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IMPACT ASSESSMENT

Accompanying document to the

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

A Roadmap for moving to a competitive low carbon economy in 2050

{COM(2011) 112 final}
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1. PROCEDURAL ISSUES AND CONSULTATION OF INTERESTED PARTIES

1.1. Policy context

The EU has a binding legal framework in place to reduce greenhouse gas (GHG) emissions for the period after 2012, when the first commitment period of the Kyoto Protocol ends. The Climate and Energy Package sets an EU wide cap for the EU emission trading system (EU ETS)[1] and national targets for the sectors not covered by the EU ETS[2]. The time horizon of the Climate and Energy Package focuses on 2020, even though the ETS cap continues to strengthen after 2020.

The Copenhagen Accord[3] underlined that low-emission development strategies are indispensable to sustainable development. This was confirmed at the 16th Session of the Conference of the Parties to the UNFCCC that decided that developed countries should develop low-carbon development strategies or plans[4].

The European Council supports an EU objective, in the context of necessary reductions according to the IPCC by developed countries as a group, to reduce emissions by 80-95% by 2050 compared to 1990 levels[5]. The European Parliament similarly endorsed the need to set a long-term reduction target of at least 80% by 2050 for the EU and the other developed countries[6].

At present, beyond the existing requirements in the Climate and Energy Package, no vision, strategy or roadmap exists in the EU on how to achieve such levels of reductions beyond 2020 up to 2050.

The Communication that this impact assessment accompanies has the intention to develop a roadmap to achieve such reductions in the EU up to 2050. This impact assessment gives information on the overall and sectoral pathways, the underlying technological and structural changes required, the investment and cost patterns and other impacts, synergies and trade-offs related to the broader sustainability and resource efficiency agenda. This is done for a broad range of sectors that cover the whole economy and all types of GHG emissions. This information will give insights in ambition required in different sectors and could be used as guidance when further developing policies and specific sectoral roadmaps for these sectors.

The EU Environment Council has indicated to look forward to the Commission’s roadmap for a safe and sustainable low-carbon economy by 2050[7]. The European Council confirmed this

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[1] Directive 2009/29/EC

[2] Decision No 406/2009/EC

[3] UNFCCC, 2010, Decision 2/CP.15, Copenhagen Accord.

[4] UNFCCC, 2010, Decision -/CP.16, Outcome of the work of the Ad Hoc Working Group on long-term Cooperative Action under the Convention.

[5] European Council, Brussels, 29/30 October 2009, Presidency conclusions. 15265/1/09

[6] European Parliament resolution of 4 February 2009 on "2050: The future begins today – Recommendations for the EU's future integrated policy on climate change; resolution of 11 March 2009 on an EU strategy for a comprehensive climate change agreement in Copenhagen and the adequate provision of financing for climate change policy; resolution of 25 November 2009 on the EU strategy for the Copenhagen Conference on Climate Change (COP 15)

[7] 3036th Environment Council meeting, Luxembourg, 14 October 2010

and indicated that due consideration should be given to fixing intermediary stages towards reaching the 2050 objective[8]. Also the European Parliament supports the establishment of action plans for achieving emission reductions in the period up to 2050 consistent with the 2°C limit[9].

Furthermore this roadmap is a key part of the initiatives to deliver on a Resource Efficient Europe, one of the 7 flagships of the Europe 2020 strategy[10], which aim is to support the shift towards a resource efficient and low-carbon economy that is efficient in the way it uses all resources, decoupling economic growth from resource and energy use, reducing CO2 emissions, enhancing competitiveness and promoting greater energy security.

1.2. Organisation

The impact assessment was elaborated by DG CLIMA in collaboration with DG ENER and DG MOVE. A joint analytical framework was elaborated between the three DGs and consulted as part of inter-service meetings on the Resource Efficient Europe Flagship. DG MOVE coordinated its modelling projections for the impact assessment of the 'White Paper on the future of transport' with those presented in this impact assessment. DG ENER will build further on the results presented here when elaborating their 'Energy roadmap 2050' planned for later in 2011. Other DGs were informed and consulted through inter-service consultations. A common EU reference scenario 2050 and a global 2ºC scenario were elaborated and consulted as part of inter-service consultations on the Energy Roadmap between April and September 2010. Further specific inter-service meetings to prepare this impact assessment and the one accompanying the White Paper on the future of transport were held on 21 October, 25 November and 14 December 2010[11].

1.3. Response to the opinion of the Impact Assessment Board

The impact assessment was presented to the Impact Assessment Board on 26 January. The board gave a positive opinion on the impact assessment and acknowledged that the submitted report provides modelling results that can be used as an essential input for the impact assessment work of related decarbonisation initiatives exploring concrete policy actions. It will help ensure coherence between these initiatives on the basis of a common analytical basis. While the Board acknowledged the analytical work carried out, it also recommended to improve it further.

Firstly, the board recommended to complement the modelling work with more qualitative analysis using other available information that goes beyond the insights that the modelling is capable of supplying. For employment impacts this was addressed with a more qualitative discussion of the issues at stake. The problem analysis and the motivation of the different scenarios has been extended and the limits of model analysis and related uncertainties have been better indicated. Text was improved to explain some of the limitations of the assessment on analysing social and environmental impacts and where further work is needed.

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[8] European Council, Brussels, 4 February 2010, Presidency conclusions, EUCO 2/11

[9] European Parliament resolution of 25 November 2009 on the EU strategy for the Copenhagen Conference on Climate Change (COP 15)

[10] COM(2010) 2020, EUROPE 2020 - A strategy for smart, sustainable and inclusive growth

[11] Participating DG's following broad invitation include AGRI, COMP, ECFIN, EMPL, ENER, ENTR, ENV, INFSO, MARE, REGIO, RTD, SG and TAXUD.

Secondly, the board recommended to provide greater clarity on any action in addition to policies already agreed that will be needed by 2020 to deliver on the decarbonisation target required by 2050. Therefore conclusions were added that have focus on the near term policy relevant implications of the assessment.

Thirdly, the board recommended to asses key macro-economic effects, such as GDP and employment impacts. The Staff working document accompanying the Communication 'Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risk of carbon leakage' of 26 May 2010 already addressed the macro economic impact of more ambitious action up to 2020. After the opinion of the board this modelling was revisited and refined up to 2030. It was not possible to project macro-economic impacts up to 2050. This work also addresses the issue of competitiveness which was listed as a fourth recommendation. But is was not possible to address distributive impacts in more depth due to a macro economic modelling set up that has the EU as one region in the world.

Fifthly, the board recommended that the report should clarify a number of methodological points including e.g. assumptions on technology, carbon and oil prices. The chapter that addresses methodology, modelling set up and scenario description was further refined.

The board also asked to give more key data and replace charts rather with tables, while also shortening the report by moving some detailed data to the annex. Summary tables per scenario on carbon prices and GHG emissions per sector were added in annex 7.10 and also the specific impacts on investment, fuel and electricity costs was put in tables rather than figures in chapter 5.2.4 and annex 7.11. The sectoral detail of this assessment of investments and costs as well as the technical detail of the scenario description was put in annex and the detailed assessment of the stakeholder consultation was put in separate Staff Working Document. The Board also advised to indicate, where possible, follow-up analysis and planned impact assessment work. This was addressed in the text in the relevant sectoral chapters.

Finally the board noted that this is not a standard impact assessment. It has a specific analytical focus that does not assess and compare policy options that could deliver on the overall policy goal.

1.4. Stakeholder consultation

Extensive reports have been recently published by stakeholders on the issue of how to decarbonise both our economy and society. To prepare this impact assessment a review was made of the reports available at the end of 2010. For a summary of these reports see chapter 1.4.1. Furthermore, the Commission consulted individuals and stakeholders on their vision and opinion regarding an EU low-carbon economy by 2050 through an online questionnaire "Roadmap for a low-carbon economy by 2050"[12]. For summary results see chapter 1.4.2. The wide range of views on how the EU can decarbonise its economy have been taken into account in the context of this impact assessment.

1.4.1. Stakeholder reports on decarbonisation of the Economy

A number of stakeholders has recently publicised reports that elaborate their thinking on how to significantly reduce EU greenhouse gas emissions in the coming decades, often focussing

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[12] http://ec.europa.eu/clima/consultations/0005/index_en.htm

on the energy sector (see bibliography in chapter 8 for list of reports analysed). There is limited attention amongst the published reports for other sectors such as the agriculture and LULUCF (Land Use, Land Use Change and Forestry) sectors. This chapter tries to give an overview of the main elements of these reports, what they have in common and where the differences exist.

All stakeholders agree on the need for action on climate change. Most endorse explicitly the need to reduce emissions in 2050 by 80 to 95% compared to 1990 levels. Eurelectric slightly differs from the EU's reduction target – in their "Power choices" scenario they set an aim of a 75% CO_2 emissions reduction via domestic action against 1990 levels.[13] In their position papers business associations refer to global targets and do not explicitly state concrete numbers for GHG reduction at the EU level. Business Europe confirms that global GHG emissions need to be at least halved by 2050 compared to 1990 levels.[14] Whereas WBCSD states that carbon emissions should be halved worldwide by 2050, compared to 2005 levels.[15]

According to most stakeholders the achievement of an EU low-carbon economy would require an increase in electricity use, the decarbonisation of power generation as well as fuel shifts in transport and buildings. Furthermore, improving energy efficiency is regarded essential.[16] Stakeholders underline the linkages between increased electrification and energy efficiency gains and think these will benefit both the environment and consumers, because of lower energy costs. Moreover, most of the stakeholders tend to agree on key technologies and measures that should be implemented: a shift towards renewable energy sources (largely wind and photovoltaic), roll-out of electric vehicles as well as the commercialisation of carbon capture and storage (CCS).

All stakeholders recognise that reducing emissions will bring additional benefits for the EU such as enhanced security of energy supply[17]. The shift towards decarbonised and more efficient electricity use in buildings and transport is expected to lower energy costs and bring more stable and predictable energy prices[18]. Investments in new energy efficiency measures, clean technology and new infrastructure are also expected to create new jobs and economic growth.[19] Some stakeholders additionally point to the reduced costs for climate change adaptation as well as better health conditions for European citizens, resulting from increased mitigation efforts.

Although stakeholders agree on a shift towards renewable energy, accelerated reduction of fossil fuels consumption and improvement of energy efficiency, opinions differ on the extent to which specific energy sources and technologies should be deployed. There is no uniform pathway leading to a low-carbon economy by 2050 and positions diverge on the share of renewables in the EU's energy mix in 2050. The European Renewable Energy Council and environmental NGOs favour a more than 90% share of renewables in EU's final energy consumption[20], while business associations refer to less ambitious levels of renewables in the

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[13] Eurelectric (2010), p. 6

[14] Business Europe (2010), p. 1

[15] World Business Council for Sustainable Development (2010)

[16] Business Europe (2010), p. 5

[17] European Climate Foundation (2010), p. 12

[18] European Climate Foundation (2010), p. 12

[19] European Climate Foundation (2010), p. 6

[20] European Renewable Energy Council (2010), p. 2-3, Greenpeace & EREC (2010), p. 7

energy mix.[21] As to the share of renewable energy sources in electricity production, the number stated by Greenpeace and EREC is around 97% by 2050 in the EU 27.[22] The Eurelectric's "power choices" scenario for 2050 assumes about 40% renewables in the power generation mix.[23] The European Climate Foundation assessed pathways with 40%, 60%, 80% and 100% renewables in power generation and concluded that an 80% renewables share would be possible without paying more for electricity.

Some stakeholders support the phase-out of nuclear power plants[24] whereas others consider nuclear power to be a key instrument for decarbonising the economy.[25] Regarding biomass some favour its rapid expansion in all sectors.[26] Others project that the future development of biofuels will be limited because of their impact on land use.[27] Regarding fossil fuels some foresee the complete abandonment of coal and oil consumption by 2050 (except for some key transport sectors).[28] Most of the stakeholders see a continued future for fossil fuels using CCS.[29] While CCS contributes to the decarbonisation of the industry sector in the long-term, COGEN underlines that combined heat and power provides the most cost effective and reliable solution in the short and near term for the sector.[30]

Business associations are generally concerned about the risk of carbon and job leakage and advocate low-carbon solutions where all energy sources play a role.[31] Positions differ also with respect to the EU Emissions Trading Scheme (EU ETS). Some stakeholders underline that European industry should receive the maximum amount of free allowances to guarantee the competitiveness of European industry[32]. Others argue that all EU ETS allowances must be auctioned and part of the revenues should finance the further development and deployment of low-carbon technologies.[33]

Policy recommendations expressed by stakeholders

Stakeholders would like to see a strong, consistent policy framework for achieving a low-carbon economy by 2050. This should provide the necessary certainty to make upfront capital investments and open up the implementation of low-carbon technologies.[34] Depending on the view of the stakeholder, the policy recommendations refer to the large-scale uptake of renewables, the fast deployment of CCS by 2025 and the promotion of new generation nuclear power plants. Most stakeholders want to see investments in a better, smarter grid.[35] . Energy efficiency and distributed power is also highlighted as policy recommendations and would be achieved through investments in better, smarter grid [36]. Measures encouraging the

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[21] World Business Council for Sustainable Development (2010), p. 24

[22] Greenpeace & EREC (2010), p. 7

[23] Eurelectric (2010), p. 61

[24] WWF (2007), p.4, Stockholm Environment Institute (2009), p. 2

[25] World Business Council for Sustainable Development, (2010), p.6

[26] WWF (2007), p.2

[27] Eurelectric (2010), p. 43

[28] Stockholm Environment Institute (2009), p. 2

[29] World Business Council for Sustainable Development (2010), p. 4

[30] COGEN (2010), p. 8

[31] Business Europe (2010), p. 6

[32] Business Europe(2010), p. 10

[33] Climate Action Network Europe (2010), p. 3

[34] Eurelectric (2010), p. 85, European Climate Foundation (2010), p. 4

[35] European Climate Foundation (2010), p. 11, European Renewable Energy Council (2010), p. 7

[36] European Climate Foundation (2010), p. 11, European Renewable Energy Council (2010), p. 7

electrification of road transport and efficient electro-technologies for heating and cooling should also be adopted.[37]

Some stakeholders propose the introduction of annual targets for emissions reduction to facilitate progress towards medium and long term. In addition, the establishment of EU/national compliance mechanism is recommended in order to impose sanctions on countries, regions and sectors that failed to meet their targets.[38] Others favour the introduction of an EU-wide carbon tax to accelerate investments in renewable energy development and infrastructure.[39]

Several stakeholders underline that an international agreement on climate change would foster the EU's transition to a low-carbon economy and efforts to conclude an international climate negotiations should continue.[40] Some stakeholders openly oppose unilateral trade measures as a way to enforce non-trade objectives and consider them ineffective given the EU's reliance on open markets.[41]

