route are two potential routes that would apply to more than one sector. Several studies (e.g. ECF, 2014; Chen and Ma, 2015) have identified the large potential for clustering and for using waste streams in one industry as resources in the other industry. Moreover, various sectors can learn from each other in demonstration projects in the next decades, to learn how to best apply CCS technology and biobased routes at the necessary scale.

There may be particular roles for governments to enable such leverage to happen. This may differentiate from financing the infrastructure for CCS, preferably in public-private partnerships. By diverting the risks of such projects on state budgets, more preferable loans can be attracted that lower the costs of such investments.

# Annex E Transport

## E.1 Introduction

Transport is responsible for about a quarter of the GHG emissions in the EU, making it the second biggest GHG emitting sector after energy. More than 70% of the transport-related GHG emissions are from road transport. However, also aviation and maritime shipping significantly contribute to these emissions, and their contribution is growing fast. While the GHG emissions form other economic sectors are generally falling over the last decades, those from transport were increasing until 2008. Despite the fact that emissions started to decrease since 2008, transport-related GHG emissions in 2012 were still 20% above 1990 levels. To meet the GHG reduction target from the Transport White paper (60% compared to 1990), a reduction by 67% is required in 2050.

In order to meet the GHG reduction targets for transport, radical measures are needed (e.g. a large scale electrification of transport), requiring very substantial investments. Such investments may be required both in technologies and infrastructure. Especially the technological measures are characterised by relatively high upfront costs and low operational costs, which results in the CAPEX/OPEX shift. This may further complicate financing the necessary measures. We explain and illustrate this in more detail in this chapter and discuss both the origins and consequences in forming a barrier to the low-carbon transition. Additionally, we discuss some mitigation options for this issue.

In the remainder of this chapter, we first briefly discuss the GHG targets for the EU transport sector and routes to meet these targets (Paragraph E.2). In Paragraph E.3 we discuss the required investments as well as the main challenges related to them. The main barriers for financing the required reduction measures are discussed in Paragraph E.4 and Paragraph E.5. In the former section, the barriers on the transport market are discussed, while in the latter section the main barriers on the financial market are described. In Paragraph E.6 potential mitigation measures and policies are being discussed. Specific policy recommendations have been moved to the main report in Paragraph 6.3.4.

## E.2 Measures to realise the GHG targets

### E.2.1 Overview of GHG targets for the EU transport sector

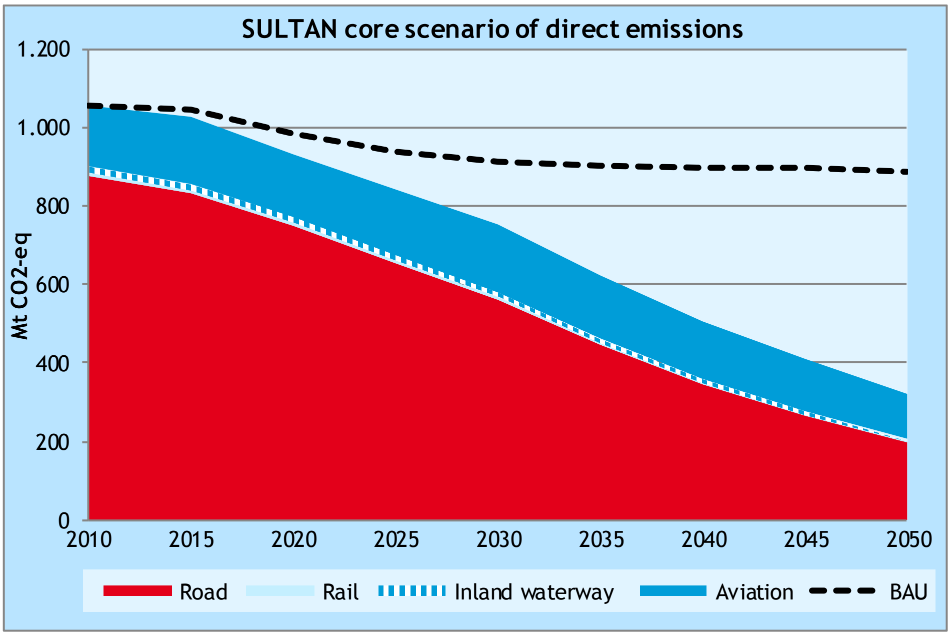
The Transport White Paper established a goal to reduce the GHG emissions from transport by 60% in 2050 compared to 1990 (EC, 2011a). In the *Roadmap for moving to a low-carbon economy in 2050* the European Commission further elaborated this objective, requiring a reduction by 54% to 67%, with intermediate targets of -20% and +9% by 2030 (EC, 2011b). More recently, the Council committed to a target of 30% by 2030 compared to 2005 for non-ETS sectors (EC, 2014a), in which road transport has a share of approximately 30% (based on EEA, 2014). If this target was to be met by transport it would translate into a GHG target of -13% compared to 1990.

The targets mentioned above cover all transport modes except GHG emissions from maritime shipping. In the Transport White Paper, the Commission suggest that the EU's $CO_2$ emissions from maritime transport should be cut by at least

40% of 2005 levels by 2050, and if feasibly by 50% (EC, 2011a). To realise this objective the Commission prefers a global approach led by the International Maritime Organisation (IMO).

In various scenario studies the contributions of the different modes in realizing the GHG reduction targets for transport are studied. Useful scenarios are developed in the 'EU Transport GHG Routes to 2050' project by using the SULTAN tool (AEA *et al.*, 2012). In that study, overall reduction scenarios for meeting a 60% reduction of TTW GHG emissions in 2050 compared to 1990 are developed. The SULTAN Core Reduction scenario (R1-b) is shown in Figure 19. In this scenario the emission reduction in 2030 is equal to 9%, which is in line with the (upper bound of the) model calculations made for the Impact Assessment of the 2050 Roadmap (EC, 2011c).

**Figure 19 SULTAN core reduction scenario for the EU transport GHG: Routes to 2050 II project**




Note: Scope of the SULTAN tool is EU27.
Note: Based on SULTAN Scenario R1-b: 60% reduction of direct transport emissions.
Source: Sultan tool "Routes to 2050 scenarios" of the GHG: Routes to 2050 II project. Available from: AEA *et al.*, 2012, adjusted by CE Delft.

As is shown in Figure 19, particularly the GHG emissions from road transport are expected to be reduced: approximately 20% in 2030 and 70% by 2050. The total emissions from the non-road modes increase with 9% by 2050 (compared to 1990), despite the expected decrease in emissions from inland navigation and rail (with approximately 60 and 85% respectively). However, the emissions from aviation are expected to increase significantly (approximately 40%) due to volume increases, undoing the rail and inland navigation emission reductions.

Next to these general GHG emission reduction targets for the transport sectors, also more specific goals related to decarbonising transport (supporting the achievement of the general targets) are defined in the Transport White Paper (EC, 2011a). For example, it is aimed to halve the use of 'conventionally-fuelled' cars in urban transport by 2030 and phase them out in cities completely by 2050.

Assuming an average lifetime of fourteen years for a passenger car, this implies that all newly sold cars in 2036 should be zero-emission vehicles. With respect to freight transport, it is aimed in the White Paper to achieve essentially $CO_2$ free city logistics in major urban centres by 2030.

### E.2.2 Routes to realise the $CO_2$ targets

In essence there are three possible routes to achieve substantial $CO_2$ reductions:

a Technical options implying investments and technology development, especially of engines.
b Modal shift implying a shift to less carbon-intensive modes of transport.
c Behavioural changes such as curbing the demand for transport.

It is safe to assume that all the three routes are required to achieve the required low-carbon transition by 2050. Focussing on technical options alone may come short of the target of setting the EU transport to reduce GHG emissions by 60% compared to 1990. In an extensive literature review of technical options AEA et al. (2010) conclude that it is unlikely that, given the expected growth in transport demand, technical options alone could contribute to more than 50% of emission reductions in 2050 compared to 1990.

Despite the importance of additional policies to support modal shift and behavioural changes, there is not much research and investigations devoted to these. For example, the reduction potential and investments in large-scale **modal shift** are only scarcely studied. Other non-technical options relate to behavioural changes. One of these is the improvement of operational efficiency, e.g. applying fuel-efficient driving and optimisation of routes and vehicle usage that may have some benefits. However, as mentioned in the Transport White Paper (EC, 2011a), **curbing transport demand** is not an objective of the Commission and little emphasis has been put into the need to alter lifestyles.

In spite of the aforementioned AEA et al. (2010) analysis, the recent impact assessments undertaken for the 2050 Roadmap and 2030 Framework do not assume that the GHG targets may pose a problem (EC, 2011c; 2014b).
For example, in the IA of the 2030 framework minimal impacts on total passenger transport activity is assumed, while total freight activity decreases by only 1-7% in 2050.

In the remainder of this chapter we will follow this route for two reasons:

1. The CAPEX/OPEX shift is much more prominent in the technological route than in the other routes. Behavioural changes, such as logistic changes, and model shift may also require investments but good information on these is lacking.

The majority of emission reductions will anyway have to be realised through the technological route, as this route is much better suited for market economies satisfying consumer demands. The other forms include some type of ‘social planning’-terms, which are highly unfashionable these days.