Stakeholders have different views on the timing of measures. Some emphasise that the first EU goal should be to achieve its 20-20-20 targets laid down in the EU 2020 Climate and Energy Package, adopted in 2008.[42] Business Europe advises against an increase of the 20% emission reduction target until the international conditions are fulfilled.[43] WBCSD assumes that the "transformation time" will happen after 2020, while the next decade defined as "Turbulent Teens" would be marked by ideas gathering and establishing of relationships.[44] Also the "Power choices" scenario of Eurelectric considers 20% reduction target by 2020 and an interim goal of 40% emissions reduction by 2030.[45] Environmental NGOs on the other hand argue for moving to 30% binding emissions reduction target by 2020[46] and underline the urgency of taking action as soon as possible.[47]

Some stakeholders would like to see further energy efficiency improvements across the economy, improvements in existing technologies such as the CCS, PV, offshore wind and electric vehicles as well as fuel shifts in energy use for transport and buildings for the next 5 to 10 years.[48] Others see a great potential in CCS and stress the need for fast investments so that it can become commercial in the next 10-15 years.[49] Many stakeholders focus on the immediate need for additional investments in renewable energy sources.[50] They insist on binding renewable energy targets for 2030[51] and the need to develop smart grids and to ensure transmission and distribution capacity. [52]

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[37] Eurelectric (2010), p. 86

[38] Stockholm Environment Institute (2009), p. 4

[39] Climate Action Network Europe, (2010), p.7

[40] Eurelectric (2010), p. 85

[41] Business Europe (2010), p. 11

[42] Eurelectric (2010), p. 35

[43] Business Europe (2010), p. 1

[44] World Business Council for Sustainable Development (2010), p. 10

[45] Eurelectric (2010), p. 35

[46] Greenpeace & EREC (2010), p. 9

[47] WWF (2007), p.21

[48] European Climate Foundation (2010), p. 11

[49] Eurelectric (2010), p. 85

[50] European Renewable Energy Council (2010), p.4, Eurelectric (2010), p. 85

[51] European Renewable Energy Council (2010), p.7

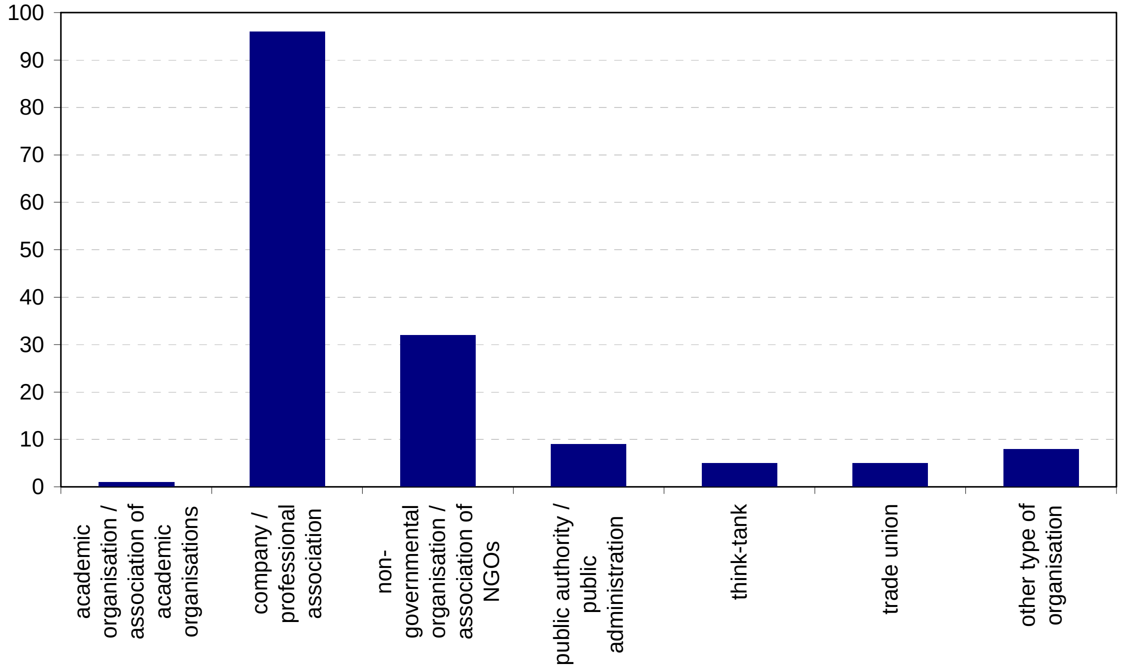
[52] Business Europe (2010), p. 8, European Climate Foundation (2010), p. 11

1.4.2. Results from the online questionnaire

For a detailed summary and further information on the answers supplied by the citizens and organised stakeholders see the public consultation website[53].

In total, 281 responses have been submitted via the online questionnaire and 7 additional answers have been sent by e-mail. Out of the 288 evaluated responses, there are 132 responses from citizens. The fact that the online consultation was available only in English did not limit the diversity of countries of origin of the respondents. Most answers have been received from France, followed by Poland and the UK. From all responses, 156 have been submitted from organized stakeholders, with very active participation from companies and professional associations - 96 in total, as well as from NGOs and associations of NGOs – 32 responses in total (see figure below).

Figure 1: Received responses from stakeholders by affiliation



The daily choices that consumers make have impact on the greenhouse gases emitted. Changing some habits and preferences could lead to reducing GHG emissions. According to the results of the online consultation, all respondents are willing to reduce waste, recycle and reuse as well as buy locally produced food. The least popular options are to buy carbon offsets and to use biofuels-blended petrol and diesel. Most of the respondents indicated that they are ready to pay even more than 12€ on a monthly basis to address climate change.

The main obstacles to reducing the EU's greenhouse gas emissions identified by respondents are the subsidies that support the production and consumption of fossil fuels such as mining. Furthermore many organised stakeholders claim that we still do not have the technologies ready to reduce emissions in all sectors and that it is too risky to invest a lot of money in new low-carbon technologies that may not work or may not pay off in the long run.

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[53] http://ec.europa.eu/clima/consultations/0005/index_en.htm

In the context of helping developing countries to cope with the challenges resulting from climate change, most of the organised stakeholders prioritise supporting the countries that generate the most pollution, while individuals bring forward the need to support countries most likely to suffer from climate change. Most of the organised stakeholders choose the ETS as the most effective EU legislation in terms of delivering emission reductions by 2020 and beyond, although it has been also extensively criticized by others.

The answers from organised stakeholders overlap to a great extent with the views represented in position papers published on the topic and discussed in chapter 1.4.1. Nevertheless the range of organisations who shared their positions through the online questionnaire was much broader. Some stakeholders updated their positions or provided more detailed information on their stance. For example Business Europe stated that it is still premature to set targets for 2050, although they indicate some support for the idea for intermediate targets, such as a target for 2030. [54] They underline that the EU will become a leader in fighting climate change only if it proves that reducing emissions and securing energy supply can be reconciled with economic development. Therefore according to Business Europe priority should be given to implementing cost-efficient measures, ensuring global competitiveness of EU industry and improving the framework for investment in low-carbon technologies next to fostering the cooperation on EU level.[55]

For the European Trade Union Confederation (ETUC) the key to low-carbon economy is to introduce competitive energy bills through regulated prices and through policies and measures that improve energy efficiency. ETUC urges the EU to provide the right economic signals which could take the form of a CO_2 tax for example. Furthermore ETUC calls for a binding energy saving target for each member state, shift of structural EU funds towards climate action and use of revenues from auctioned emission allowances as a financial basis for energy savings[56].

WWF proposed to adjust the EU 2020 objective to a 40% reduction target. This reiterated the position of many environmental NGOs, including the European Environmental Bureau (EEB). At the same time a minimum of three-quarters of this target should be achieved within the EU and not through offset mechanisms.[57] Furthermore WWF proposes that once the emissions reduction target for 2050 is set, milestones for every decade can be established[58], while Greenpeace opposes targets for 2030 because it would take focus away off 2020 and 2050 targets. Greenpeace favours the implementation of stronger carbon and energy taxation as a means to achieve energy security and reduce the use of natural resources[59]. Also the EEB puts the focus away from technologies that support unsustainable and growing energy consumption and underlines that policy measures should address consumption also[60].

Some public authorities within the EU (UK, Czech Republic, Spain, Sweden, the Netherlands and France) and beyond (Norway) have also shared their views on the EU's Roadmap towards

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[54] "BUSINESS EUROPE's Preliminary Views on the Roadmap for a Low Carbon Economy by 2050", Position Paper, 15 December 2010, p. 2.

[55] "BUSINESS EUROPE's Preliminary Views on the Roadmap for a Low Carbon Economy by 2050", Positio Paper, 15 December 2010, p. 3.

[56] ETUC, "Resolution on Energy Strategy for Europe 2010-2020", 1 December 2010, p. 2.

[57] WWF, Answer to the Online Questionnaire

[58] WWF, Answer to the Online Questionnaire

[59] Greenpeace, Answer to the Online Questionnaire

[60] EEB, Answer to the Online Questionnaire

a 2050 low-carbon economy. The UK consider moving to a 30% emissions reduction target by 2020 as the best means to demonstrate the EU's commitment, to create incentives for investment in low-carbon technology and to unlock greater ambition in the international negotiations. Furthermore the UK supports the creation of new large scale sectoral market mechanisms to promote net emission reductions in developing countries[61]. The Czech Ministry of the Environment and the Department Environment and Housing of the Government of Catalonia also support the deployment of sectoral crediting[62]. In addition, the Czech Environmental Ministry highlights the need of increased investments in the infrastructure and smart grid technologies and mid-term objectives which should lie on the linear trajectory between the targets for 2020 (as set by the Climate and Energy Package) and 2050[63]. The French authorities argue that the EU's future climate action should be accompanied by the creation of new jobs and accelerated innovation. In addition, investments should prioritise technologies identified in the Strategic Energy Technology Plan (SET Plan) of the European Commission[64].

2. PROBLEM DEFINITION

2.1. Impacts of climate change, the costs of inaction

Whereas temperatures were exceptionally low in December in large parts of Europe, globally records were broken in the opposite direction during 2010. Global temperatures for 2010 tied with 2005 and 1998[65]. The first ten years of this millennium where the highest ever recorded, confirming the finding of the IPCC that total temperature increased already with 0.76°C from the period 1850–1899 to the period 2001–2005[66]. Annex 7.1 gives a further overview of some of the weather related global climate highlights in 2011[67].

Such weather anomalies seem to result more frequently in weather related catastrophes. Munich Re[68], one of the world's leading reinsurers, estimated that 2010 was the year with the second-highest number of natural catastrophes since 1980, i.e. 950 (nine-tenths of these were weather-related), markedly exceeding the annual average for the last ten years (785 events per year). Two major weather related catastrophes stood out with a heat wave in Russia (July to September) and major flooding in Pakistan (also July to September).

Figure 2: Weather catastrophes globally 1980 – 2009

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[61] UK Government, Department of Energy and Climate Change, Answer to the Online Questionnaire

[62] Government of Catalonia, Department of Environment and Housing, Answer to the Online Questionnaire & Czech Ministry of the Environment, Answer to the Online Questionnaire

[63] Czech Ministry of the Environment, Answer to the Online Questionnaire

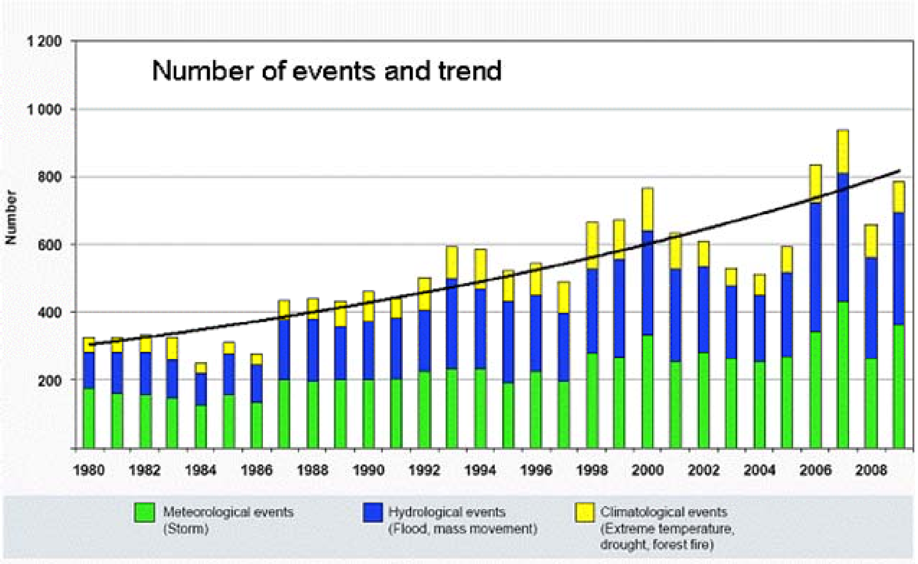
[64] The Permanent Representation of France to the European Union, Answer to the Online Questionnaire

[65] World Meteorological Organization, press release nr 906, http://www.wmo.int/pages/mediacentre/press_releases/pr_906_en.html

[66] IPCC, 4th Assessment Report, Climate Change 2007: Working Group I, Summary for Policymakers

[67] Source: National Oceanic and Atmospheric Administration.

[68] Munich, 3 January 2011, Press release Munich Re : Overall picture of natural catastrophes in 2010, http://www.munichre.com/en/media_relations/press_releases/2011/2011_01_03_press_release.aspx



Source: NatCatSERVICE, Geo Risks Research, Munich Re (July 2010)

According to the European insurance and reinsurance federation (CEA)[69] the World-wide the average number of major weather-related natural catastrophes has increased significantly, from about 1.5 in the 1950s to 4.5 in recent years. Apart from the increase in the frequency of weather-related natural catastrophes, the global economic impact of these events has also increased significantly, with a record high cost of weather related catastrophes of US$ 228 billion in 2005, which included Katrina, the costliest hurricane of all time.

Whereas in 2010 the US coast was not affected majorly by hurricanes in 2010, the number and intensity of the storms was one of the severest hurricane seasons of the past 100 years with 19 named tropical cyclones[70], equalling the number recorded in 1995 and putting 2010 in joint third place after 2005 (28) and 1933 (21). Also in China severe weather events have been reported hitting the country with a frequency and intensity rarely seen, with areas severely affected by drought, with other experiencing exceptional rain[71].

Also 2011 started with major catastrophes, associated with a strong La Niña, such as the floods affecting large areas of Australia and Sri Lanka.

Munich Re concluded that "the high number of weather related natural catastrophes and record temperatures both globally and in different regions provide further indications of advancing climate change".

The consequent economic and social impacts can be large. For instance the World Bank and Asian Development Bank[72] estimated that the Pakistani flood, in terms of the likely economic impact, is the worst natural disaster in Pakistan's history. Overall damage is estimated at the

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[69] CEA, Brussels, June 2007: Reducing the Social and Economic Impact of Climate Change and Natural Catastrophes - Insurance Solutions and Public-Private Partnerships

[70] National Hurricane Center, 2010 Atlantic Hurricane Season, http://www.nhc.noaa.gov/2010atlan.shtml

[71] http://www.cma.gov.cn/en/news/201101/t20110113_84904.html

[72] World Bank, Asian Development Bank: Pakistan Floods 2010 - Preliminary Damage and Needs Assessment, November 2010, Islamabad, Pakistan

equivalent of 5.8% of GDP, resulting in likely substantial adverse impacts on economic growth.

According to Munich Re, less than one third of global losses related to natural catastrophes were insured. This also affects high income regions such as the EU. For instance the most expensive individual event in the EU was winter storm Xynthia, which mainly affected Spain and France and caused overall losses of € 4.5 billion, of which only little more than 50 % was insured.

But social impacts can also be dire. The Russian drought and subsequent fire were estimated by Munich Re to have led to 56000 dead as a result of heat and air pollution, making it the second biggest deadly natural disaster last year after the earthquake in Haiti. The Russian drought has been generally also indentified as one of the elements that contributed to the increasing global food prices over the last year. Climate change will have impacts on the long term on food production. As the IPCC indicated, the potential for food production is projected to decrease globally with increases in local average temperature over a range of 1-3°C[73].

Without taking additional action, temperatures are expected to rise well above 2ºC already this century (see also chapter 5.1.5) leading to more weather anomalies and catastrophes. In 2007 the IPCC collated current scientific research in its 4th Assessment Report (AR4) on the potentially dramatic impacts of temperature increases (see Figure 3) showing potentially large scale impacts if temperatures indeed increase beyond 2ºC.

As the Stern Review pointed out, this could have significant economic impacts with GDP per capita losses ranging from 1 to 8% (taking into account market, non-market impacts, risks of catastrophes and climate feedbacks) by the end of his century and 2.9 to 35.2 % by 2200[74]. This could disproportionally affect the poorest, who are also the least capable of adapting to the impacts of climate change.

But the largest impacts can be expected from potentially large scale irreversible impacts, including potential tipping points[75] in our earth climate system with potential dramatic impacts. It is the magnitude and implications of such potential large scale events that are particularly difficult to capture in a quantitative analysis.

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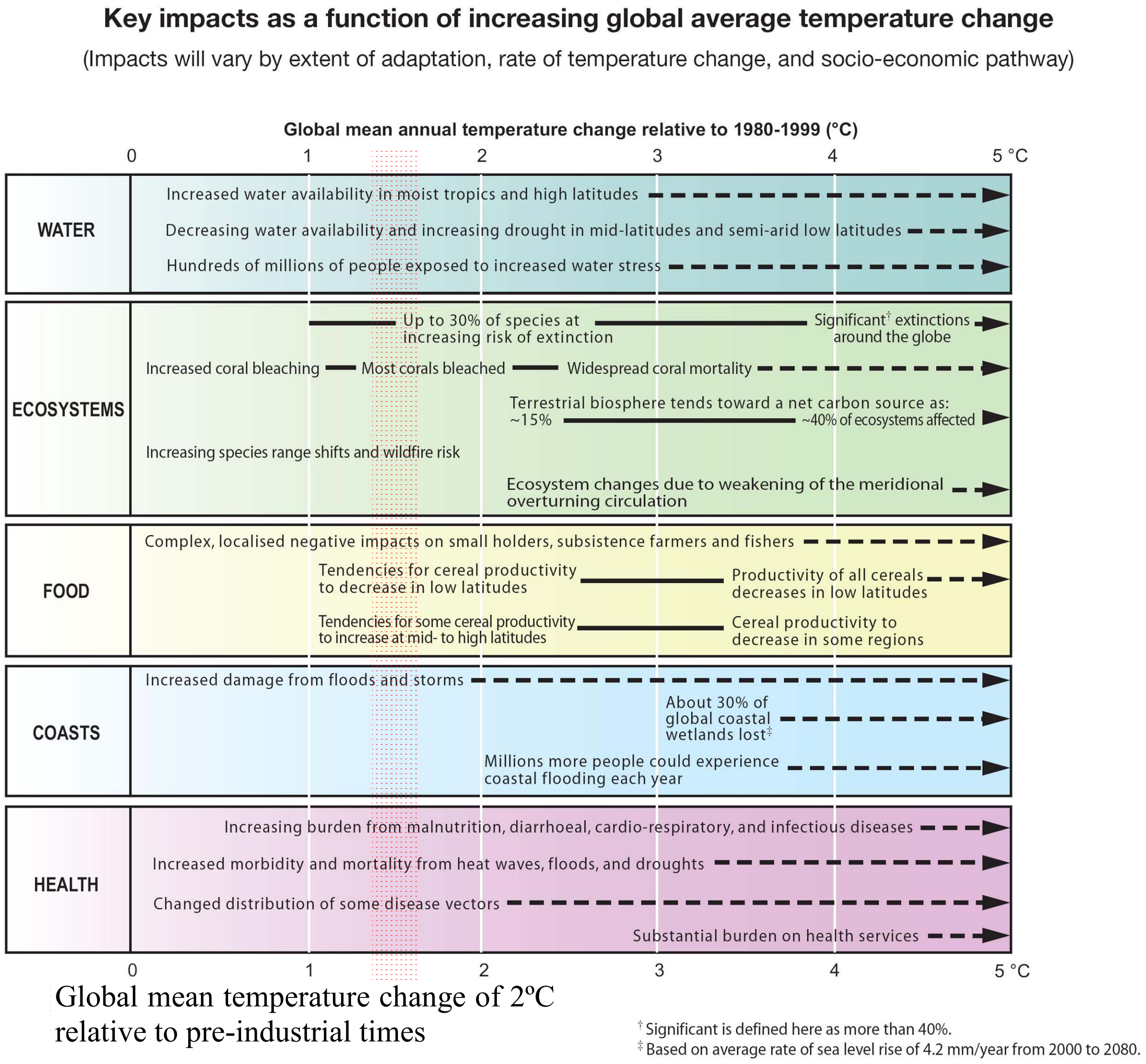
[73] IPCC, 4th Assessment Report, Climate Change 2007: Working Group Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Summary for Policy Makers.

[74] Stern (2007) The economics of climate change, Cambridge University Press, pp. 177-179.

[75] Lenton et al., 2008

Figure 3: Key impacts as a function of increasing temperature change



Source: Adapted from 'IPCC, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Summary for Policymakers, Figure SPM.2, 2007

For Europe similar effects can be expected of climate change, with significant differences between regions. For a review of recent findings, see annex 7.2.

2.2. Avoiding dangerous climate change

To avoid dangerous impacts, the EU has a stated objective of limiting global climate change to a temperature increase of 2ºC. The Copenhagen Accord[76] included reference to this objective. It was further confirmed within the UNFCCC in the decision of the 16th Session of the Conference of the Parties to the UNFCCC that[77] recognised that deep cuts in global greenhouse gas emissions are required according to science with a view to reducing global

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[76] UNFCCC, 2010, Decision 2/CP.15, Copenhagen Accord.

[77] UNFCCC, 2010, Decision -/CP.16, Outcome of the work of the Ad Hoc Working Group on long-term Cooperative Action under the Convention.

greenhouse gas emissions so as to hold the increase in global average temperature below 2°C above pre-industrial levels[78].

In order to have a likely chance to limit long term global average temperature increase to 2°C or less compared to pre-industrial levels, global emissions need to peak by 2020 and be reduced by at least 50% globally by 2050 compared to 1990. The EU has endorsed this GHG emission reduction objective[79]. Annex 7.3 gives an overview of the science that translates the 2ºC objective into this ambition level of global GHG reductions. The Intergovernmental Panel on Climate Change (IPCC) reported in 2007 that the existing science indicated that developed countries would need to take a target within the range of 80 to 95% below 1990 emissions by 2050 to limit global climate change to a temperature increase of 2ºC compared to pre-industrial levels[80]. The European Council and Parliament have endorsed this as an EU objective, in the context of necessary reductions according to the IPCC by developed countries as a group (see chapter 1.1).

Whereas the EU as a whole has seen its GHG emissions (without LULUCF) decrease over the last 2 decades, the EU GHG emissions are not on a path in line with an 80 to 95% reduction below 1990 levels by 2050.

In 2008 GHG emissions where estimated to be 11% below 1990 levels[81]. For 2009 the EEA estimates even significantly lower emissions levels of 17% below 1990, in part due to the impact of the economic crisis [82]. Including aviation this reduction would be around 16% below 1990 levels. Currently implemented policies such as the EU emissions trading system (ETS) or the legally binding renewable energy and non-ETS targets would lead at best to 20% reductions by 2020 and provide an important basis to decarbonise further. Decreases by 29% in 2030 and by 39% in 2050 compared to 1990 are projected (see Figure 4) mainly delivered by ETS sectors, with emissions nearly 50% lower than 1990, due to its linearly decreasing cap also beyond 2020.

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[78] It also includes the need to consider in the context of a periodical review the strengthening of the long-term global goal on the basis of the best available scientific knowledge, including in relation to temperature rises of 1.5°C.

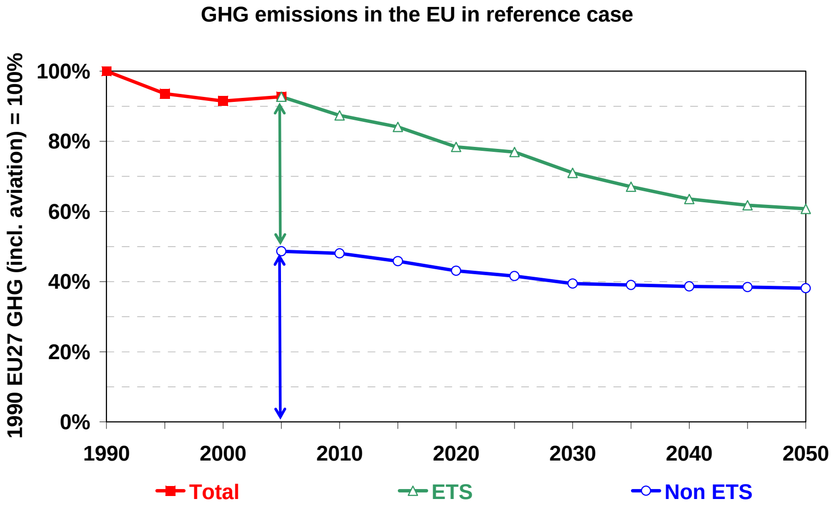
[79] The EU has expressed itself as preferring the option of global peaking by 2020 and to have global GHG emissions reduced at least with 50% compared to 1990 levels by 2050. See Council conclusions on Climate change, Follow-up to the Copenhagen Conference, 3002nd Environment Council meeting, Brussels, 15 March 2010; European Council Conclusions, 29/30 October 2009,

[80] IPCC, 4th Assessment Report, Climate Change 2007: Working Group III: Mitigation of Climate Change, chapter 13.3.3 Proposals for climate change agreements, box 13.7. Scenario category for GHG concentration levels of 450 ppmv $CO_{2\text{-eq}}$.

[81] Source: Annual inventory submissions to the UNFCCC, 2010. This excludes bunker fuel GHG emissions. If emissions from aviation fuels sold in the EU would be included, the level of emissions would rather be around -10% compared to 1990 in 2008.

[82] EEA 2010a, this does not include the emissions from aviation, nor other bunker fuels.

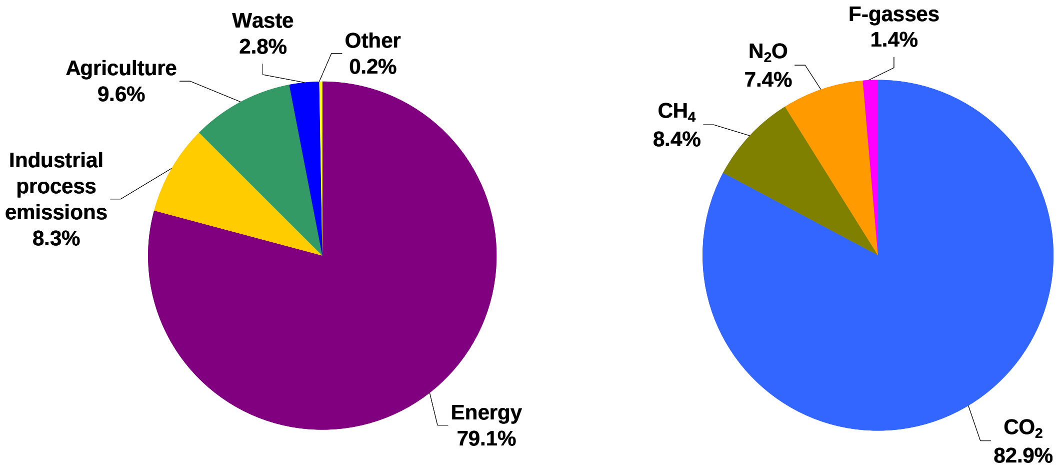
Figure 4: GHG emissions in the EU under current trends and policies



Source: PRIMES, GAINS (reference scenario)

The energy system remains the single largest source of emissions in the EU producing around 80% of GHG emissions, with the energy sector itself taking the largest share (31% of all emissions) followed by transport (22%), industry (11%) and heating for housing (11%). Most of the energy emissions are CO2 emissions, in total representing 83% of the EU's emissions, including certain CO_2 emissions from certain oxidation processes in industry.

Figure 5: GHG emission profile EU27, per sector



Source: Annual inventory submissions EU Member States to the UNFCCC, 2010, GHG emissions 2008 excluding emissions and absorption from Land Use, Land Use Change and Forestry

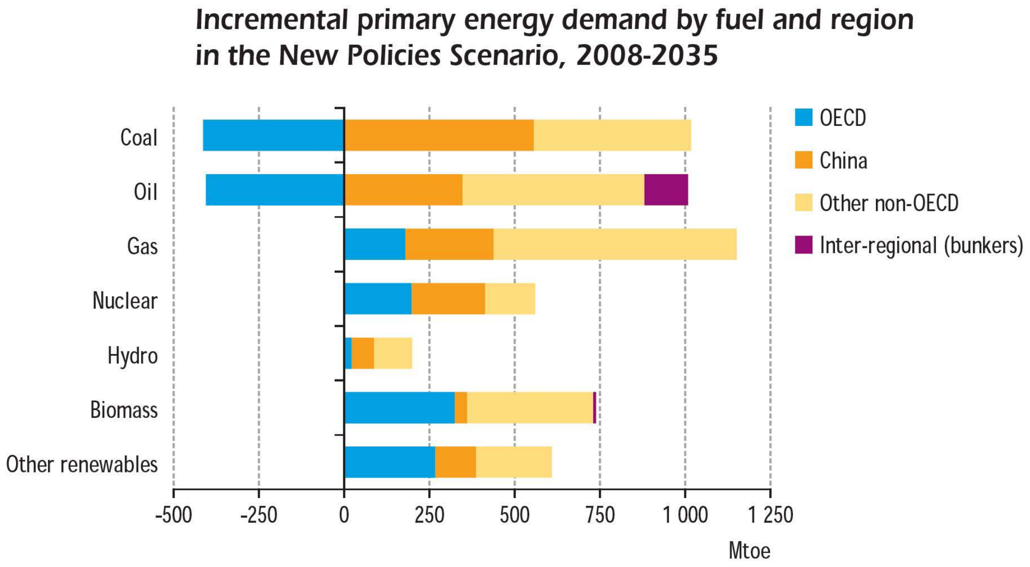
All sectors need to contribute to limiting GHG emissions, but it is clear that CO_2 will be the single largest gas contributing to any GHG emission reductions total. Therefore the term 'decarbonisation' is used when referring to the need to achieve very large greenhouse gas emission reductions, whether or not those reductions are take the form of CO_2 or other GHGs.