### E.2.3 Options in the technological route

Several studies (e.g. AEA et al., 2012; European Commission, 2014b) provide an overview of technical options to realise the required additional emission reduction compared to business-as-usual:

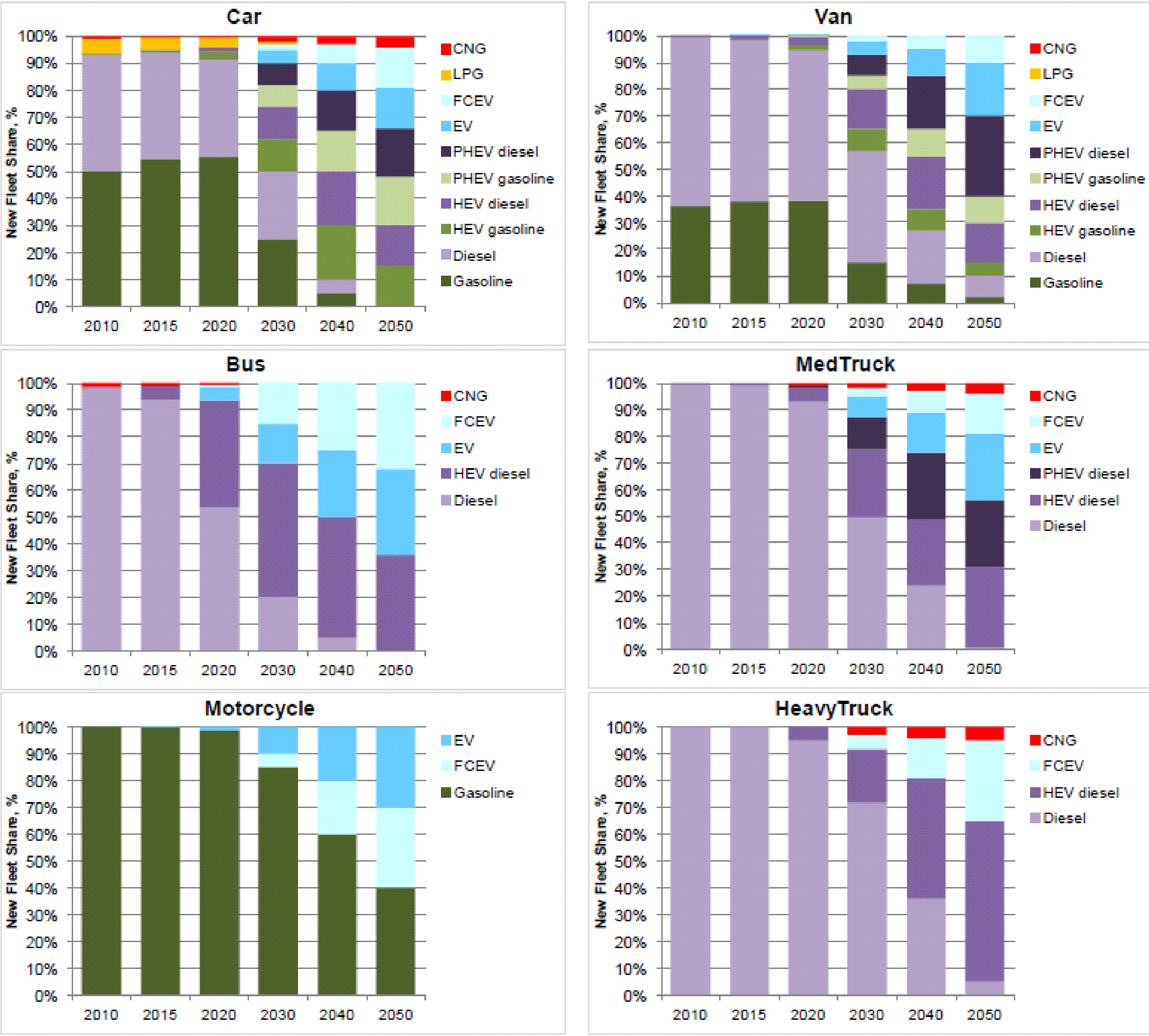
- With respect to **light duty vehicles** (LDVs), it is expected that further improvements of the internal combustion engines (ICEs) will be important on the short to medium term, while a shift to (semi-)electric (or hydrogen) cars is foreseen for the medium to long term.
- Similar to LDVs, there is a significant reduction potential of increased energy efficiency of conventionally-fuelled **heavy duty vehicles** (HDVs). For buses and specific types of heavy goods vehicles (e.g. urban delivery trucks) electrification or hydrogen propulsion systems can be applied (on the medium to long term), while for long-distance trucks biofuels are a reasonable option.
- With respect to **rail transport**, further decarbonising electricity production is the main option to reduce its GHG emissions. This topic is discussed in Annex C.
- Increasing the energy efficiency of conventionally fuelled ships and the use of biofuels/LNG are the main technical options to reduce the GHG emissions from **maritime and inland navigation shipping**.
- As for shipping, improving the energy efficiency of conventionally fuelled planes and the use of biofuels are the main technical options to decarbonise **aviation**.

The main challenge, from an investment and regulatory perspective, will be to decarbonise the road transport. In Figure 19 it is shown which new vehicle technology penetration assumptions are used for road transport in the SULTAN core reduction scenario. It becomes clear from this figure, that large shifts to AFVs (Alternative Fuel Vehicles) are needed to realise the targets for road transport.[58] For example, in 2050 all new passenger cars are AFVs, while in 2030 already 50% of the new passenger cars have to be AFVs.

With respect to biofuels, no CAPEX/OPEX shift is expected. Although this reduction measure also requires large investments (particularly in production facilities), no reduction in operational costs can be expected. For this reason, we will not consider biofuels in the remainder of this chapter. Instead, we will focus on a shift to fuel-efficient conventional and electric/hydrogen vehicles.

[58] We use the term AFV in this chapter to summarise electrical, hybrid and hydrogen technologies since at present we do not know which technologies will prevail.

Figure 20 Overview of new vehicle technology penetration assumptions for road transport in the SULTAN core reduction scenario




Source: Sultan tool "Routes to 2050 scenarios" of the GHG: Routes to 2050 II project. Available from: www.eutransportghg2050.eu/cms/illustrative-scenarios-tool/.

## E.3 Investment challenges

### E.3.1 Size of investment

The various measures to meet the $CO_2$ targets (as described in Paragraph E.2) require significant investments. In Table 22 estimates from the 2030 Impact Assessment regarding the required investments in the energy system is presented (see Chapter 2 for more information on this IA).[59] These figures include investments in energy infrastructure and vehicles.

59 The investments calculated in the 2030 framework were significantly lower than those in the Low-carbon Economy. However, we believe that this is rather due to improvements in PRIMES modelling rather than choosing a different scenario. That is why we have chosen to report here only the figures from the 2030 Framework.

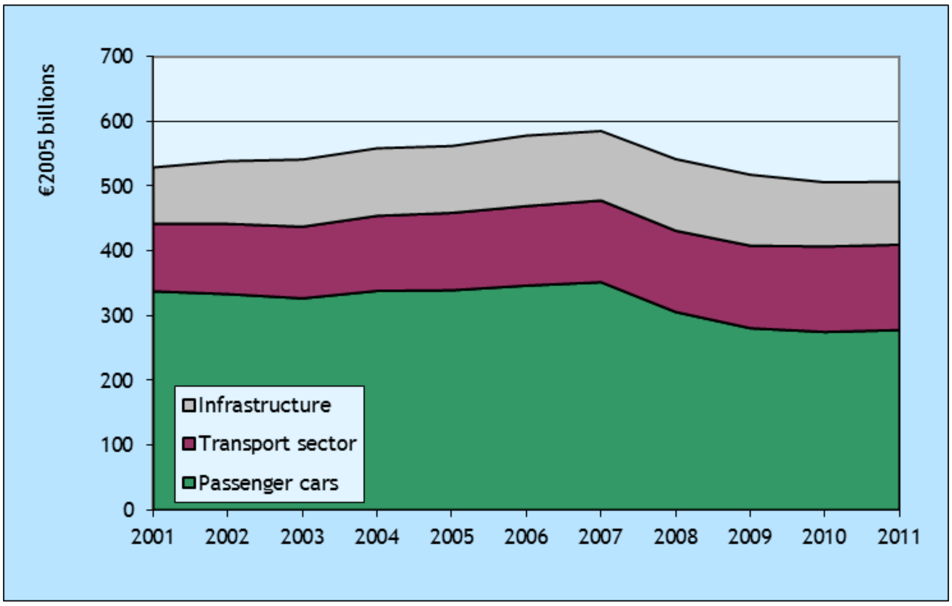
Table 22 **Average annual investment expenditures for the EU transport sector (€ 2010 billion)**

| Scenario study | Reference scenario | | Policy scenario[a] | |
|---|---|---|---|---|
| | 2011-2030 | 2031-2050 | 2011-2030 | 2031-2050 |
| 2030 Policy Framework | 660 | 782 | 662 | 843 |

[a] The policy scenario refers to the GHG40 scenario (2030 Policy Framework).

As is shown in Table 22, significant investment expenditures are already projected for the reference scenario. These investments outweigh those in other sectors, as already was identified in Chapter 2. However, historical investments in the transport sector are also substantial, especially because the replacement of existing vehicle cars forms such a high investment component. Figure 21 shows a conservative estimate of the historic investment levels in the transport sector.[60]

Figure 21 **Historic investment levels in the EU28 transport sector in constant € 2005 (billions)**




Note: Data sources: Own calculations using OECD for infrastructure investments (Cyprus excluded), European Vehicle Market Statistics 2014 for passenger car investments and Eurostat for fixed capital consumption in the transport sector.

When compared to historical investment levels, the investments in the reference scenario are only 20-40% higher as was historically observed between 2001-2007. The policy scenario adds another 10% to this figure in 2050. The increase post-2030 is mainly related to the investments needed for the electrification of road transport. However, compared to the earlier Impact Assessment of the Low-carbon Roadmap, these investments seem to be relatively small as the 2030 Framework seems to have assumed larger cost reductions and learning curves.

60 This can be regarded as a conservative estimate since the investment in transport equipment from non-transport business sectors is not included here.

## E.3.2 Description of the CAPEX/OPEX shift

Investments in fuel-efficient conventionally fuelled vehicles and AFVs do require higher investment expenditures (as was shown in the previous subsection), but they also result in lower operational/energy costs.
For conventionally fuelled trucks, this is illustrated in Table 23. In this table, the additional investment costs and annual fuel savings of three different types of fuel-saving technologies are presented.

**Table 23 Additional investment costs and annual fuel savings of three fuel-saving technologies for HGVs**

| |  Urban delivery truck | |  Long haul truck | |
|---|---|---|---|---|
| Fuel-saving technology | Additional investment costs (€) | Annual fuel savings (€) | Additional investment costs (€) | Annual fuel savings (€) |
| Low resistance tires | 922 | 646 | 1,261 | 4,114 |
| Material substitution | 3,855 | 493 | 2,401 | 573 |
| Advanced engine | 3,920 | 2,125 | 10,953 | 5,211 |

Source: MACH model (CE Delft, 2012a).

A shift from fossil-fuelled vehicles to AFVs often results in a CAPEX/OPEX shift as well, as is illustrated for passenger cars in Table 24. In this table the investment costs and annual energy costs of a (semi-)electric car are compared with a comparable conventionally fuelled car.

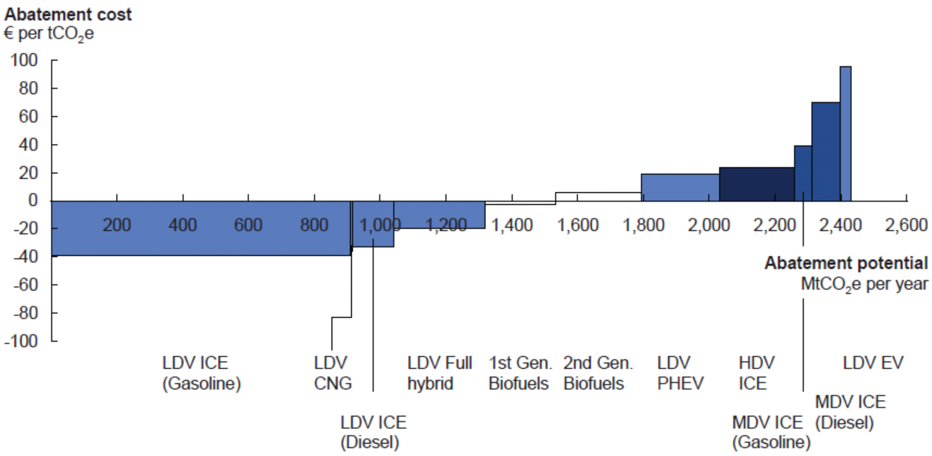
**Table 24 Investment and fuel costs of several electric and fossil-fuelled passenger cars**

| |  Renault Zoe |  Renault Clio |  Volvo V60 Plug-in Hybrid |  Volvo V60 |
|---|---|---|---|---|
| Vehicle type | Battery electric vehicle | Gasoline | Diesel Plug-in hybrid | Diesel |
| Vehicle base price (Germany) without VAT (€) | 21,422 | 13,277 | 51,571 | 43,412 |
| Annual energy costs (€) | 394 | 718 | 847 | 928 |

Note: Vehicle base prices and fuel consumption figures are based on ICCT (2014). Furthermore, the following assumptions have been made:
- Petrol price: € 1.67/litre; diesel price: € 1.45/litre; electricity price: € 0.27/ kWh.
- Annual mileage of 10,000 km is assumed.

It should be noted that just solving the CAPEX/OPEX issue is not enough to realise large market shares for electric and hydrogen vehicles. As it is shown in Figure 22 the abatement cost of electric vehicles are rather high and although this cost will decrease in the next years, investments in these vehicles will probably not be cost effective in the short to medium term (CE Delft and TNO, 2011). This is at least until 2020. Also for the period 2020-2030 the literature suggests that these investments will not be cost effective, although this depends heavily on developments in battery costs. Next to solving the CAPEX/OPEX issue, an overall decrease of the total cost of ownership of these vehicles is required to realise a cost effective large-scale market penetration.

**Figure 22** **Road transport abatement cost curve**




Source: McKinsey (2009).

## E.3.3 Financing the measures

The shift to more fuel-efficient vehicles and AFVs requires investments by several players:

- **Consumers**: households and businesses (lease companies, transport companies, etc.) have to invest in vehicles with higher purchase prices. They can (partly) compensate these higher investment costs by lower operational costs.
- **Vehicle manufacturers**: manufacturers (mainly the traditional OEMs, but also some new players can enter the market) have to invest in R&D, new production facilities, etc. They can pass on (part of) these additional costs to consumers (in the long term).[61]
- **Operators of charging/refuelling infrastructure**: large investments in charging/refuelling infrastructure are required. These investments could be done by traditional energy companies, but also by new players.
  **Governments:** as a business case is currently often lacking investments in AFVs and their infrastructure, governmental support is needed to realise private investments.

[61] They can decide to not pass on the full costs due to oligopoly market behaviour aiming to maximizing profits.

## E.4 Barriers to financing

### E.4.1 Overview of barriers

As was made clear in the previous section, a shift to more efficient conventionally fuelled vehicles and/or AFVs often results in higher investment and lower operational expenditures. This CAPEX/OPEX shift may hamper the investments in fuel-efficient vehicles in several ways:

- **Revenues are not convincing**. In the short run, AFVs are not earning enough profit for rational investments. However, this is likely to be a temporary problem. More problematic is that consumers do not fully account for future operating cost savings in their purchases of vehicle and hence OPEX play a smaller role in the purchase process than economically rational. This phenomenon is referred to as **consumer myopia**. It does not only apply to consumers, as also business may demand unrealistically short payback periods.
- Consumers and manufacturers perceive risks. They are **uncertain on future cash flows** (e.g. energy cost savings and/or value of the car on the second hand market), and as a consequence a CAPEX/OPEX shift results in higher investment uncertainty. In addition, consumers' **lack of knowledge** on the actual costs and effects of fuel-efficient measures may discourage them to invest in more fuel-efficient but also expensive vehicles.
- **Uncertainty on future market shares** of AFVs and charging/refuelling points for these vehicles may hamper the investments of both consumers and manufactures in AFVs and energy companies in charging/refuelling infrastructure, particularly because these investments require a lot of capital.
- The investor in fuel-efficient or AFVs is not always the agent who benefits from the investment (in terms of fuel savings). This phenomenon, referred to as **split incentives**, may hamper investments in these types of vehicles.

These barriers are discussed in more detail in the remainder of this section.

### E.4.2 Revenues and consumer myopia

In the short run, at least up to 2020, uptake of AFVs will be small because the revenues do (not yet) outweigh the costs. But even at the moment that technological progress will be such that the yearly benefits are larger than the annualised costs, the uptake of such vehicles may be severely limited since the existing empirical evidence suggests that consumers do not fully account for future operating cost savings in their purchases of fuel-efficient vehicles. For example, Allcott and Wozny (2010) find that market prices of new and used passenger cars respond as though consumers account for at most 61% of the fuel costs. It is regularly stated that consumers require a short payback period of 2-4 years with respect to additional investments in fuel-efficient vehicles (Greene, 2010). This short-sightedness of consumers (compared to a fully rational and informed consumer) is called consumer myopia.

Consumer myopia may hamper investments in fuel-efficient vehicles, as investments in vehicles with positive net present values, but with relatively longer payback periods, are rejected. For vehicles with negative present values (e.g. hybrid vehicles) consumer myopia will act as an additional barrier to investments and technology development.

Consumer myopia exists not only in the passenger car market. In the shipping sector, very short payback periods are required (IMO, 2010).[62] Also in the road freight market relatively short payback periods are used in investment decisions on fuel-efficient vehicles (CE Delft, 2012b). This is not different from the industrial sector where expected high revenues of opportunity investments also form an obstacle for the low-carbon economy transition (see Annex D).