2.3. Growing energy resource and security concerns

Today, some 55% of Europe's primary energy is imported. With reduced oil and gas output in the North Sea, this is expected to increase to 57% by 2030 and 58% by 2050, despite increasing contributions from renewables (achievement of 20% target by 2020). For oil and gas this is even higher, with import dependency of over 60% for gas and 80% for oil today already, increasing to over 80% and 90% in 2030 and to over 90% (gas) and close to 100% (oil) in 2050 in the worst case if no action is taken. While energy dependence in itself does not constitute an economic problem per se, there are several energy developments that require careful attention.

First, increasing energy consumption in emerging economies will continue to push up demand and competition for gas and oil, requiring the exploration of less accessible and more expensive resources. Already today oil prices exceed 100$ despite the economic crisis. As an example of increasing demand in emerging economies, the IEA projects passenger vehicles to double from 800 million vehicles today to 1.6 billion in 2035, with the increase coming almost exclusively from non OECD countries.

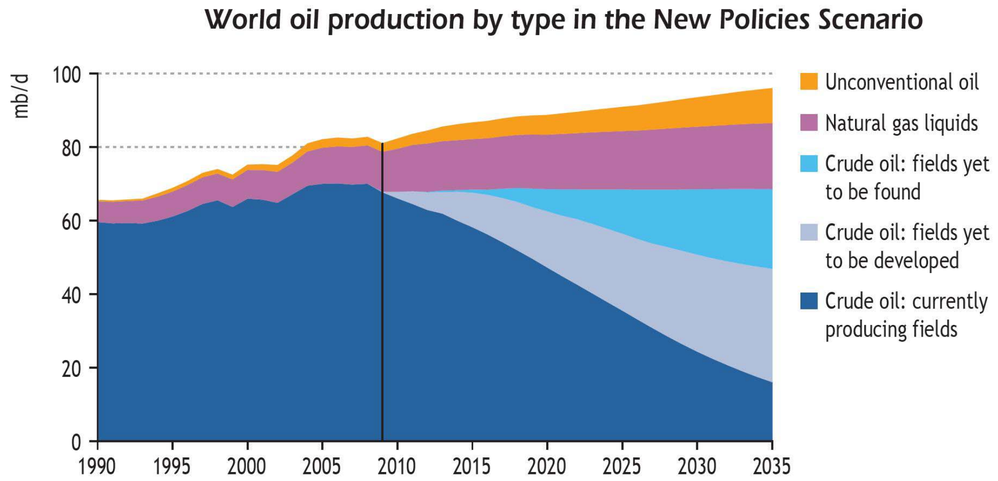
Figure 6: Incremental primary energy demand, 2008-2035



Source: IEA, WEO 2010

Secondly, IEA data suggest that supply side investments are not in-line with increasing demand and with the declining production of depleting oil fields. It projects that conventional crude oil production will plateau for the next 25 years with additional demand being met by unconventional sources. By 2035 it is estimated that some 75% of conventional crude oil production will have to come from fields yet to be developed or found.

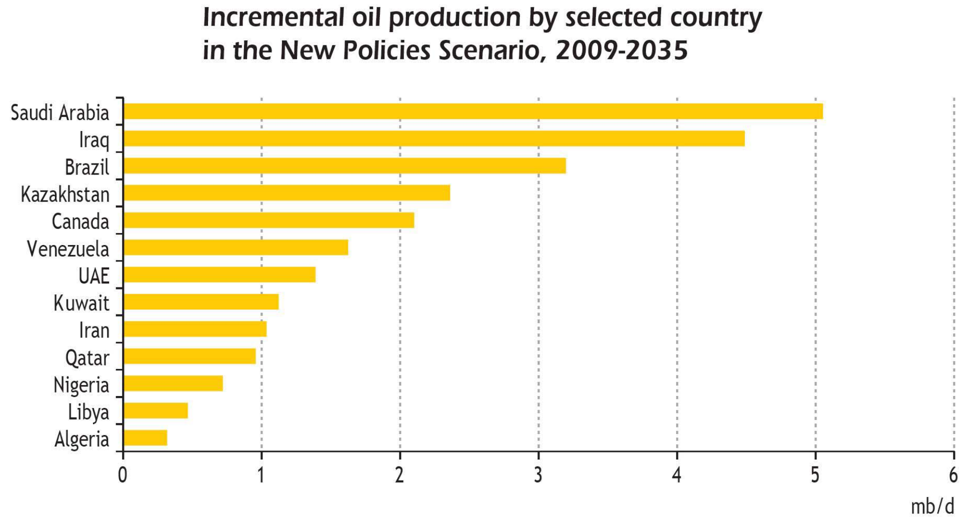
Figure 7: World oil production



Source: IEA, WEO 2010

Thirdly, global reserves are often localised in geo-politically unstable regions, and are in many cases owned by state-run companies that are not always reacting adequately to market forces. Additional supply would need to be delivered to a large extent by the Gulf region.

Figure 8: Incremental oil production by country



Source: adapted from IEA, WEO 2010

While the overall dependency of the economy on oil has decreased significantly, transport still remains for more than 90% dependent on oil.

Unless significant increases in resource efficiency are achieved, the European economy will continue to be exposed to serious risks related to energy prices, including potential oil shocks or gas shortages. 2010 is an example of this volatility. The IEA estimated that the EU oil import bill has increased in 2010 alone with $ 70 billion, and is estimated to represent in 2011 2.1% of its GDP[83]. As experienced in the 70s and early 80s, oil price shocks can again lead to

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[83] Financial Times, interview chief economist F. Birol of the International Energy Agency, 05/01/2010.

deep recessions, reduced competitiveness and rising unemployment. Household incomes and transport dependent industries will suffer from increasing oil prices, resulting in inflation as well as budgetary and trade deficits.

2.4. Making growth and jobs sustainable by overcoming barriers to the development and deployment of low carbon technologies

Today, the EU faces the most serious economic and financial crisis in decades. There is a need to get out of this crisis, and to create new jobs as quickly as possible. Beyond this timeframe, further efforts are needed to turn the EU into an economy delivering high levels of employment, productivity, competitiveness, sustainability and social cohesion. The Europe 2020 strategy sets the framework for delivering smart, sustainable and inclusive growth and jobs. To become a resource efficient, carbon low economy the way energy is produced and consumed will need to undergo fundamental changes with a range of low carbon technologies deployed at a much wider scale than today. These technologies will be one of the key growth sectors of the future and a source of competitive advantage for a wide range of manufacturing industries in a world that will goes towards low carbon development, and their widespread deployment is considered one of the key domains of sustainable job creation.

However, low carbon technology development is not only hampered by market failures related to the non inclusion of GHG externalities. There is also the well known problem of uncertainty and knowledge spill-over in general, which may lead to lower investment in R&D as optimal from a societal perspective. In addition, there is a commercialisation problem for capital intensive technologies in sectors and markets in which investments are marked by long lead times. Energy technologies are a prime example of such problems[84]. It will hence be critical to foster low carbon technology development and accelerate the learning curve as cost-effective as possible. The wide scale application of low carbon technologies, replacing today's mainstream technologies, and often transforming the required skills, presents both a major challenge and an opportunity for European businesses and employees.

How the EU develops its R&D, demonstration and innovation policies, creates framework conditions inducing technological change and fosters the competitiveness of a wide range of key manufacturing industries of the EU is an essential consideration in the overall development of a low carbon economy roadmap.

2.5. Sustainable shift towards a low carbon economy

The transition towards a low a carbon economy has important implications for the sustainable use of resources beyond energy resources, and hence on other elements of the Europe 2020 Resource Efficient Europe Flagship. Reducing emissions from fossil fuels tends to coincide with significant reductions in pollutants other than GHGs. This reduction in local air pollutants has significant co-benefits; not only impacting positively human health, but also reducing pressures on our ecosystems and additionally decreasing the costs of air pollution specific polices.

The roadmap also needs to consider land use and agricultural and forestry practices and the use of the available land for different services: the production of sufficient food and the

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[84] See analyses for the SET Plan Communication on Investing in the Development of Low Carbon Technologies, SEC(2009) 1297.

enhancement of food security, the production of feed, fibre (timber, pulp & paper) and the maintenance of essential ecosystem services (soil quality, water availability, biodiversity).

Whilst individual assessments of these changes would go beyond this impact assessment, the most relevant element to the low carbon economy roadmap is the role of bio-energy. Bio-energy could be a significant element in the shift away from fossil fuels, however its use must be considered as part of wider sustainability view of land use, within the EU and globally. This requires careful analysis to identify the conditions under which different needs can be made compatible. In this regard, changes towards more sustainable agricultural and forestry practices including potential productivity increases are important parameters to consider.

3. OBJECTIVES

3.1. General objectives

Shape a vision and strategy of how the EU can become a low carbon economy by 2050 and in doing so make its contribution to the global challenge to keep climate change below 2°C, to prevent severe and irreversible impacts of climate change on the global economy and ecosystems.

3.2. Specific objectives

The specific of this roadmap objective is to develop give insight on how the EU policy framework should develop in the next 10 years and beyond to (1) enable deep reductions of greenhouse gas emissions consistent with science while at the same time (2) reducing vulnerability to oil shocks and other energy security concern, and (3) reaping opportunities for sustainable growth and jobs (related to new low carbon technologies), while taking into account wider sustainability and resource efficiency considerations.

3.3. Operational Objectives

This impact assessment has the intention to give information on the overall and sectoral pathways, the underlying technological and structural changes required, the investment and cost patterns, impacts on energy security and other impacts, synergies and trade-offs related to the broader sustainability and resource efficiency agenda that would need to be associated with a economy that decarbonises by 2050.

In developing these insights, it is important to take into account:

(1) the specificities of sectors, and the interaction between them;

(2) risks and uncertainties related to climate and energy actions by third countries, subsequent energy price developments and technological developments;

(3) synergies with other policy objectives, co-benefits and potential trade-offs.

The insights from this impacts assessment can be used as guidance when further developing climate policies and specific sectoral roadmaps at sectoral detail (e.g. the Transport White Paper and the Energy Roadmap 2050). Such policies can include:

(1) to set more clearly sectoral milestones or potential targets to mobilise stakeholders, benchmark progress and give certainty to the business community;

(2) to develop policy instruments that provide the specific required economic stimuli towards low carbon investments, such as the ETS;

(3) to develop a broader policy framework comprising regulatory, sectoral, budgetary and financial measures to enable the low carbon transformation.

4. SCENARIOS TO DECARBONISE THE EU IN LINE WITH THE 2°C OBJECTIVE

4.1. Methodology

This impact assessment is not a traditional impact assessment that lists policy options to meet a certain policy goal and that then assesses these policy options to determine a preferable one. It assesses rather a set of possible future 'decarbonisation' scenarios to get more robust information on how the EU economy could decarbonise by 2050 in line with the 2ºC objective and compares this to a reference scenario that projects existing policies. It does this at two levels, the global level, because climate change and energy security are to a great extent global problems and cannot be addressed by looking at the EU only, and, as primary focus of the analysis, at EU level, but consistent with the different global settings.

Projecting sectoral developments up to 2050 is a long time from today. If ones looks back forty years, for instance in the field of energy, one sees fundamental changes that might have been difficult to project exactly in 1970. Commercial nuclear was still tiny, North Sea oil and gas exploration were not yet developed and renewables other than hydro were not used on a large scale commercial basis. On the other hand, these technologies were already proven technologies in the 1970s, but still required further innovation to make them widely commercially available. The incentives to do so were provided by the numerous oil crises since the 1970s, in combination to policy initiatives that reacted on these crises and later on policies to achieve the Kyoto Protocol climate targets, as in part was demonstrated with the huge surge in renewable technologies that came to market in the last 5 years. Hence also important long term regularities and stable causal relations can be observed on which quantitative modelling can build for scenarios extending in the future.

The methodology applied uses energy system modelling tools that project the evolution in supply and demand sectors in a coherent manner, without looking at any sector in isolation. This coherent modelling set also allows to take into account resulting changes in energy prices, an important driver for change in the energy system. The models used are POLES for the global energy system modelling and PRIMES for the EU energy system modelling.

This modelling framework is expanded with specific modelling tools that address sectors that emit greenhouse gases that are not directly related to the energy system. The Non CO2 emissions from agriculture and industry are assessed with the GAINS model, with input from the CAPRI agricultural model to assess production from agriculture and subsequent emissions (e.g. livestock emissions, emissions from fertiliser use). The land use, land use change and forestry emissions and removals are assessed with the G4M and GLOBIOM. These modelling tools are used in a coherent manner with the energy system models. For instance the land use and agriculture models require to foresee, where possible, sufficient supply of natural resources to correspond to the demand for bio-energy and biofuels from the energy system models.

Not all aspects could be modelled. Significant environmental impacts that go beyond greenhouse gas emissions, such as on biodiversity, were not assessed quantitatively. The exception is air pollution, for which the impact through climate action was assessed using the GAINS model.

GDP and overall employment impacts, as well as competitiveness impacts for energy intensive industries were assessed using the GEM E3 model. It was not possible to assess impacts on different household income levels, neither distributional impacts at Member State level. The global version of GEM E3 that was used does not have Member States detail.

Thus a quantitative methodology is the core of this assessment, supplemented by qualitative considerations where appropriate. It is applied in a way that factors in uncertainties but ensures for a coherent approach based on proven technologies, applying the following principles and limitations:

- Take into account existing capital infrastructure and limitations regarding capital stock turn-over;

- It is not possible to predict one future. Uncertainties and different options must be recognised. In this impact assessment the focus is on the major technological and energy price drivers. The level of the energy price is driven predominantly by the level or not of global action on climate change;

- Only by looking at different scenarios is it possible to draw more robust conclusions;

- Limitations of modelling long term horizons must be considered. Technological progress over time is assumed as typical in long term modelling (see also annex 7.9.1).Potential break-through technologies depending or unforeseeable structural change have not been taken into account. A particular example is the limitations in terms of modelling energy storage and smart grid solutions that would enable very wide scale deployment of distributed generation.

- Similarly, major lifestyle changes, beyond demand side effects of carbon pricing on behaviour, have not been taken into account in quantitative terms, as this goes beyond the capabilities of the quantitative modelling tools.

- The modelling also could not take into account effects of the changing climate itself on GHG emissions and potential reductions. These will have an impact on the energy system and the agriculture sector. Effects can go in different directions and will depend on how climate changes in different parts of the EU (e.g. more demand for cooling, less demand for heating, impact on water availability for power plant cooling or hydroelectricity production,, changing agricultural patterns). These impacts can also be more or less outspoken depending on fragmented or global action to mitigate climate change. Research on these aspects is ongoing (see for example the ClimateCost project[85]).