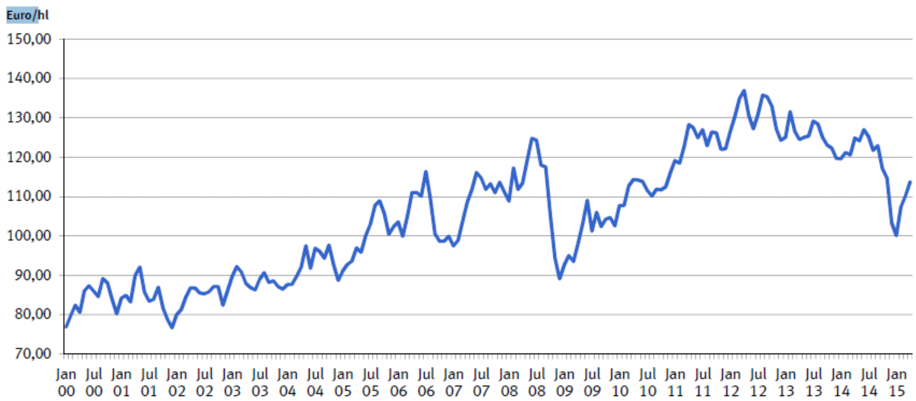
Although there is evidence for the existence of consumer myopia, the explanation for this phenomenon is not clear (Greene, 2010). Possible explanations are: imperfect information, information overload in decision-making and risk or loss averse behaviour (e.g. Kahneman's prospect theory). However, empirical evidence does not give any clear indication which of these explanations is the most appropriate.

### E.4.3 Uncertaincy on cash flows

The benefits of fuel-efficient vehicles depend heavily on external factors, such as energy prices and governmental policies (CE Delft, 2012b). Fluctuations in these external factors can therefore significantly affect cash flows resulting from the investment in fuel-efficient vehicles, and hence may increase investment uncertainty.

Market changes in fuel prices have an important influence on benefits that can be obtained with fuel-saving technologies: the higher fuel prices, the larger the benefits that result from these technologies. As shown in Figure 23, short term fluctuations of fuel can be large, resulting in relatively large uncertainties on the benefits of fuel-efficient technologies. Therefore, it will be difficult for investors to estimate the exact benefits that will result from the investment. This uncertainty may hamper the investments in fuel-efficient vehicles.

**Figure 23 Development of petrol prices (€/hectolitre, without VAT) in Germany in the period 2000-2015**




Source: Statistisches Bundesamt, 2015.

Cash flows are also uncertain since investments in fuel-efficient vehicles (and particularly in AFVs) heavily depend on governmental policies. This is illustrated by Figure 24, showing the data from several countries regarding the

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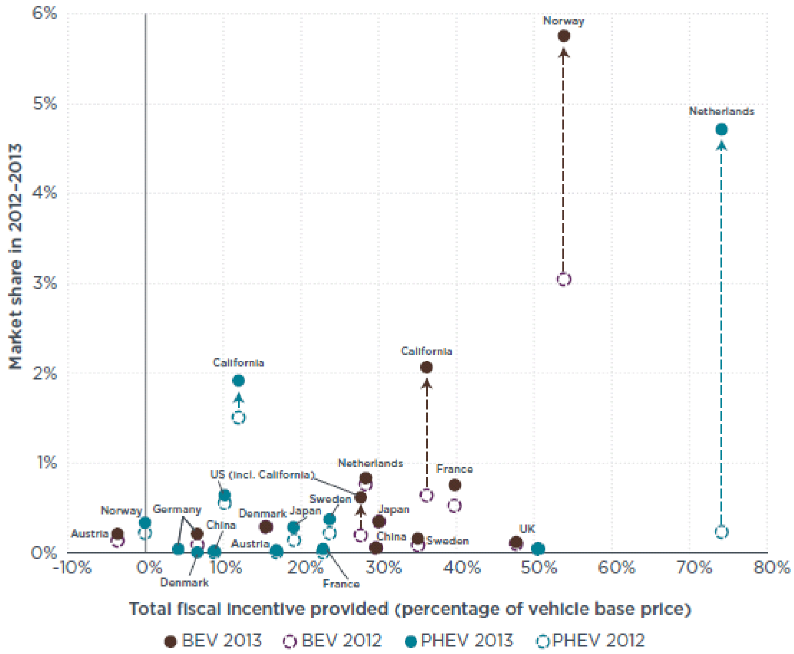
[62] IMO (2010) mentions the failure to subsidise energy savings in the US shipping sector in a subsidy program as 'even a four-year payback time is insufficient incentive to many ship-owners'.

market shares of battery electric vehicles (BEVs) and plug-in hybrid vehicles (PHEVs) vs. the fiscal incentive provided to these vehicles. It is clear that in countries with relatively large incentives the market shares of BEVs and PHEVs are higher (and grow faster) than in countries that only provide limited fiscal incentives. Uncertainty on the robustness of these types of fiscal incentives may increase investment uncertainty, as it will become more difficult to estimate future cash flows from investment in AFVs and their charging/refuelling infrastructure (as the demand for AFVs will be more uncertain). This is mainly relevant for vehicle manufacturers and charging/refuelling infrastructure operators.

**Figure 24** **EV market share in newly sold vans vs. per-vehicle incentive provided for BEVs and PHEVs (company cars)**




Source: ICCT, 2014.

Next to external factors, there are also technological factors that contribute to the uncertainty on cash flows. For example, for electric vehicles the lifetime and residual value of the battery are still very uncertain, causing large uncertainty on the total cost of ownership (TCO) of these vehicles. These technological uncertainties also result in uncertainties on the value of these vehicles on the second hand market, which increases the uncertainty on the TCO of AFVs.

## E.4.4 Uncertainty on future market shares

The market for alternative fuel vehicles has a significant coordination failure, as investors do not invest in alternative fuel infrastructure because there is an insufficient number of AFVs, manufacturers do not invest in the production and development of AFVs as there is not sufficient consumer demand, and consumers do not purchase AFVs as dedicated charging/refuelling infrastructure is lacking (EC, 2013b). This market failure, often referred to as the ‘chicken and egg issue’, causes uncertainty on the size of future demand for AFVs and thereby hampering manufacturers’ investments in these types of vehicles. Furthermore, it generates uncertainty on the profitability of investments in alternative charging/refuelling infrastructure, hindering the deployment of these.

Closely related to this, is the first-mover disadvantage of investing in alternative fuelling infrastructure (EC, 2013b). First-mover investors are confronted with high risks and initial investments (due to the low initial demand for alternative fuel vehicles), while running the risk of losing some of their future market share and profits to players entering the market at a later stage (when the market is more mature). This limits the economic incentive for any individual market player to enter the market first.

Lock-in effects may also discourage players to enter the market for AFVs. Manufacturers and oil companies may oppose a shift to AFVs, as they have invested billions of dollars in the supply and production of (infrastructure for) conventional vehicles (RAND, 2012). Investing in these technologies early is purely a necessity to retain future market shares. As mentioned by Steinhilber et al. (2013), car manufacturers in countries like Germany and the UK have announced that they do want to develop electric vehicles in the long run, but that their short term $CO_2$ reduction solutions will be based on optimised conventional vehicles. These lock-in effects may hamper the development of a market for AFVs, in turn increasing the uncertainty for investors in charging/refuelling infrastructure.

### E.4.5 Lack of knowledge

Generally, a lot of information is available on the fuel economy of newly sold vehicles, which might indicate that a lack of information is not a barrier for consumers to invest in fuel-efficient vehicles. However, differences between real-world and test cycle figures may be significant (e.g. caused by driving style, tuning of the vehicles for test cycles, etc.), resulting in substantial uncertainty in the actual fuel economy consumers can actually achieve (Green, 2010). This issue is definitely very relevant for freight transporters. CE Delft (2012b; 2014) show that many transporters are sceptical on the actual fuel cost savings that can be realised by applying fuel-efficient measures; they are doubting whether fuel economy figures from the test cycle are relevant in real world conditions.

Particularly in the passenger car market, consumers often lack knowledge on the cost of fuel economy (Green, 2010). Generally, only the overall vehicle price is communicated to consumers, giving no explicit information on the cost of fuel economy measures. In such cases, consumers must infer the cost of fuel economy by comparing the multiple attributes of different vehicles, a very complex task. This results in uncertainty on the individual profitability of purchasing fuel-efficient technologies.

With respect to AFVs, it is broadly recognised that consumers lack knowledge on the cost and performances of these vehicles (CE Delft et al., 2012). Consumers do not know or are uncertain on the total cost of ownership (TCO) of these vehicles as well as on their fuel cost savings, durability and resale values (Dougherty and Nigro, 2014). This may discourage them from investing in vehicles with relatively high purchase prices.

### E.4.6 Split incentives

Split incentives occur when the investor in a technology is different from the person who benefits from it. This can be considered as a principal-agent problem (Ecofys et al., 2007). Split incentives may significantly hamper the investments in fuel-efficient technologies, as the person who has to make the investment has little incentive to do so.