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[85] http://www.climatecost.cc/

By comparing results from different decarbonisation scenarios, it is possible to extract more robust conclusions, how key parameters influence the results and how various parts interact with each other. The impact assessment hence considers what it would require for the EU to achieve very large emissions reductions in line with the 2ºC objective under different alternative scenarios ("decarbonisation scenarios", instead of policy options) which vary in terms of key parameters, e.g. in terms of the global conditions in which decarbonisation would need to materialise, in terms of the key energy developments (most notably fossil fuel prices), and in terms of key technological changes over time. Chapters 4.2 and 4.3 will outline the different scenario options assessed and explain the quantitative methodology at global and EU level in more detail.

4.2. Action in a global context

4.2.1. EU internal action in the context of global action

To achieve the stabilisation of GHG concentrations at a sufficiently low level to be in line with the 2ºC objective, IPCC AR4 concluded that the existing science estimated that developed countries would need to take a GHG emission reduction target within the range of 80 to 95%, below 1990 levels by 2050[86]. The IPCC was not explicit about what the level of internal reductions would need to be to achieve this target of 80% to 95%, and how much of this could be achieved via the international carbon market.

To assess the order of magnitude of the required EU's own internal GHG emission reductions by 2050, a review of recent science is presented in chapter 5.1.1. Additionally, specifically for this impact assessment, the POLES model[87] was used to assess a mitigation scenario that reduces global emissions by 50% by 2050 compared to 1990[88].

4.2.2. Fossil Fuel Prices and how they relate to global and EU action

Fossil fuel prices matter when one needs to assess required efforts and impacts of reducing GHG reductions in the EU. But fossil fuel prices are not determined by the EU but are to a large extent set in the global market. At the same time global action on climate change can impact the price level of these fossil fuels due to the impact in reduced global energy demand and changes in the type of energy sources used.

To assess this potential interaction of climate action on a global level and fossil fuel prices 3 scenario's are compared in chapter 5.1.2, using the POLES model:

– Global baseline: globally no additional climate action is undertaken up to 2050. The EU implements the climate and energy package but nothing additional is undertaken (for the EU this is actually similar to the so called reference case).

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[86] IPCC, 4th Assessment Report, Climate Change 2007: Working Group III: Mitigation of Climate Change, chapter 13.3.3 Proposals for climate change agreements, box 13.7.

[87] For a description of the major drivers in the global POLES scenarios (i.e. global GDP and population growth) see annex 7.5.

[88] Preliminary results that looked at the required EU internal effort were already presented in the Staff Working Paper, Part II, Chapter 4, accompanying the Communication "Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risk of carbon leakage" (SEC(2010) 650).

– Global Action: global action that leads to a reduction of global emissions of 50% by 2050 compared to 1990 (same scenario as the one presented in chapter 4.2.1)

– Fragmented Action: EU pursues an ambitious reduction strategy (represented by the same carbon price signal as in the Global action scenario up to 2050). But other countries do not follow the Global action scenario. They only comply with the lower end of the Copenhagen Accord pledges until 2020[89]. 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.

This analysis will give information of potential price impacts on fossil fuel prices of global or fragmented climate action. This information will be used to determine fossil fuel price assumptions in subsequent scenarios that model ambitious EU climate action in more detail (see chapter 5.2)[90].

4.2.3. Macro economic impacts

EU action on GHG emissions does not only have direct impacts through changing production and consumption patterns in foremost the energy sector, but it also has indirect effects on the economy on a wider scale. To assess these, a macro economic model is used, i.e. the GEM-E3 model, that can also look at the indirect effects of interconnections between sectors with in the EU and third countries with home EU sectors compete.

The impact of scaling up EU action up to 2020 beyond the present 20% target was already assessed for the Communication 'Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risk of carbon leakage'[91]. The Staff Working Document assessed emission reduction levels by 2020 similar to those assessed in this impact assessment, with internal reduction by 2020 in the range of 20 to 25%.

This Macro economic modelling was revisited and extended to the 2030 time horizon, with a focus on the impact of ambitious EU action without other regions going beyond the pledges of the Copenhagen Accord after 2020.

For a more detailed description of the scenarios assessed and the impact on GDP, employment and production in the energy intensive industries exposed to international competition see chapter 5.1.3.

4.2.4. The missing global link, agriculture, forestry and energy

Most models only address emissions from energy and industry. But a significant amount of global emissions comes from the agriculture and forestry sector (typically deforestation),

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[89] Under the Copenhagen Accord the largest global emitters have pledged action to mitigate emissions. This is estimated not to be sufficient to be on track to achieve the 2ºC objective. See for instance: Chapter 2.4, Staff Working Paper, Part II, accompanying the Communication "Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risk of carbon leakage" (SEC(2010) 650) or UNEP: The Emissions Gap Report: Are the Copenhagen Accord pledges sufficient to limit global warming to 2 or 1.5°C?, 9 November 2010.

[90] The analysis presented in chapter 5.2 is done by the PRIMES – GAINS modelling tools. These tools focus on the EU and have fossil fuel prices as an exogenous variable.

[91] COM(2010) 265 final, SEC(2010) 650

representing around 30% of global emissions[92]. At the same time, remaining forest act as a carbon sink. Climate change policies in the energy sector will have an impact on those emissions and removals through increased demand for bio-energy. This cannot be seen in isolation. Production and trade of agriculture and forestry products will be influenced by climate action, both directly and indirectly.

At the same time in order to achieve a 50% GHG reduction globally, also these sectors should actually contribute considerably to global emissions reductions by 2050. To achieve the most efficient outcome, the sink function and competing uses (such as for materials and energy) should be balanced. Important questions can be raised regarding the impact of these opposing forces on the agricultural and forestry sector on a global scale, sectors that are crucial for global sustainable development (i.e. food supply, biodiversity, etc.). Chapter 5.1.4 assesses this in more detail.

4.2.5. EU action and global action, the likelihood of meeting the 2ºC objective

Meeting the 2ºC objective requires the halving of global emissions by 2050 (see also annex 7.3 for more background). EU action alone cannot achieve this objective, given that the EU represents only a bit more than 10% of global emissions, a share that continues to decrease[93]. Chapter 5.1.5 assesses the likelihood of achieving the 2ºC objective in the three different action cases as examined in chapter 5.1.2, i.e. the global baseline, fragmented action and global action scenarios.

4.3. The EU perspective towards a low carbon economy and society by 2050

Whereas chapter 4.2 introduced scenarios that look at impacts of action on a global scale, this chapter will focus on EU action, using an EU quantitative modelling approach, looking at the different actions and investments that can over time lead to large scale reduction of GHG emissions in the EU.

To do so, the PRIMES energy system model covering all EU CO_2 emissions is used in combination with the GAINS emissions model for projections of EU Non CO2 emissions, using also the agriculture EU production projections from the CAPRI agricultural model. See annex 7.4 for more background information on the modelling tools used and annex 7.9.1 for an overview of assumptions used in all scenarios with PRIMES – GAINS modelling.

A common feature of EU-level models is that variables mainly determined at the global level (e.g. fossil fuel prices) are exogenous, i.e. have to be defined by assumptions. Therefore some results of the analysis with the POLES model looking at the global scenarios presented in chapter 4.2 and assessed in detail in chapter 5.1 are important inputs into the scenario development at the EU level.

Foremost there is the EU internal reduction effort required by 2050. As chapter 5.1.1 points out, internal reductions in the order of magnitude of 75%, 80% or more are projected as appropriate for the required EU internal reduction in the context of achieving the 2ºC objective. In line with these results a decarbonisation challenge of -80% domestic reductions of GHG below 1990 by 2050 is used as key constraint for the EU decarbonisation scenarios.

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[92] IPCC, 4th Assessment Report, Climate Change 2007: Working Group III: Mitigation of Climate Change, Technical Summary, figure TS.2b: GHG emissions by sector in 2004.

[93] EEA 2009

Furthermore as chapter 5.1.2 demonstrates, the EU could be confronted with considerably different fossil fuel prices depending on what level of climate action others do. In case of fragmented action fossil fuel prices seem likely to remain high even if the EU takes action itself, with a remaining risk of future oil shocks and high fossil fuel prices. In the case of true global action these risks on oil shocks or high fossil fuel prices reduce, actually showing a considerable reduction of fossil fuel prices compared to the baseline price development. Hence low import fossil fuel prices are introduced to reflect significant impacts on global fossil fuel prices in case of Global action on climate change while fossil fuel prices are assumed to increase in the reference scenario, which projects current trends and policies, as well as in the Fragmented action scenarios, which models fragmented global action on climate, fossil fuel prices are assumed to increase over time. Additionally a high fossil fuel price scenario and an oil shock scenario are modelled to reflect the remaining risk of such events in case of only fragmented action at global level.

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. This is in line with approaches used in climate mitigation science[94] and differs from the approach of some stakeholder 2050 scenarios which start with a predefined target for the energy mix in 2050[95]. A common carbon price across all sectors and gases is assumed. This reflects economic cost-effectiveness considerations, because it ensures that in all sectors the same level of economic effort is applied to reach the target.

Chapters 4.3.1 to 4.3.3 explain key features of the different EU scenario types, e.g. the reference scenario, decarbonisation scenarios in the context of global action and decarbonisation scenarios in the context of fragmented action. The table below gives an overview of the detailed EU scenarios assessed.

Table 1: Overview of all EU level scenarios

SCENARIO	**KEY ASSUMPTION**
REFERENCE	ONLY CURRENT TRENDS AND POLICIES
GLOBAL CLIMATE ACTION	**-80% GHG IN EU, GLOBAL ACTION RESULTING IN REDUCED ENERGY IMPORT PRICES COMPARED TO REFERENCE**
Effective and widely accepted technology	Enabling framework for all technologies
Delayed CCS – higher efficiency	Lower contribution CCS (timing and costs)
Delayed electrification	Lower contribution electrification of transport (timing and costs)
Delayed climate action	Reinforced action only from 2030 onwards
FRAGMENTED ACTION	**ONLY FRAGMENTED ACTION**

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[94] See for instance work done in the context of the ADAM FP7 project (Schade et al., 2010) or the 2050 EU vision report of the Netherlands Environmental Agency and the Stockholm Resilience Centre (PBL, 2009).

[95] E.g. European Climate Foundation: Roadmap 2050. A practical guide to a prosperous, low-carbon Europe. Technical Analysis, 2010; European Renewable Energy Council: Re-thinking 2050 – a 100% Renewable Energy Version for the European Union, 2010. A mixed approach of emission constraints and predefined technological choices is taken by the Stockholm Environmental Institute: Europe's share of the Climate Challenge. Domestic Actions and International Obligations to Protect the Planet, 2009.

	GLOBALLY, NOT RESULTING IN REDUCED IMPORT ENERGY PRICES COMPARED TO REFERENCE
Effective and widely accepted technology	Enabling framework for all technologies, -80% GHG target maintained
Specific measures for sectors exposed to global competition (2 variants)	a) As Effective and widely accepted technology, but society compensating additional costs energy intensive industry b) carbon prices for energy intensive industries only as in reference scenario and thus resulting in lower emission reductions in this sector
High fossil fuel price variants	a) Oil shock occurring 2030 with prices returning close to reference afterwards b) Structural increase of fossil fuel prices from 2030 onwards
Delayed climate action	Reinforced action only from 2030 onwards

4.3.1. Reference scenario: where do current policies lead us to by 2050?

The aim of the reference scenario is to project trends up to 2050 based on already implemented EU and national policies[96]. A common reference scenario has been defined between different Commission services for this purpose. It also includes those policies agreed in the Climate and Energy package for which national measures have not yet been fully implemented, i.e. the legally binding targets for renewables to achieve a 20% overall share and a specific 10% share in transport and the legally binding targets for non-ETS GHG emissions and the ETS target to achieve the 20% reduction target in 2020 compared to 2005. Current policies, including the achievement of the legally binding renewables and greenhouse gas target do not result in the full achievement the 20% energy savings target by 2020, compared to the 2007 baseline, but would only realise half of this.

See annex 7.9.2 for more details on the specific policy assumptions for the reference scenario. See Figure 4 in chapter 2.2 for the overall emission profile in the reference case.

It provides a long term baseline or benchmark with which the results of the decarbonisation scenarios can be compared. It is a projection of developments in the absence of new policies which will be decided at the EU and national level. It is not a forecast but a benchmark for evaluating new policy measures against developments under current trends and policies.

International fossil fuel price assumptions do not presuppose significant global climate action and thus follow global baseline projections. Energy import prices follow a rising trend with oil prices increasing to 127 $(08)/barrel in 2050. Gas prices follow oil prices reaching 98 $(08)/boe in 2050 whereas coal prices remain much lower at 30 $(08)/boe[97] (see Figure 9).

4.3.2. Decarbonisation scenarios in the context of Global Climate Action

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[96] The agreed cut-off date for policies which could be taken into account is March 2010.

[97] Baseline global fossil fuel prices were calculated based on the stochastic PROMETHEUS world energy market model. These price developments are comparable with the IEA World Energy Outlook 2009.

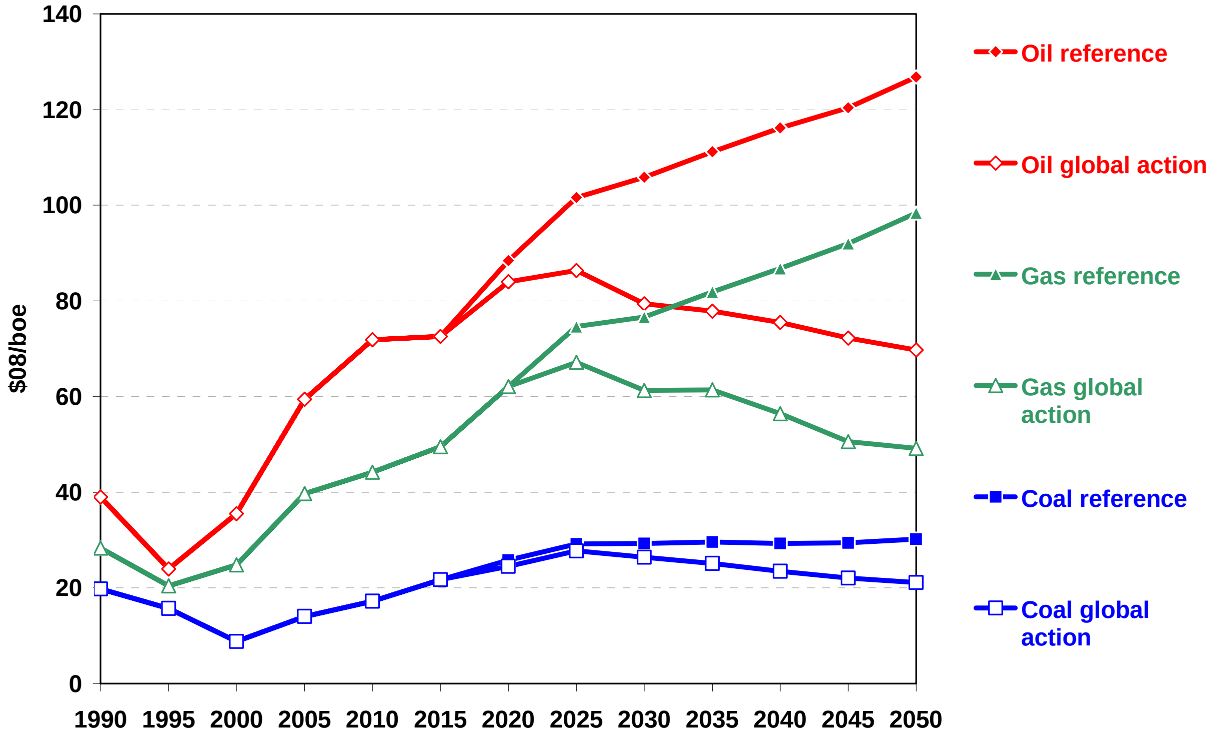
An internal greenhouse gas emission reduction contribution of around 80% in 2050 is taken as key constraint for exploring different scenarios on how such a decarbonisation would be possible in the EU.