There are several studies that indicate that split incentives indeed impede the adoption of fuel-saving technologies in the transport sector (CE Delft, 2012b; IMO, 2010). These split incentives can have several causes:

- Contract structure: in case transport companies and shippers use an open book contract, agreeing on a fixed operational margin, fuel savings have to be passed through to shippers, removing any incentives to transport companies to invest in fuel-efficient vehicles. On the other hand, in case fixed price contracts are used, agreeing on a fixed price per freight unit, transport companies do have an incentive to invest in fuel-efficient vehicles.
- Ownership patterns: if the fuel saving benefits are not received by the actual owner of the vehicle, the incentive to invest in fuel-efficient or alternative fuel vehicles may be limited. This is, for example, relevant for third party logistics providers, who generally do not own vehicles themselves. Also in case of leasing constructions split incentives may exist.

With respect to charging infrastructure there may also be a 'principal-agent' type market failure, which is manifested in the scarce interest of landowners in providing charging points for users in private dwellings and office buildings (EC, 2013b).

## E.5 Barriers on the financial market

Investments in AFVs and related infrastructure often require external sources. Consequently, banks and/or other private financers have to be willing to provide the required capital. When an actor fails to arrange funding, this will impede the investments in fuel-efficient vehicles and AFVs. Therefore, next to the barriers on the markets for these vehicles and related infrastructure, also barriers on the financial market should be considered. Dougherthy and Nigro (2014) distinguish four types of barriers:

- information and uncertainty related barriers;
- legal and regulatory barriers;
- liquidity risks;
- scale barriers.

These barriers largely apply both to the investments for new production technologies as for investments by consumers in new vehicle types. They may refer to as the 'chicken-egg' question. Manufacturers need to develop and invest in new fuel-saving technologies, while consumers and (transport) companies benefit from the reduced fuel consumption (CE Delft, 2012b; Greene, 2010). As R&D is highly expensive and risky, manufacturers may be reluctant to do so, especially if they are not certain to earn back their investments from charging a premium price or from increased sales.

In the remainder of this section we will briefly discuss these barriers in more detail.

### E.5.1 Information and uncertainty related barriers

A lack of information and uncertainty on future cash flows and market shares of AFVs do not only discourage consumers, manufacturers and infrastructure operators to invest in fuel-efficient and alternative fuel vehicles and related infrastructure, it may also impede providers of private equity to provide capital for these investments. Because of these uncertainties investors require a relatively high interest rate, increasing the capital costs for such investments. An additional source of uncertainty is related to the fact that loan officers have only limited knowledge on the repayment history of AFV buyers, again resulting in higher interest rates required for these loans.

### E.5.2 Legal and regulatory barriers

Financing investments in fuel-efficient vehicles or AFVs and related infrastructure may be limited by legal and regulatory barriers. Particularly for highly regulated investors such as banks, pension funds and insurance companies a lot of rules exist on what types of financial assets they can hold with respect to their overall portfolios' risk. For example, some private equity providers are not allowed to own securities without credit rating.
Governmental rules for consumers, transport companies or infrastructure operators may also hinder financing investments in AFVs or related infrastructure. For example, in several European countries there are restrictions on truck leases, making it difficult for companies operating in these countries to arrange funding (CE Delft, 2012b). This will result in fewer acquisitions of fuel-efficient trucks or AFVs as these are more expensive than conventional trucks.

### E.5.3 Liquidity risks

Access to finance may be limited due to the illiquid nature of investments in AFVs/fuelling infrastructure. Due to the small size of the market, these assets cannot be purchased or sold without a significant concession in price.
To induce investors to provide capital for such investments, they must receive higher rates of return (i.e. high interest rates). Some financial institutions are legally limited on owning illiquid assets (e.g. by requirements on the amount of highly liquid assets that they should hold to balance the illiquid assets), as a consequence of which they want a higher rate on return in order to compensate them for the opportunity cost of holding more highly liquid assets. Liquidity is particularly a concern with respect to investments with longer timeframes. So, while these types of loans are very helpful for investors in AFVs or related infrastructure, they are not for private equity providers.

### E.5.4 Scale barriers

In private finance economies of scale do exist, as the transaction cost of financial tools are higher for small, unique investment projects compared to large, standardised projects. These higher transaction costs results in higher interest rates on loans for small-scale investments and hence may hamper such investments.

Currently, many investments in AFVs and/or related infrastructure are relatively small, resulting in high transaction costs. This barrier for investments in these assets will be lowered once the market for AFVs reaches a larger scale; financial products will become more liquid if there are more sellers and buyers and hence the financing costs of these projects will decrease.

## E.6 Mitigation options

### E.6.1 Private financial instruments

Many of the barriers discussed in Paragraphs E.4 and further can be addressed by specific private financial instruments. Those can contribute to the reduction of high upfront cost of AFVs (consumer myopia) and investment uncertainty due to uncertain future cash flows or market shares. The barriers on the financial market may be addressed by these instruments as well.

Dougherty and Nigro (2014) mention three specific instruments that can be used to address the barriers for (financing) AFVs and their infrastructure:

- By using a **leasing** model, consumers do not own the electric or hydrogen car but rather pays monthly to use the car. The car is owned by a third party, i.e. leasing company. This option may help overcome the barrier of consumer myopia (high upfront costs), investment uncertainties and information problems for consumers. It may also address some of the barriers on the financial market, e.g. loan officers' lack of information about the repayment history of AFVs (since the leasing company keeps the ownership of the car). With respect to electric vehicles, the leasing model can also be applied for the battery package only. As most of the uncertainty on these cars is related to the lifetime and residual value of the battery, providing a leasing model for batteries may significantly reduce investment uncertainty.
- **Energy service companies (ESCO)** and **energy savings performance contracts** can be used to finance the high upfront capital costs of AFVs using the savings on operational costs based on reduced fuel expenditures. With these financial constructions, an outside party guarantees that the energy savings will be enough to repay the initial capital costs. This protects consumers (e.g. fleet owners) from the uncertainty on future cash flows. These instruments can also contribute to the realisation of investments in charging/refuelling infrastructure, as risks on lower demand for electricity/hydrogen is (partly) transferred to third parties. ESCOs and energy saving performance contracts can also address some of the barriers on the financial market. For example, by contributing in several projects ESCOs may gather a lot of information/knowledge on AFVs and their infrastructure, tackling the information-related barriers. Scale barriers may be addressed as well, as a larger number of 'standardised' projects can be executed by one party. Although the potential role of ESCO's has been widely acknowledged, we are not aware of any energy service company that has stepped into the transport market so far. Therefore, its role and potential still needs to be investigated further.
- **Green banks** can also be used to reduce the cost of capital and improve loan terms for AFVs and related infrastructure. Green banks are public or quasi-public financing institutions that provide low-cost, long term financing support to low-carbon projects by leveraging public funds through the use of various financial mechanisms to attract private investments so that each public euro supports multiple euros of private investments. Financial mechanisms that can be used are long term and low interest rate loans, revolving loan funds, insurance products and low-cost public investments. A key characteristic of green banks is that they reduce the risks for private capital by guaranteeing that the first loss on a project is taken by the bank. By lowering the risk for private investors, the required rates of return to attract these investors can be reduced. Green banks may also address the information-related barriers; as the same type of projects are replicated over and over, more reliable data on AFVs and related infrastructure as well as on customers credit performance is gained, lowering the risks for future projects. By creating a greater market also illiquidity and scale concerns may be addressed.

### E.6.2 Policy instruments

Public policies can be used to address barriers on both the market for fuel-efficient and alternative fuel vehicles and related infrastructure as well as on the financial market. With respect to the low-carbon transformation, the most important issues that policy should address is consumer myopia and how to create incentives ensuring that the infrastructure is well developed. Consumer myopia can best be targeted with regulatory standards and providing information. Also reducing long term risks can be a good strategy to enhance the uptake of AFVs.

In the short run, the negative revenue case of AFVs can also be addressed by means of subsidies and fiscal incentives.

Therefore we arrive at the following list of possibilities for policy:
- **Vehicle standards** set binding targets for the maximum fleet average $CO_2$ emissions of new vehicles sales. In Europe these standards are implemented for passenger cars and vans. This instrument is known to be very effective in reducing $CO_2$ emissions of new passenger cars (and vans), at least with respect to the test cycle emissions (EC, 2012a). Although vehicle standards do not directly affect any of the barriers on the vehicle and/or financial markets, indirectly some of these barriers may be addressed as manufacturers are stimulated to convince consumers to buy more fuel-efficient cars. They can do this by lowering the upfront costs of these vehicles (reducing consumer myopia), or by providing information on the benefits of fuel-efficient cars (addressing information and uncertainty related barriers). This instrument may also (partly) solve the split incentive resulting from the fact that manufacturers actually develop and invest in new fuel-saving technologies, while consumers benefit from the reduced fuel consumption.
- **$CO_2$ labelling** is required for all new passenger cars sold in the EU. Although no clear evidence is available on the effectiveness of this instrument on stimulating fuel-efficient vehicles (AEA et al., 2010), it is clear that it addresses to some extent the information-related barriers. The labels are required to provide information on the (test-cycle) $CO_2$ emissions and fuel economy of the vehicle, which is very useful data with respect to investment decision. However, the effectiveness of these labels in addressing the information-related barriers can be further developed, e.g. by providing specific data on the real-world fuel economy of cars.
- In the Clean Power for Transport Directive the European Commission, among other issues, requires Member States to realise **a minimum amount of charging/refuelling points for AFVs** (EC, 2013b). This instrument may partly reduce the uncertainty on future market shares, as more certainty on the realisation of alternative charging/refuelling infrastructure is established.
- At a national level, **fiscal measures** aimed at stimulating the purchase of fuel-efficient or alternative fuel cars by reducing the purchase costs of these vehicles may be very effective in addressing some of the barriers (CPB, 2015). In this respect, particularly exemptions/discounts in registration taxes (including bonus-malus schemes) and direct subsidies for AFVs are effective in reducing the relatively high upfront costs of these vehicles and uncertainty on future cash flows. Fiscal measures aimed at reducing the annual cost of fuel-efficient or alternative fuel cars (e.g. incentives in company car taxation) are less effective in addressing these specific barriers, as these measures do not affect the cost structure of these vehicles. However, notice that these measures may be still effective in stimulating these types of vehicles.[63]

[63] Next to the instruments above, also ETS and fuel duty excises may be mentioned to reduce the GHG emissions of transport. Theoretically, these instruments can also provide incentives to invest in more fuel-efficient or alternative fueled vehicles. However, as they do not (directly) affect the CAPEX/OPEX structure of these investments and are not primarily targeted at reducing the impact of consumer myopia, they do not provide any solution to the barriers discussed in the previous sections.

- **Public investments in or subsidies for charging/refuelling infrastructure** may help to overcome consumers' and manufacturers' uncertainty on the availability of such infrastructure.
- **National and EU R&D subsidies (Horizon 2020) and pilot projects** may lower the upfront costs of AFVs or reduce the uncertainty on future cost flows from investments in these vehicles and/or related infrastructure.

# Annex F Built environment

## F.1 Introduction

Nearly 40% of final energy consumption, as well as 36% of all GHG emissions can be attributed to the built environment. It is generally acknowledged that the sector has a high savings potential. Nevertheless, diverse hurdles, for owner-occupiers, real estate companies and investors (pension funds, banks), hinder the uptake of decarbonisation measures. Policy solutions can contribute to overcome those hurdles.

Decarbonisation of the built environment is a difficult challenge because of the complexity of the sector. The sector is large and includes a wide range of building types, of different ages, with different types of owners and energy consumption patterns. The complexity ensures that single policy measures will probably not be sufficient.

The built environment includes both buildings and electrical appliances. Focus of this chapter will be on buildings. The main reason for focusing on buildings is that the decarbonisation mechanism will be different for appliances and that the CAPEX/OPEX shift poses problems particularly in the built environment rather than in the markets for, and use of, appliances. [64] The increasing penetration of electric appliances implies a growing electricity use. This concerns mainly ‘black’ appliances (mobile phones, TVs, PCs, etc.). At the same time the eco-design regulations drive significant energy savings in specific electricity uses; the average efficiency of appliances and lighting will improve by approximately 25% in 2020 and by 45% in 2030, relative to 2005 with current legislation. A tightening of eco-design regulations seems feasible and logical. The regulation could even provide EU producers of such appliances with comparative advantages provided that they would take this up more seriously than e.g. Chinese manufacturers. Investments in EU manufacturing could then be compensated by increasing market shares. If EU manufacturers are not capable of picking this up, the investments will have to be done in other parts of the world and may not hamper EU industries. Therefore, we believe that energy consumption of appliances imply only modest investments not different from the current model.

This is a bit different when it comes to buildings. Especially for buildings the investment challenges are very fundamental. Potentially the building sector could reap net benefits from investing in energy efficiency but the required investments are very large and the organisational challenges regarding stimulating and materialising these investments are substantial.

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[64] For appliances, decarbonisation can be realised via the electricity sector, which is part of the ETS system (see Annex C), via labelling (Energy Labelling Directive; 92/75/EEC) or the design process of new appliances (Ecodesign Directive; 2009/125/EC). Regulation forces producers to produce appliances that meet the most recent environmental standards. The shorter lifetime of appliances (10 to 15 years for e.g. refrigerators) will lead to a much faster penetration. The autonomous trend is positive, e.g. the efficiency of refrigerators and boilers improves very fast.

### Outline of the chapter

The chapter starts with an introduction of the investment challenge and a discussion whether the current efforts are sufficient to meet the targets (Paragraph F.2). Paragraph F.3 focus is on the hurdles that hinder the uptake of investments. Paragraph F.4 gives an overview of possible policy solutions to overcome the obstacles. While the built environment is an important sector, both with respect to the sheer size of GHG emissions involved and the expected difficulties to achieve very substantial GHG emission reductions, the situation is very complex and difficult to summarise in a single chapter. We do not aim here to provide a full-fletched analysis of all potential hurdles in the built environment but rather to summarise the main issues.

## F.2 Transformation to a low-carbon built environment

### F.2.1 Introduction to targets

In the GHG40 scenario an 82% decrease in carbon emissions will be achieved between 2005 and 2050 in the residential, services and agriculture sector. Between 2005 and 2030 the reduction target is 39% (see Table 25).[65]

**Table 25 Emission targets in reference scenario and GHG40 scenario**

| | 2030 | | 2050 | |
|---|---|---|---|---|
| | 2030 Ref | GHG40 | 2050 Ref | GHG40 |
| Residential, Services & Agriculture | -31% | -39% | -39% | -82% |

Source: EC, 2013a; EC, 2014b.

Current new buildings energy performance is already very much regulated by building codes. By 31 December 2020 all new buildings have to be nearly zero-energy buildings[66] (EBPD recast; 2010/31/EU). Government buildings will be required to comply with this rule in 2018. New buildings account for only 1% of the building stock per year. This implies a maximum reduction of 35% in 35 years until 2050. Thus follows that improvements of the energy performance of the existing building stock are necessary to achieve the emission targets. For this analysis we will further focus on the existing building stock, since this part represents most challenges.

### F.2.2 Investment needed for existing buildings

Table 26 shows the total investments that are required to meet the targets for the residential and tertiary (services) sector, which sum up to the built environment sector. Until 2030, the investment level has to increase by a factor 1.5 compared to the reference scenario. After 2030, a tripling of the investment level is needed.

65 Focus of this sector study is on the built environment, which is more narrowly defined than the ‘residential, services and agriculture sector’, but covers the lion’s share of the ‘residential, services and agriculture sector’.

66 The definition of ‘nearly zero-energy’ differs per Member State.

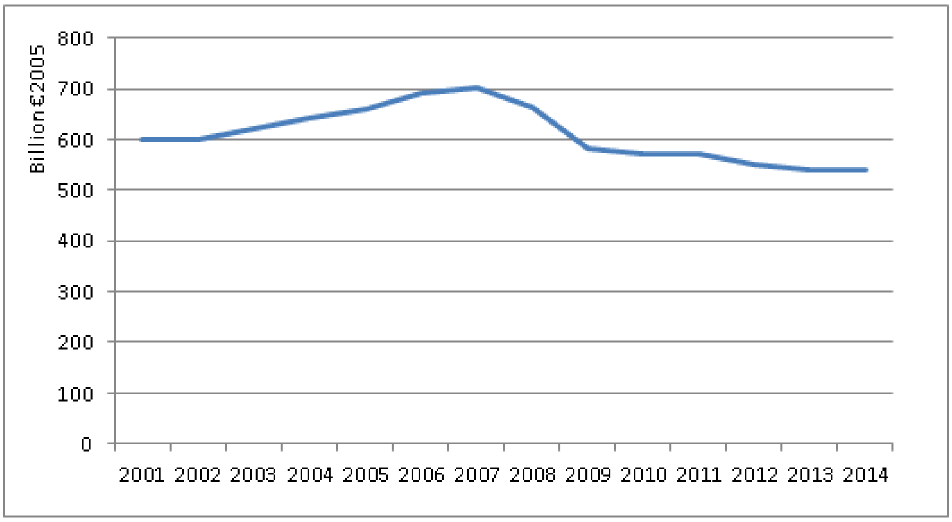
Table 26 **Average annual investment expenditures per investing sector (€ 2010 billion)**

| | Reference Scenario | | GHG40 policy scenario | |
|---|---|---|---|---|
| | 2011-2030 | 2031-2050 | 2011-2030 | 2031-2050 |
| **Investment expenditures** | **50** | **38** | **74** | **118** |
| Residential | 36 | 28 | 49 | 77 |
| Tertiary (services) | 14 | 10 | 25 | 41 |

Source: EC, 2014a.

Although these investments seem to be very substantial, they are relatively small compared to existing investments in dwellings. Figure 25 gives the average investments in dwellings according to the system of national accounts (ESA2010).