To ensure that decarbonisation efforts are comparable across options and scenarios, the equalisation of cumulative emissions across scenarios is used as an additional constraint, underlining the importance of the climate impacts of cumulative emissions over the whole period until 2050 (and beyond)[98].

Common carbon values applied to all sectors and greenhouse gas emissions, covering ETS and Non ETS sectors, are used as key driver to reach the GHG emission reductions and to ensure cost efficient reductions across sectors. As economic drivers, they influence technology choices and demand behaviour. Their respective level is not an assumption but a result of the modelling.

A second driver are international energy prices. Given that these scenarios assume global action, significantly lower fossil fuel prices are assumed than those in the reference scenario. Their order of magnitude has been set at a similar level as the results of the global analysis in chapter 5.1.2 and recent IEA projections which assessed the impacts of ambitious climate policies[99].

Figure 9: International energy prices in reference and in the context of global climate action



Starting from these common assumptions, different decarbonisation options are defined to reflect uncertainty and the role and impact of potential key drivers to decarbonise. In particular, different assumptions on technological progress and diffusion speed of key low

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[98] Meinshausen et al. 2009

[99] International Energy Agency, World Energy Outlook 2009, Energy Technology Perspectives 2010

carbon technologies have been specified to assess the impact of remaining barriers to technology development (for those technology assumptions which remain constant across scenarios see annex 7.9.1, for a description of the technology assumptions that differ across the scenarios see annex 7.9.3):

- **Effective and widely accepted technology scenario:** An Effective and widely accepted technology scenario assumes that climate policies provide a sufficiently enabling context which overcomes barriers to the commercial deployment of low carbon technologies, such as energy efficiency and renewables, carbon capture and storage (CCS), nuclear and electrification of transport.

- **Delayed CCS scenario:** Carbon Capture and Storage has the potential to become a key low carbon technology which allows continued use of fossil fuels (coal and gas) for electricity supply even under a strict carbon constraint and enables radical emission reductions of industrial processes. However, the commercialisation of the technology presupposes continued improvement of capture technologies and the availability and public acceptance of a new transport and storage infrastructure for CCS. A Delayed CCS scenario explores the consequences if CCS is enabled less successfully and to which extent other low carbon power technologies and increased energy efficiency can step in.

- **Delayed electrification scenario:** Electrification of transport is currently widely regarded as promising a decarbonisation technology in the transport sector. These expectations are underpinned in particular by recent technological progress in battery development and an increasing offer of electric vehicles on the market. However, it is uncertain if the current speed of development and cost reductions continues and how quick a corresponding fuelling infrastructure will be developed. A delayed electrification scenario explores the consequences for abatement in other sectors and technologies if further innovation and large scale deployment is delayed. To enable a meaningful analysis of the impacts of technology failure, it is not assumed that another possible future key transport decarbonisation technology, e.g. hydrogen and fuel cells, could easily step in.

Delayed climate action scenario: In addition to these technology variations, the impacts of a 10 year delay to further climate action beyond the current Climate and Energy package are explored in a delayed climate action scenario. Is it still feasible to achieve deep carbonisation levels in 2050 under these conditions, and what would be the economic impacts of such a delay?

4.3.3. Decarbonisation in the context of Fragmented Climate Action

The scenarios grouped under fragmented climate action explore the important possible consequences if the world did not act in line with the 2ºC target, but the EU would maintain its policy of climate leadership and act consistently with available scientific evidence of what the required reduction effort should be. Such scenarios would be characterised by two main differences with regard to global climate action as described in chapter 4.3.2 (for a technical description of the different scenarios see annex 7.9.3):

World energy prices would be not as low as in case of a Global Climate Action scenario, but correspond rather to those in the context of a fragmented action globally. As can be seen from the analysis in chapter 5.1.2 this results in a significantly lower reduction in global energy prices and continued risks regarding long term energy security.

This is reflected in the detailed EU projections by assuming the same fossil fuel import price level as in the reference scenario. The impact of a fossil fuel prices that continue to increase over time is explored only in the 'Effective and widely accepted technology scenario' variant for the EU. Furthermore 2 high oil price scenarios are projected using this scenario variant. As such it isolates the effects of different fossil fuel prices and allows for meaningful comparisons of the impact on EU decarbonisation efforts between the contexts of global and fragmented climate action.

The 2 high oil price scenarios reflect the remaining realistic risk of oil price development in a world that does not act globally on climate change. The exact probability and extent of impacts of such risks cannot be predicted. To appropriately take related uncertainties into account, two different scenarios are developed:

- **Oil Shock scenario**: This explores the impacts of a temporary oil price increase, assumed to double prices around 2030.

- **High Oil Price scenario**: This explores a world where demand side reactions are not sufficient to counterbalance problems related to supply[100]. It assumes that prices remain at a continuously high level after the price increase in the period around 2030.

Both scenarios are also assessed in the context of the reference case in the EU with no additional climate action beyond the existing policies to see by comparison what the impact is of fossil fuel price risks on the EU with or without additional climate policies in place.

Specific measures for sectors exposed to global competition:

Furthermore in the context of fragmented action in which the EU acts more strongly than other countries in the world carbon leakage may become a problem. An assessment of impact of this is on the EU economy overall and more specific on the energy intensive industries up to 2030 was carried out using a macro-economic model, GEM E3, in chapter 5.1.3.

But also more specific measures in the EU for sectors exposed to global competition after 2030 up to 2050 are considered, a timeframe where CCS becomes important to reduce industrial emissions in the energy intensive sectors. These scenarios explore either what compensation energy-intensive industries would require for the deployment of such technologies or what the impact would be of not requiring additional emission reductions compared to the reference scenario for such industries. The EU internal efforts in power generation, land transport, heating and cooling and agriculture are, however, assumed to remain similar to those in the global climate action scenario. Again this scenario was only modelled using the 'Effective and widely accepted technology scenario' variant for the EU.

Finally also in the context of fragmented action, a **delayed climate action** scenario is explored. What are the impacts of such a delay if energy prices remain at the higher levels of the reference scenario?

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[100] For instance due to underinvestment in new capacity, problems related to unconventional oil sources, problems with deep sea exploration or simply political insecurity in key exporting countries)

5. ANALYSING THE IMPACT OF DIFFERENT SCENARIOS

5.1. Action in a global context

5.1.1. EU internal action in the context of global action

The 22nd Energy Modelling Forum exercise (EMF 22)[101] compared the results of a set GHG mitigation scenarios modelled with different tools at a global scale. It looked at different combinations of GHG concentration stabilization cases with ten integrated assessment models (IAMs) or energy models. Fifteen projections saw emissions reduce globally in 2050 by around 50% or more compared to 2000 levels. Twelve out of 15 of these projections saw internal emissions in the EU reduce by around 80% or more compared to 2000.

The IEA in its WEO2010 publication also assessed the required emissions reductions for achieving low GHG concentration levels in the longer term, stabilising at 450 $CO_{2\text{-eq.}}$ ppmv. It projected CO_2 emissions from the energy system up to 2035. For the EU, this resulted in a reduction of energy CO2 emissions by 54% over the period 1990 – 2035[102].

The Final Report of the ADAM project[103] concluded that Europe can make its proportionate contribution to achieving the 'two-degree target' by reducing greenhouse gas emissions by between 60 and 80 per cent by 2050. The ADAM project also assessed actions and technologies, at sectoral level, that could result in EU GHG reductions of 80% by 2050[104].

Specifically for this impact assessment, the POLES model by JRC, IPTS, was used to estimate emissions from energy and industry on a global scale and the resulting necessary reductions in the EU. Emissions from international bunkers (international maritime and air transport)[105] are included but not disaggregated by country or region.

The global action scenario projected by POLES, is a policy case in which global emissions are reduced by around 50% with respect to 1990 levels by implementing energy efficiency policies and the introduction of a global carbon price incentive. It is assumed that there is gradual participation of the different areas in the global effort and in the international carbon market, resulting in a gradual equalisation of carbon price incentive across regions and sectors[106]. According to this scheme, a carbon price is first established in the EU ETS sectors.

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[101] Clarke et al 2009

[102] Annex A, WEO 2010, IEA

[103] http://adamproject.info/index.php/Download-document/456-Adam-Final-Report-revised-June-2009.html

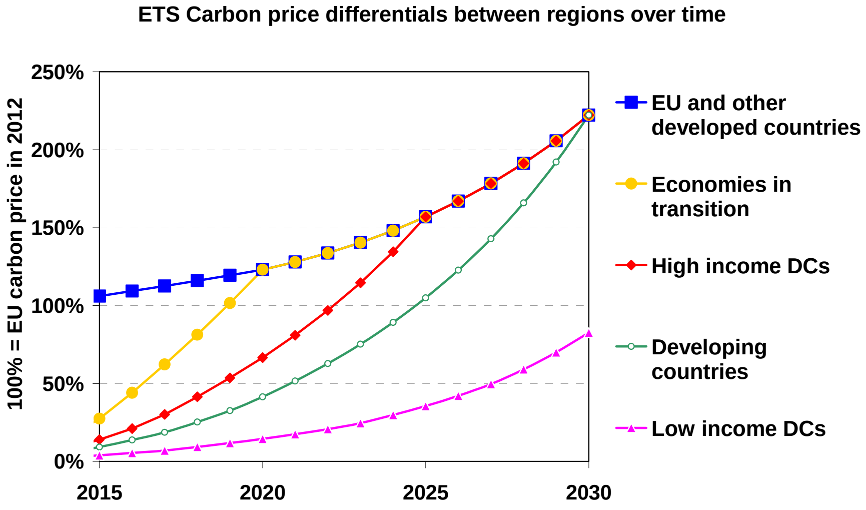
[104] See Schade et al. 2010.

[105] The POLES model estimates international maritime and aviation emissions to represent 0.76 and 0.44 Gt CO_2 in 2010. Furthermore this underestimates the relative impact on the climate of aviation emissions which has been estimated by the IPCC as being two to four times higher than the effect of CO_2 emissions alone due to releases of nitrogen oxides, water vapour and sulphate and soot particles (excluding cirrus cloud effects) (see Summary for Policy Makers IPCC Special Report on Aviation and the Global Atmosphere, 1999).

[106] The methodology, with global climate goals achieved through the gradual development of carbon markets was first presented in the impact assessment accompanying the Communication 'Limiting Global Climate Change to 2 degrees Celsius- The way ahead for 2020' (COM(2007) 2 final), adopted on 10/01/2007, which formed the basis for the Commission's proposal to adopt a 20% unilateral greenhouse gas target for the EU and a 30% conditional target. The methodology also formed the basis for the information on global efforts and mitigation costs as presented in the staff working document

In other regions the carbon price for the ETS sectors gradually catches up with the EU price. For the sectors outside the ETS, energy efficiency policies are first implemented and subsequently carbon prices are introduced. By 2030, carbon prices are equal to the ETS sectors in all countries except low income developing countries including India. By 2050, all sectors and countries globally experience the same carbon price.

Figure 10: ETS carbon price differentials between regions over time



Source, POLES, JRC, IPTS

Results of the global GHG emissions projections using the POLES model:

Globally, greenhouse gas emissions from the energy sector and industry in the Global action scenario peak between 2010 and 2020. By 2050 emissions return to a level that represents a 49% reduction with respect to the 1990 level (a 55% reduction if international bunkers are not included). This reduction corresponds to a 77% reduction with respect to the baseline in 2050 (-79% if international bunkers are not included). The reduction in emissions for developed countries is 80% with respect to 1990 and 76% with respect to baseline in 2050. Developing countries emissions keep growing until 2020 but reduce significantly by 2050, down to a level of about 5% below 1990 levels or 80% below baseline. This latter figure should give an appreciation of the level of action required also by developing countries.

Table 2: Greenhouse gas emissions in the Baseline and Global action scenario

Region		**1990**	**2000**	**2005**	**2010**	**2020**	**2030**	**2040**	**2050**
1990 = 100%									
World	Global baseline	100	112	128	140	160	180	201	220
	Global action	100	112	128	139	139	109	75	51
Developed	Global baseline	100	95	96	91	88	86	85	82
	Global action	100	95	96	91	72	51	33	20
Developing	Global baseline	100	143	190	232	296	354	414	477

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accompanying the Communications 'Towards a comprehensive climate change agreement in Copenhagen '(SEC(2009) 101) and 'Stepping up international climate finance: A European blueprint for the Copenhagen deal' (SEC(2009) 1172/2).

	Global action	100	143	190	232	265	211	141	95
EU27	Global baseline	100	93	95	88	82	77	71	66
	Global action	100	93	95	86	73	55	36	22

Source: POLES, JRC, IPTS

For the EU, emissions in 2020, 2030 and 2050 respectively are 28, 45 and 78% below 1990 levels (about 66% less than in the POLES baseline by 2050). There is in principle no economic incentive to do fewer reductions internally through the acquisition of international carbon credits, given that carbon prices are equal globally. No cheap reduction options remain available in other regions outside the EU.

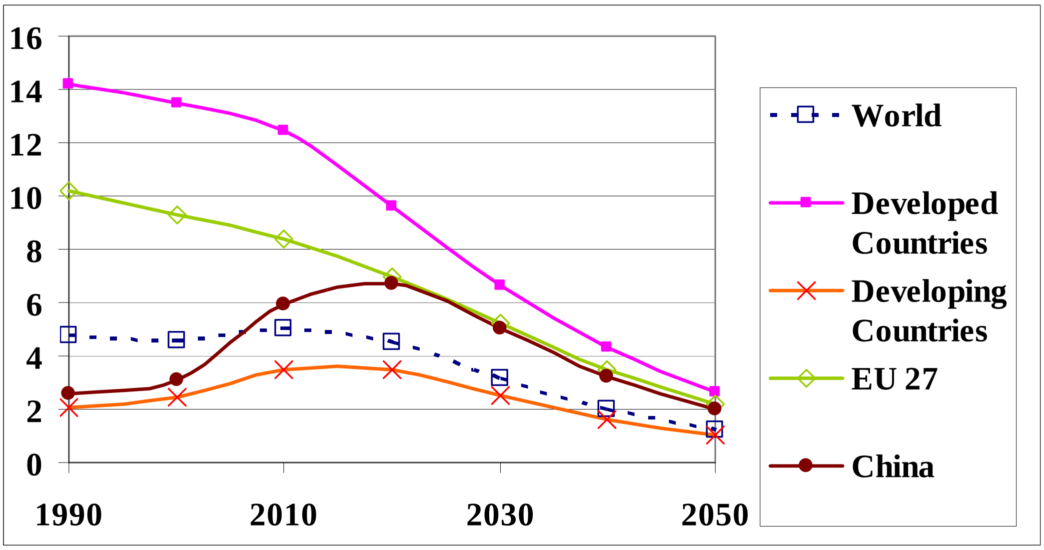
Thus in order to meet the 2ºC objective, the EU is bound to make very large reductions internally, in the POLES model resulting in reductions or 78% in the EU by 2050 compared to 1990. Taking into account the lower reduction potential in agriculture, not going beyond halving of GHG emissions by 2050 compared to 1990 (see chapters 5.1.4 and 5.2.9), which is the major sector not included in the POLES reductions, total internal reductions are around 75% in the EU.