Figure 25 **Annual investments in constant € 2005 in dwellings in EU28**

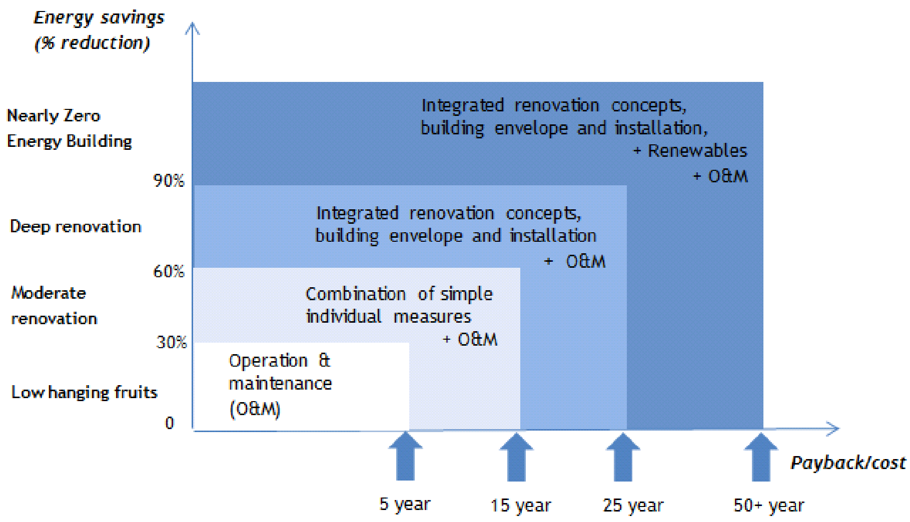



Source: Eurostat, National accounts (ESA, 2010).

This shows that the additional investments in the policy scenarios are between 10-20% of historic investments.

To improve the energy performance of the existing building stock different types of measures are possible. They can be classified into renewable energy (RE) measures and energy efficiency (EE) measures. Both groups of measures may be used on an individual (single dwelling) or collective (neighbourhood; apartment block) scale.

**Figure 26  Categorisation of Sustainable Energy measures**




Source: (ICF International, Hinicio & CE Delft, 2013).

Figure 26 shows the required measures to reduce a certain amount of energy use. Low hanging fruits and simple individual measures are relatively cost efficient and have short payback periods. But to reach an 82% carbon reduction, more complex measures are needed. This type of measures has a long payback time and requires a large initial investment.

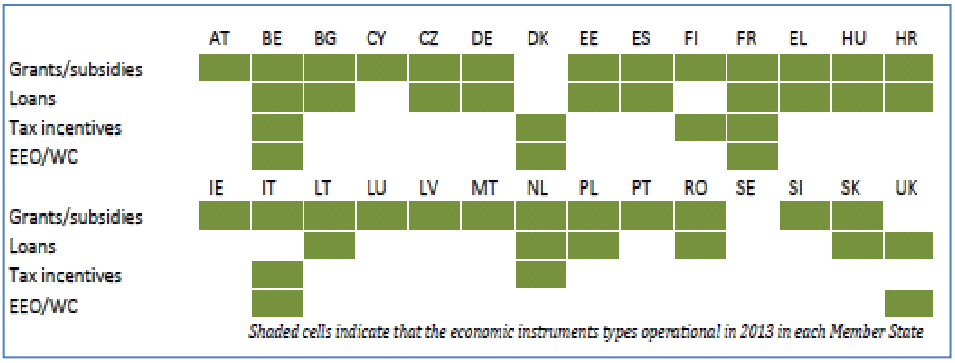
For 'nearly zero energy buildings' a combination of measures is needed, including the use of renewables. The exact combination of measures will differ per building type. Recent studies (PBL, 2012) confirm that a combination of individual and collective measures will result in the highest $CO_2$ reduction in a cost efficient way.

(BPIE, 2011) has calculated the investment costs for different types of renovation packages. The estimated reduction is determined by energy savings and decarbonisation of the energy supply sector. Three packages result in more than 80% $CO_2$ reductions between 2010 and 2050. Total investment costs (present value) range between € 551 billion and € 937 billion. In the most cost efficient package a two-stage renovation strategy is used: buildings undergo a shallow renovation between 2010 and 2030 and a second, deep, renovation 20 years later. This package shows an internal rate of return of 13.4% and shows that investing in decarbonisation can be an interesting investment opportunity.

## F.2.3 Current efforts

The current renovation rate is around 1.3% per year. Only a minority of these renovations are substantial or deep retrofits (EIU, 2013). A deep renovation can be defined as a more than 75% energy efficiency improvement, with a high focus on the efficiency of the building envelope and high use of renewable energy.
Figure 27 shows the current economic instruments used by Member States for promoting energy renovations. It shows a wide range of instruments available, mainly grants and subsidies. Besides, the EED has a 3% annual renovation target for public buildings owned and occupied by central governments from the beginning of 2014 onwards.

Figure 27 Main EU28 economic instruments in 2013 targeting energy renovations




Source: (JRC, 2014).

### F.2.4 Efforts needed

An annual 2-3% (deep) renovation level is needed to meet the GHG40 targets. BPIE (2011) states that a significant improvement of energy performance is needed to stay in line with the EU 2050 Roadmap. Model calculations show that a much higher capital and renovation level than business-as-usual is required to reach the targets. Continuing business-as-usual, with a 1% renovation rate, will result in an 18 or 72%[67] decarbonisation rate in 2050. To meet the targets of the GHG40 scenario an increase of the 'deep' renovation rate is needed. Continuation of current trends is insufficient to meet the challenge. Apparently, current policies do not give sufficient support to reach that renovation level. Many policies, like subsidy schemes, are more focused on the support for more shallow renovations, but do not give the right incentive to invest in more expensive deep renovations.

## F.3 Investment-related challenges

The CAPEX/OPEX shift in the built environment means that high initial investments are needed for e.g. renovations and renewable energy technologies. After the investment phase operational cost i.e. energy costs lower significantly and can even – ideally - reduce to zero. In case of an improvement in energy efficiency return on investment is a decrease in the energy bill. The return when using renewable energy measures differs per type of measure. Using solar panels and individual heat pump systems will result in a lower energy bill. Using collective heat systems, like geothermal heat systems on a neighbourhood level, does not automatically result in a lower energy bill for households. Apart from that, owners can profit from an increase in asset value. Capital is needed to finance the initial investment. Owner-occupiers and real estate companies have to attract capital, and investors have to decide to invest in projects that contribute to the decarbonisation of the built environment. Despite the sector gives interesting investment opportunities, the renovation level is relatively low. This paragraph introduces some important hurdles that hinder the uptake of investments.

67 The higher rate (72%) assumes an annual 5% decarbonisation rate of the energy supply sector, while the lower rate assumes slow decarbonisation effort in the energy supply sector.

### F.3.1 Hurdles for owner-occupiers

Owner-occupier's return on investment is a direct saving on the energy bill and a possible increase in asset value. Moreover, renovations can improve comfort of a building (residential or non-residential).

#### Owners are not always sure of an increase in asset value

Owner-occupiers can increase private returns if their investments lead to a premium in asset value, increases sales value and improve the marketability compared to other buildings. One study (Maastricht University, 2011) reviewed the literature on the relation between energy certification and selling price in the residential sector in different countries and found a positive relation between energy certificate and selling price but an insignificant relation between selling price and energy consumption. It seems that location and size of the house are more important to potential buyers and energy performance is still undervalued in the sales process (Avelino et al., 2011).

#### Rebound effects

Energy use after an investment is uncertain. Rebound effects can lead to a difference in technical calculations and actual energy use. Energy savings in retrofit buildings are often overestimated, because residents adjust their habits to the energy performance of their house. The more energy efficient a building becomes, the more it is the behaviour that determines energy use. Literature shows different estimations of the size of the rebound effect. (Aydin et al., 2014) estimate a rebound effect of 26.7% for homeowners in the Netherlands. This implies that actual energy savings are more than a quarter less than estimated. For UK households (Chitnis et al., 2012) estimate 5 to 15% rebound rate in GHG terms. They state most of this effect is indirect: after energy efficiency improvement households buy more goods and services that require energy.

#### High implicit discount rate for households

In general, owner-occupiers do not like having home life disrupted while renovations take place. In most cases deep retrofits can only be implemented in a vacant building, so the resident has to be re-located for 4 to 10 weeks (BPIE, 2011).

Calculations for investments use standard NPV calculation and 'reasonable discount rates'.[68] Implicit discount rates for households may be far higher. The profitability of investments depends fundamentally on the rate at which individuals discount future energy savings relative to the required upfront investment. Higher discount rates reduce the likelihood of an investment. (Houston, 1983) found an implicit discount rate of 22.5% for the purchase of energy saving goods in a stated preferences experiment. (Neij, et al., 2009) give an overview of discount rates found in literature. Rates found differ from 10 to 32% for insulation, 4 to 36% for energy efficient space heating and over 50% for energy efficient appliances. The paper shows that information programmes are the best solution to improve (reduce) the implicit discount rate.

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[68] E.g. Fraunhofer et al. (2009) use a discount rate of 4-8% for households, depending on the background scenario. (BPIE, 2011) uses a 10% discount rate for households and business.

### Lack of supply of financing products

Financing energy measures for households can be unattractive for private institutions. The small-scale size of investments leads to high transaction costs. The payback time for deep renovations is relatively long, which makes the business case unattractive. In most countries energy installations (like solar-PV) are considered as intrinsically part of the building. In case of a default the bank or mortgager has the first right to sell the house, including the installations. This increases the risk for the financer of energy measures, which in turn leads to a lack of large-scale supply of financing products.