This confirms the results of the other global GHG projections discussed above, with similar internal reductions for the EU or even higher ones of 80% and more.

For a sectoral differentiation of global and EU reductions between sector see annex 7.6. The results of the split in EU sectoral reductions are in line with those projected for the detailed EU analysis presented in chapter 5.2.1.

Emissions per capita would converge over time. Developed countries emissions continue to decline, but at a higher rate from 2010 onwards. Developing country emissions per capita peak sooner than total emissions, due to continued population growth. Notable is also that Chinese and EU emissions per capita are similar from 2020 onwards in a Global Action Scenario. By 2050 absolute differences are significantly smaller, even though per capita emissions remain higher in developed countries.

Figure 11: Per capita GHG emissions in the Global action scenario



Source: POLES, JRC, IPTS (excludes emissions from land use, deforestation and agriculture)

5.1.2. *Fossil Fuel Prices and Global Action*

Global fossil fuel prices are driven by supply and demand. The POLES model projects both endogenously, representing a global market for oil and linked regional markets for gas and coal. As such it is an ideal tool to assess impact from global climate change action on fossil fuel prices. This impact would primarily be driven through the impact of climate change policies on demand for energy and a shift in the type of energy resource used.

The POLES model is used to assess the impact of baseline, global action and fragmented action as described in chapter 4.2.2.

The energy projections underpinning the Global action scenario project a 38% increase in world primary energy demand by 2050. But this increase is significantly smaller than in the baseline (149%). The Fragmented action scenario has a global energy demand increase of 124%, which is not very different from the Baseline case. All of the growth in demand, as could be expected, takes place in developing countries (+171% and +370% by 2050 compared to 1990 in the Global action and the Fragmented action scenarios, respectively, but 395% in the Baseline), while developed countries have a slight increase over the baseline and a more or less pronounced energy demand reduction in the policy scenarios. In the Fragmented action scenario the global energy demand increase is so strong that world energy prices are pushed up to a level very close to those in the baseline scenario.

In the EU, energy demand in the policy cases returns to 1990 levels by 2020 and falls by 33-35% by 2050 compared to the base year. This corresponds to a 38-40% reduction with respect to baseline. While such reductions are not spectacular overall, by 2050 they become significant for fossil fuels: -60% to -63% for oil, -31 to -41% for gas, -87% to -88% for coal (smaller absolute figures correspond to the global action case). Given that in the Fragmented action scenario global oil prices (as well as those of the other fossil fuels) are projected to increase substantially, this energy frugality could provide a valuable shield against price shocks for the EU energy system.

Table 3: Primary energy demand in the Baseline, Global action and Fragmented action scenario

Region	Scenario	1990	2000	2005	2010	2020	2030	2040	2050
		%							
World	Global baseline	100	115	130	139	164	190	218	249
	Global action	100	115	130	139	155	153	145	138
	Fragmented action	100	115	130	139	158	177	199	224
Developed	Global baseline	100	102	105	100	105	107	111	113
	Global action	100	102	105	100	96	86	75	65
	Fragmented action	100	102	105	100	98	95	93	91
Developing	Global baseline	100	139	178	211	273	340	411	495
	Global action	100	139	178	211	265	275	271	271
	Fragmented action	100	139	178	211	268	327	393	470
EU27	Global baseline	100	104	110	105	107	107	107	108
	Global action	100	104	110	105	100	90	78	67
	Fragmented action	100	104	110	104	99	89	76	65

Source: POLES, JRC, IPTS

On top on this reduction in energy demand, climate change policies also are a driver that shifts energy demand away from fossil fuels towards low carbon energy sources. Whereas in baseline in 2050 73% of primary energy demand is met with fossil fuels, this reduces to 70% in the fragmented action scenario and even 45% in case of Global action on climate.

The combined effect of reducing energy demand and reducing the fossil fuel share in supplying this demand has an impact on oil prices. Whilst in the Baseline scenario the oil price grows, to 138 $/barrel in 2050, due to stringent energy efficiency and carbon mitigation policies in the Global climate action case it has a more moderate growth until 2030 and declines to 69$/barrel in 2050 (see table below). On the other hand, in the Fragmented climate action case, the oil price trajectory follows just below the baseline case, as it continues growing until 2050, when it reaches 117$/barrel. With global climate action, oil prices are projected to halve by 2050 compared to baseline, while with fragmented action, even if the EU continues to decarbonise in line with the 2ºC objective, oil prices reduce by only 15% compared to baseline, or less than a third of the reduction projected in case of global action.

Table 4: Global oil prices in different scenarios

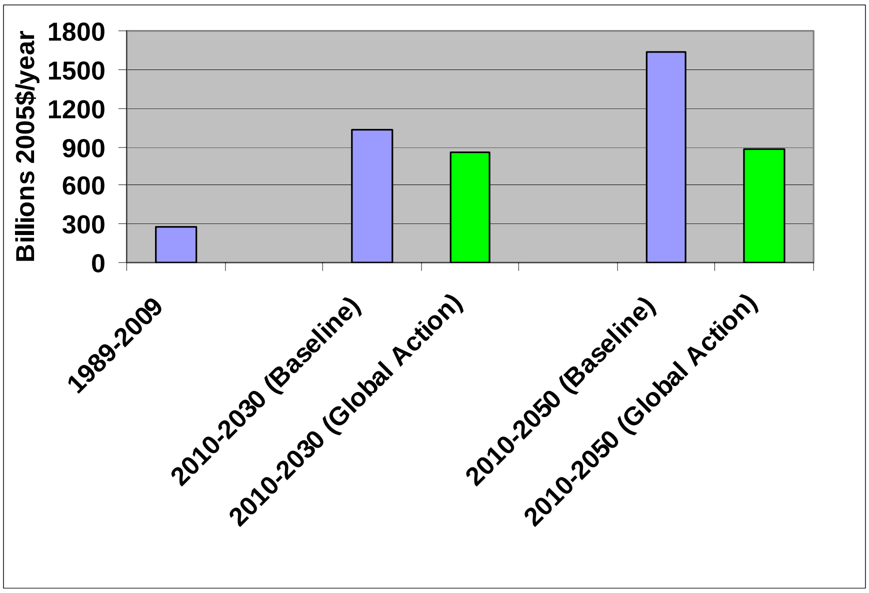
Oil Prices (2005$/barrel)	2005	2010	2020	2030	2040	2050
Global baseline	55	70	78	96	115	138
Global action	55	70	74	77	76	69
Fragmented action	55	70	75	88	102	117

Source: POLES, JRC, IPTS

In conclusion, the Global action scenario results in a major divergence in global demand for fossil fuels, with consequential impacts on projected world energy prices. Global Action leads a reduction of fossil fuel demand compared to baseline, leading to significantly lower prices. On the other hand, Fragmented Action means that world demand keeps on growing fast, leading to higher prices close to those in baseline. For a discussion on what this could mean for expenses on imports of oil and gas, see annex 7.8).

Changes in prices for energy sources will results in changes in income of countries that export these goods. But these impacts are manageable. Historically OPEC has earned annually a bit less than $ 300 billion from oil exports (see figure below, all prices are expressed in 2005 $). This is projected to triple in the coming two decades, with not that large a difference between the Baseline and the Global action scenario. Only after 2020 this stagnates in case of global action, with earnings being stable, but still 3 times higher than the historical average. In baseline or in the Fragmented action scenario without global action on climate change these would have continued to increase.

Figure 12: Average annual OPEC oil export revenues per scenario



Source: POLES, JRC, IPTS

Not acting on global climate change will result in continued high risks for high oil prices or temporary shocks. This risk remains high in the Fragmented action scenario. For illustration see Figure 13, comparing the oil production projections in POLES for the Fragmented action case with the projections made by the IEA in the New Policies Scenario of the World Energy Outlook 2010, which incorporates the Copenhagen pledges (see also Figure 7, chapter 2.3). The projections are very similar in total quantity.

As shown in the IEA graph, global oil production in the coming decades would become more and more reliant on oil fields still to be developed or yet to be found and on unconventional oil (see Figure 13). Oil wells in production today by 2035 will produce only a quarter of their current output, making the energy system highly reliant on new investments in OPEC countries and deepwater wells[107]. This further highlights the fact that the supply remains a considerable source of uncertainty and risk regarding future price in case of fragmented action on climate change.

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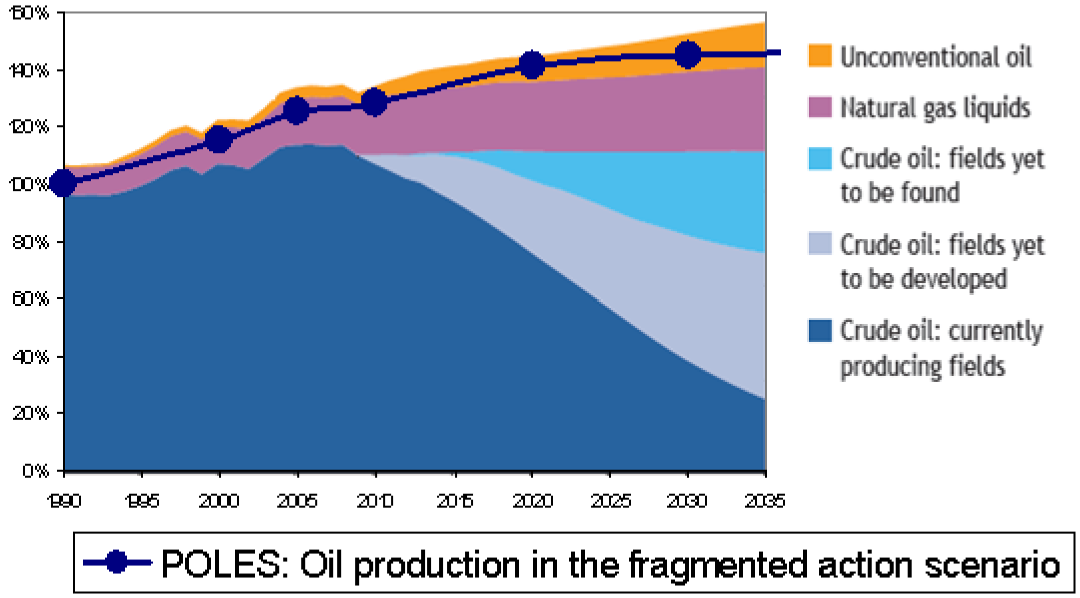
[107] See also IEA, WEO 2010, Figure 3.21.

Figure 13: World oil production up to2035 in case of the new energy policies scenario of WEO 2010, compared to POLES projection oil production fragmented action



Source: Adapted from IEA, WEO 2010, Figure 3.19 + Oil production in the fragmented action scenario from POLES (JRC, IPTS)

Instead Global action on climate change would greatly mitigate the risk on oil shocks and continuously high oil prices. It would require much less investments in unconventional oil and it would ensure for a more stable economic environment with being detrimental for the revenues of oil exporting countries.

5.1.3. Marco-economic impact

In order to assess the macro economic impact with the GEM E3 model, 2 scenarios, the Reference and the Fragmented action scenarios, where assessed and compared.

The following assumptions were applied for the two scenarios:

For the EU:

- In the Reference scenario the EU achieves its 20% GHG reduction target by 2020 internally, and keeps this level of emissions constant up to 2030.

- In the Fragmented action scenario, the EU is assumed to achieve a 25% GHG reduction internally by 2020, increasing to 40% by 2030.

For the other regions:

- In the Reference scenario other regions are assumed not to implement specific policies.

– In the Fragmented action scenario other regions implement the low end ambition level of the Copenhagen pledges up to 2020, afterwards the pledges are assumed to stay constant[108].

For the Non ETS sectors 2 variants are assessed: one where a carbon tax is introduced and one without a carbon tax. In the ETS only the power sector is assumed to have auctioning, other sectors get a fixed amount of free allocation.

One additional variant was introduced in GEM E3 scenarios with respect to how companies define their product price in case of free allocation.

Normally the GEM E3 model assumes that the ETS companies fully take into account the opportunity cost of those allowances when setting its prices of the goods they sell. The product price thus includes the carbon price even for those allowances that they have received for free.

In sectors without international competition, that can fully pass on the opportunity costs of the allowance, this inclusion of the opportunity cost can lead to a corresponding increase in the price of the good sold, and to significant windfall profits in case of free allocation. The power sector has often been associated with such behaviour. At the other extreme, there could be sectors that simply cannot raise the price of their goods due to international competition (this could only happen for sectors that have no product differentiation at all). In these sectors full inclusion of the opportunity cost of allowances would in principle lead to companies reducing some of their production[109]. This behaviour is identical for allowances being auctioned or allocated for free to these sectors and is optimal behaviour in systems where the fixed allocation (be it free allocation or auctioning) is determined for an indefinite period.

But not all industries agree that this behaviour correctly describes what takes place. Some, certainly the energy intensive sectors exposed to outside competition, claim that they do not engage in such type of price-setting, when they receive allowances for free. They claim they see free allocation rather as a compensation for the costs of the introduction of a carbon price on emissions which they will not include in the pricing of their goods. This type of behaviour rather focuses on keeping production volumes and market share high, results in principle in a lower production loss but also lower profits than the profit maximising behaviour that includes opportunity costs of all allowances in the production and pricing decisions of companies. It is also associated with allocation systems for free allowances where allocation in future periods is dependent on previous periods of production as the benchmarking approach does. In such systems companies may have an incentive to maintain production in order to have sufficient access to free allocated allowances in the next period. Here, the product price does not include the opportunity cost of the allowances that were received for free (but still does include the cost of the additional allowances that were bought on the secondary carbon market).

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[108] See chapter 5.4.1 of SEC(2010) 650 (Part 2) for further description of how the pledges of other countries are modelled. It is assumed that their 2020 pledge can be met in part (up to 1/3rd of the effort) through international credits. After 2020 it is assumed that countries with pledges that are absolute targets by 2020, keep emissions stable after 2020. Countries whose pledges are relative target by 2020, can see emissions increase again.

[109] Companies reduce production as long as the opportunity cost for the allowances associated with this reduced production are higher than the reduction in revenue from the lower production itself.