## F.3.2 Hurdles for attracting finance for real estate companies

Real estate companies are defined as owners of buildings that let their buildings to households (residential; housing corporations; private rental companies) or businesses (non-residential).

### Split incentive

The return on investments is intangible. Real estate companies do not profit automatically from energy bill savings. The split incentive problem implies that a different party than the investor reaps the benefits from a sustainable energy investment. In the rental sector the tenant most often pays the energy bill. After an investment, the tenant reaps the benefits of a lower energy bill (and a more comfortable dwelling). In the residential sector, the landlord is not always allowed to increase the rent by the same amount as the energy savings. Recently, regulations have changed in some countries[69], but in practice energy efficiency costs are not always fully passed to the tenants. Moral institutions also play a role. Interest groups of residents fear an increase in housing costs for poor households and often advocate for a smaller rent increase than the energy savings. The split-incentive problem is less important in the non-residential sector (ENEA/FIRE, ÉMI, 2014).

### Increase in asset value

In the professional real estate sector investments in energy efficiency increase the ‘value’ of the building (Bozorgi, 2015). ‘Green’ buildings are more attractive, not only because of lower energy costs, but also benefits beyond cost savings – health and productivity – increase value. A higher asset value can increase revenues for owners. (Kok et al., 2011) show that energy efficient offices command higher rents than comparable energy inefficient buildings in the commercial property market. This implies that uncertainty about an increase in asset value is less a hurdle for real estate companies than for owner-occupiers and small-scale landlords.

### Problem with fragmented ownership

Energy efficiency investments in multi-apartment blocks can be problematic because usually a majority is required for renovation. In many cases even 70% of the households have to agree. Decision structures and voting rights differ per apartment block and country.

## F.3.3 Hurdles for investors

Investors can be institutional investors (pension funds; insurance companies) and banks. They seek for an optimal risk-return combination.

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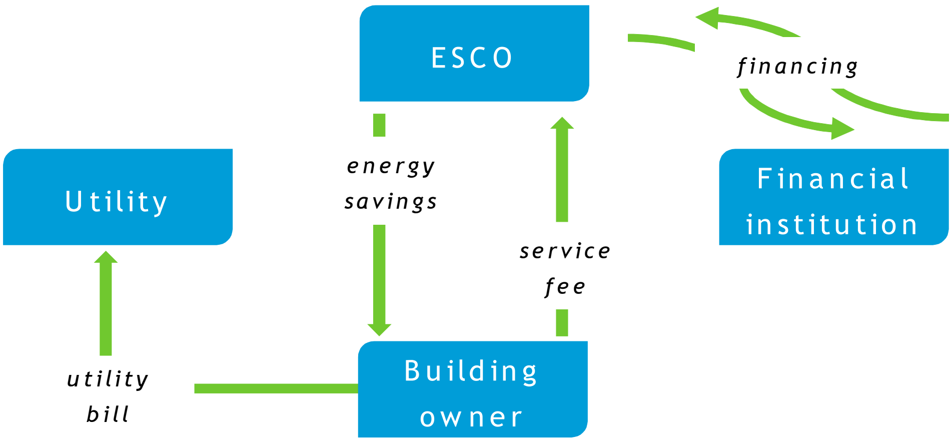
69 Article 19 of the EED (2012/27/EU) states that Member States must evaluate and, if necessary, take appropriate measures to remove regulatory and no-regulatory barriers to energy efficiency including the split incentive problem.

### Intangible revenue streams

Institutional investors are used to receive inflows from rents or company's profits. Other sustainable solutions like large-scale windfarms receive solid cash flows from the sale of the produced wind energy. These intangible revenue streams increase the risk for financers, especially in the case of individual solutions. A solution for this problem might be an 'Energy Services Company' (ESCO). An ESCO charges the building owner a fee to deliver energy savings on the owner's utility payments. Profit for the building owner is a lower energy bill minus the service fee for the ESCO. The service fees are the revenue streams for the ESCO. An ESCO can arrange financing for the programme. The ESCO takes on the performance risk: if no energy is saved, the ESCO does not profit.
Most ESCOs are focused on non-residential buildings with single, long term owners (schools, hospitals) and mostly focus on the 'low hanging fruits', like improving the lighting or insulation of a building. More advanced measures may be perceived as more risky. Using the ESCO model for residential buildings faces some more problems, like the small scale of the dwellings, complex decision structures in apartment blocks and high transaction costs (JRC, 2013).
The use of ESCOs is mentioned in Article 18 of the EED: Member States must promote the use of energy services and energy performance contracting.

**Figure 28** **illustration of an ESCO financing model**




### Investors cannot sell an energy efficiency improvement

For real estate investors investing in energy measures can be less attractive, because they cannot sell the product afterwards. Normal investment cycles in for instance real estate include the development and rental phase of a building. Afterwards the building can be sold.

### Investments at the demand site are still perceived as risky

Investments in energy efficiency in the built environment can have positive returns, but if returns on other investments are higher or risks are lower this type of investments is less attractive. Most institutional investors perceive investments at the demand side as more risky and are more familiar with investment in supply side energy companies.

### F.3.4 General picture

The three previous paragraphs summarised the hurdles that hinder the uptake of investments in the build environment. For owner-occupiers in the residential sector the hurdles can be summarised as 'household inertia' that lead to high discount rates and a low uptake of investments, despite positive investment opportunities and long term comfort advantages. They can also experience problems with finding interesting financing products, because private banks do not offer them on a large scale.

Real estate companies face problems with intangible revenue streams.
The split incentive problem in the residential sector is in principle solved by regulation, but in practice it is still difficult to increase rents after an energy efficiency improvement.

Investors are not used to invest in this sector and may be reluctant because of a lack of solid cash flows and perceived high risks. Fragmented ownership in the residential sector may be unattractive for investors and is normally not solved by the use of ESCOs.

## F.4 Policy solutions

Current policies appear to be insufficient to meet GHG40 targets in 2050.
This paragraph summarises some policy solutions that help to overcome the identified hurdles.

#### Market drivers

A stable regulatory framework is an important driver to stimulate the uptake of energy efficiency investments.
Owners face high implicit discount rates that hinder the uptake of renovations. Improving the return on investments create additional demand from households. A carbon tax increases the return and makes investments more attractive, but would probably be insufficient to overcome the problem of a lack of demand, unless the rates are set very high.
Mandatory requirements for renovations can help to overcome the problem of lack of demand because of high discounts rates. Building codes of many member states already include requirements for existing buildings, but the technical nature of the requirements gives problems with compliance (BPIE, 2011). The requirements should be clear and unambiguous for the different target groups.
A different option would be the extension of grants and subsidies, but in order to stimulate expensive deep renovations, this solution would be very costly. Grants and subsidies are more suitable for shallow renovations.

#### Leverage

The key for attracting sufficient financial capital is to use public money to attract private money. Public money can be used to cover investment risks and to leverage private capital. Government guarantees or loss reserve funds can reduce risks for private investors. EEEF (European Energy Efficiency Fund) and EIB already support large energy efficiency projects (project size € 5-25 million) with loans and grants. EIB also issues Climate Awareness Bonds for investors like banks and pension funds. On Member State level different initiatives exist.

**UK Green Investment Bank**
The UK Green Investment Bank was created in 2012 by the UK government to attract private funding for financing private investments related to environmental preservation and improvement. Projects include building retrofits (lighting, insulation, and glazing) and onsite generation (CHP, renewable heat, and heat pumps). Most projects are for large non-residential buildings, but the bank also supports projects for residential complexes. Project sizes range from € 2.8 million to € 1.4 billion.

**KfW bank in Germany**
This government-owned bank in Germany promotes energy efficiency for homeowners and landlords. They promote energy efficient refurbishment of existing residential buildings in particular with grants or loans at favourable conditions. Financing is available for complete renovations, and individual measures like insulation, renewal of windows and doors, and HVAC systems. Available grants are available up to € 18,750, loans up to € 75,000. Maximum size of the grant depends on the efficiency standard; refurbishing to a higher standard leads to a higher grant. Homeowners can apply for loans with their banks. Also housing companies and other enterprises can apply for loans with favourable interest rates if they invest in energy efficiency.

## Bundling
To meet the 2050 targets a combination of energy efficiency and renewable energy measures is needed. More focus on collective solutions instead of deep renovations can solve the problem of a lack of demand from households. Examples of collective solutions are geothermal energy systems or other heat systems on a neighbourhood or apartment block level. For instance energy companies can invest in this type of projects and can charge normal fees for the supplied energy. This overcomes the problem of an intangible revenue streams. This type of projects can be more interesting for investors, because a ‘traditional’ business model can be used.

## New financing models
The problem of intangible revenue streams can be solved by the use of ESCOs. The EED already promotes the use of ESCOs. Currently, ESCOs are mostly used in the non-residential sector. They appear to be less suitable in the residential sector, but may be an attractive business model after renovations in the social housing sector. They can overcome the split incentive problem: the ESCO will finance the refurbishment, the landlord will not increase rent, but the tenant will pay reduced energy costs plus a service fee to the ESCO.