As a sensitivity analysis also this incentive-based price-setting was assessed for the industrial sectors in the ETS that receive a fixed amount of free allocation, keeping allocation fixed over time but not including the opportunity costs of the freely allocated allowances in the price setting mechanism.

Table 5 gives the GDP results for the 4 fragmented action scenarios compared to the reference scenario. The impact on GDP is limited, even with a 40% reduction, and confirms previous results that higher reduction targets, achieved through taxation and smart revenue recycling, could even have a positive impact on GDP development[110].

No inclusion of opportunity costs of free allocation in industrial price setting leads to slightly better GDP results as inclusion of opportunity costs. No inclusion of opportunity costs of freely allocated allowances results in higher emissions in those industrial sectors that get free allocation (even if the amount of free allocation is the same) and thus pushes up carbon prices in the ETS because others need to reduce more. The indirect positive effect of this increased revenue recycling from auctioning compensates the negative impact of suboptimal reductions in industrial sectors with free allocation compared to the projections that assume full inclusion of opportunity costs.

Table 5: GDP impacts fragmented action

GDP			
Tax non ETS	Industry in ETS price-setting strategy: Include opportunity costs free allocation	Vs reference in 2020	Vs reference in 2030
Yes	Yes	-0.18%	-0.89%
	No	-0.09%	-0.74%
No	Yes	-0.97%	-1.95%
	No	-0.93%	-1.86%

Source: GEM E3, JRC, IPTS

The overall employment effects are represented in Table 6, gives a similar results as the GDP impacts, with a positive impact from recycling policies[111] and slightly better overall impacts if industrial companies would follow a price-setting strategy that does not include opportunity costs of free allocation. The net impact on jobs can be an increase by 0.7% compared to reference, or an increase with a bit more than 1.5 million jobs by 2020.

Table 6: Employment impacts fragmented action

Employment			
Tax non ETS	Industry in ETS price-setting strategy: Include opportunity costs free allocation	Vs reference in 2020	Vs reference in 2030
Yes	Yes	0.57%	0.22%
	No	0.68%	0.38%
No	Yes	-0.11%	-0.62%
	No	-0.04%	-0.49%

Source: GEM E3, JRC, IPTS

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[110] Revenue recycling is assumed to lead to lower labour costs. See SEC(2010) 650 (Part 2), chapter 5.4.2, table 20.

[111] Lowering labour costs through recycling makes labour relatively cheaper to capital goods in the production process, increasing overall employment compared to scenarios where other forms of recycling are applied.

The impacts on energy intensive sectors are represented in Table 7, giving similar results as presented in previous assessments[112]. Production decreases are very limited in 2020. By 2030 the impacts are more outspoken, when the EU would reduce emissions internally with 40%. In the worst case, production decreases with 2.7 to 4.3 % by 2030 compared to reference. But this depends to a large extent on the optimisation strategy by industry itself. If they would apply a price-setting strategy that does not include the opportunity costs of free allocation then impacts are much less outspoken. Together with the benefits from increased recycling in the whole economy, and thus slightly higher overall GDP growth, impacts are limited to a decrease in production between 1.5 and 2.9%. Free allocation thus protect energy intensive industry in the ETS, even if the EU would implement more ambitious targets in a world where other regions have more limited ambition.

Table 7: Impacts on energy intensive industrial sectors from fragmented action

Production Other Energy Intensive Industries

Tax non ETS	Industry in ETS price-setting strategy: Include opportunity costs free allocation	Vs reference in 2020	Vs reference in 2030
Yes	Yes	-0.27%	-2.70%
	No	0.21%	-1.78%
No	Yes	-1.03%	-3.62%
	No	-0.61%	-2.78%

Production Chemicals

Tax non ETS	Industry in ETS price-setting strategy: Include opportunity costs free allocation	Vs reference in 2020	Vs reference in 2030
Yes	Yes	-0.81%	-3.77%
Yes	No	0.03%	-2.29%
No	Yes	-1.36%	-4.34%
No	No	-0.57%	-2.91%

Production Ferrous and Non Ferrous

Tax non ETS	Industry in ETS price-setting strategy: Include opportunity costs free allocation	Vs reference in 2020	Vs reference in 2030
Yes	Yes	-0.91%	-3.22%
Yes	No	-0.29%	-1.69%
No	Yes	-0.94%	-3.24%
No	No	-0.37%	-1.77%

Source: GEM E3, JRC, IPTS

5.1.4. *Interaction between energy, agriculture and land use emissions on a global scale*

The POLES model was linked to the GLOBIOM and G4M model[113] to assess global GHG emissions from agriculture and forestry (including the impact of land use changes) in a consistent manner. The POLES model itself does not estimate emissions in land use and agriculture sectors but iterative runs are carried out with GLOBIOM and G4M in a consistent manner with the POLES results to achieve a global reduction of around 50% for all GHG emissions (see annex 7.7.1 for more detailed information on the methodology applied).

Global population is estimated to increase from a bit more than 5 billion people in 1990 to over 9 billion by 2050, who are estimated to see their welfare on average, expressed in GDP per capita, increase by a factor of 3 or more. This increase in income will cause dietary habits

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[112] See SEC(2010) 650 (Part 2), chapter 6.1, table 20.

[113] Both the G4M and GLOBIOM models are maintained by IIASA.

to change, with more meat consumed per capita. As a result, global non-energy GHG emissions of agriculture increase in the baseline significantly over time, nearly doubling over the period 1990 to 2050 from 4.8 to 9.1 Giga ton CO_2-eq.

Instead, gross deforestation globally is estimated to decrease through efforts to reduce the rate of forest loss, predominantly in developing countries. Emissions from gross deforestation in the baseline decrease from around 4.9 Giga ton CO_2-eq. in 2010, down to 2.2 Giga ton CO_2-eq. in 2050.

It should be stressed that the order of magnitude of uncertainty is large with deforestation emissions. Furthermore, this estimate only addresses emissions from gross deforestation and not absorptions from afforestation[114]. Finally this analysis does not take into account possible impacts from global warming itself over the period on agricultural production.

Emissions in agriculture are predicted to increase and those in deforestation are estimated to decrease. The exact outcome of the opposing trends in agriculture and deforestation is uncertain, but projections including the effects of the increasing bio-energy requirements from POLES in baseline, with GLOBIOM and G4M, result in relatively stable aggregate emissions.

To consider the reduction potential in the agricultural and forestry sectors, the global action scenario takes into account the following requirements:

(1) The need to ensure food security to feed the global population.

(2) The EU stated objective of reducing deforestation as part of a co-ordinated global action, in particular within developing countries.

(3) Efforts to reduce agricultural emissions, or rather limit the increase of these

(4) Increased biomass use for energy as a result of global action on climate change

(5) Dietary habits remain the same as in the baseline (i.e. changes towards more carbon intensive food linked to welfare increases).

In the global action case, carbon price incentives are introduced to meet these 5 requirements.

Total aggregate emissions of agriculture and deforestation reduce by 48% compared to 1990 levels. Gross deforestation is very small by 2030, but the figures show continued emissions from soils and degradation of dead wood post-2030. Note that in this scenario whilst food demand increases in-line with the baseline, deforestation needs to be halted, emissions from agriculture need to be stabilised and at the same time an increased demand of biomass for bio-energy production has to be satisfied.

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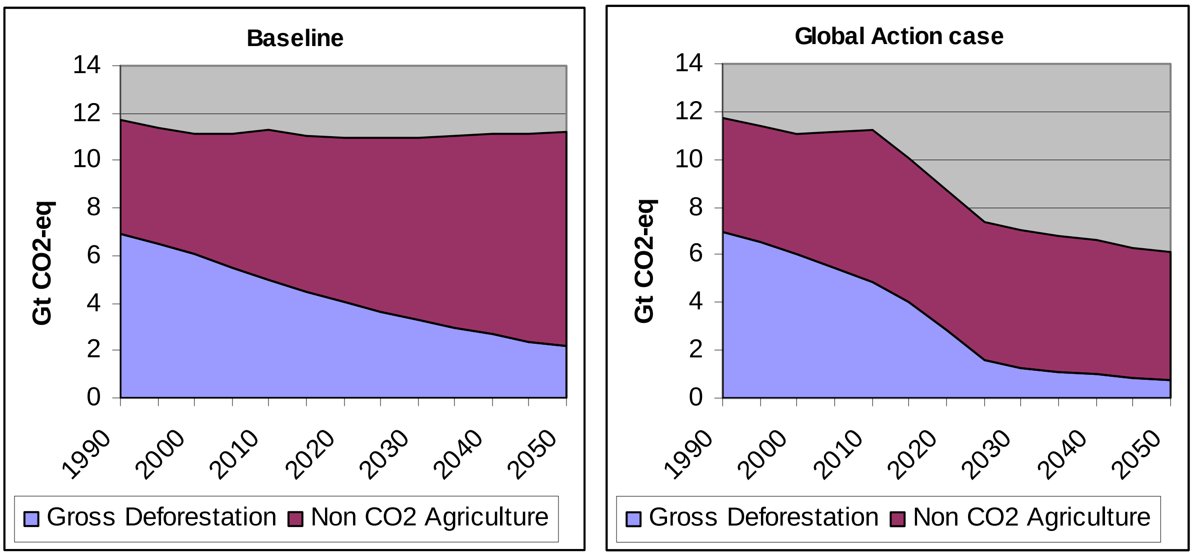
[114] Note that for instance recent preparatory work for the IPCC 5th assessment report in the context of the representative concentration pathways, when addressing emissions from deforestation actually looks at net deforestation and thus includes absorptions from afforestation.

Figure 14: GHG emissions from Agriculture and gross deforestation in baseline and Global Action Case



Source: IIASA, GLOBIOM + G4M

The impact on agricultural products' prices resulting from this policy scenario is moderate. While in the baseline, by 2050 prices of agricultural crops on a global scale are projected to reduce by 15% compared to 2000, in the reduction case the reverse is true, with prices actually increasing by 28% in the same period.

This result of the global action case (moderate food price increases compared to present levels, combined with eliminating deforestation, increasing food production, increasing bio-energy use) is critically dependent on productivity increases in the agricultural sector.

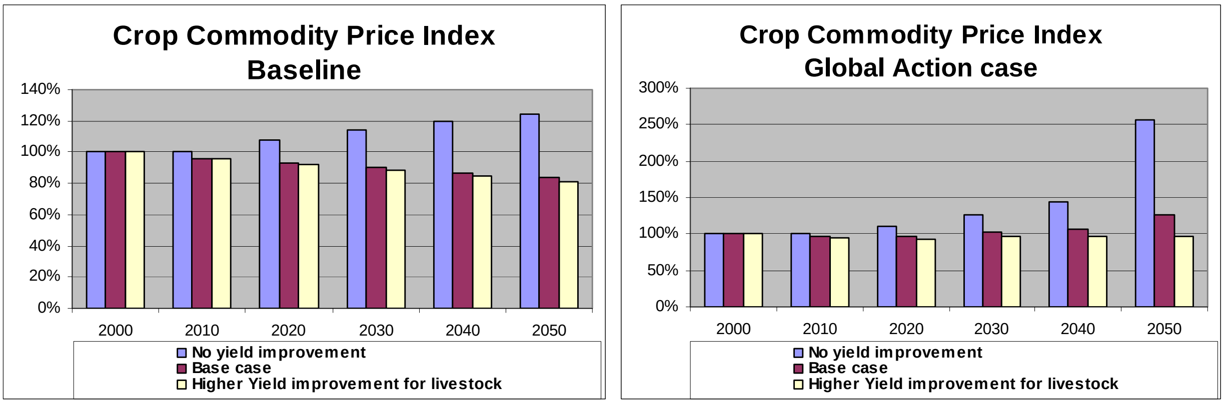
The scenarios in the GLOBIOM model assume in 3 ways that yields can be improved (see annex 7.7.2 for more information on the scenario description and yield assumptions):

- Switches are possible between production systems, for instance for a switch from purely grassland based cattle systems to more intensive production systems is feasible.
- Furthermore, crop and livestock production could be geographically shifted to areas where the natural resources allow for higher productivity
- Finally, exogenous yield growths have been assumed within crop production systems at 0.5% a year. For livestock no such assumption has been made.

It is crucially important that these yield increases are actually realised. In Figure 15 the results of a sensitivity analysis are shown projecting the impact on prices of agricultural crops of a scenario with lower and higher exogenous yield improvements than those assumed in baseline and global action case (see annex 7.7.2 for more information on the scenario description and yield assumptions).

Having no yield improvement in agricultural production systems would have adverse effects. If there are no yield improvements, prices would increase in baseline by 24% over the period 1990 to 2050 and by 156% in the Global action case. This situation seems unlikely; both from looking at historical yield improvements and given that it would result in increasing prices which in turn will be a strong incentive to allow farmers to increase agricultural productivity. On the other hand, there is increasing soil degradation globally (thus lower soil fertility), depletion of water resources for irrigation and the potential impact from climate change itself that could lower yields[115].

Figure 15: Impact yield improvements on overall costs agricultural goods.



Source: IIASA, GLOBIOM + G4M

Achieving such yield increases requires specialisation and improvement of agricultural practices, often implying intensification of farming, with certain crops or livestock production activities "migrating" to those regions where soil, climatic and other resources (including capital) give them a comparative advantage relative to others. Examples of improved agricultural practices and intensification include:

(1) Shifts from traditional grassland based livestock production systems to more intensive ones requiring less land area, these would need important changes in the diet of the cattle, but would require no additional deforestation and may even free up land for forest-based biomass production. But care should be taken that conversion of existing grassland to other land use activities does not lead to higher net emissions.

(2) Shifts from low input and rain-fed agricultural practices towards high input and irrigated crop production systems. However, the feasibility of this option would need to be assessed in specific site-conditions according to the projected evolution of water availability and other environmental impacts.

(3) Improvement of soil management practices to increase soil fertility and to recover degraded farmland soils.

These are processes underlying the increase in agricultural outputs the world has seen in the past 50 years. But in the global action case the improvement in efficiency and yields is on a truly global scale and is crucial to deliver the combination of often competing requirements. Such changes will require support from R&D, capacity building in improved agricultural practices, investment in agricultural and rural infrastructure and sometimes institutional changes, all implying strong domestic land use policies. Also development aid policies by the EU will need to further address this issue in both tropical and temperate developing countries.

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[115] Moriando M. (2011)

In conclusion, agriculture and forestry can make a substantial contribution to halving global emissions by 2050 by improving agricultural practices and eliminating deforestation, whilst also ensuring food supply and provide biomass for energy purposes. But delivering on the goals to reduce GHG emissions and increase biomass for energy and food requires continuously improving agricultural productivity. Otherwise not all goals can be met. The sector can also provide biomass for energy purposes, but the development of land based bio-energy options needs to be checked in terms of the compatibility within a wider sustainability agenda of food security and climate change mitigation.

Biomass can also contribute to mitigation if used to substitute materials that are more GHG intensive to produce. This was not assessed in this analysis.

Global action towards a 2ºC target will be beneficial for biodiversity since it limits the negative impacts of temperature increases to which natural systems would have to adapt, therefore reducing the stress on living systems. In addition, tropical deforestation is halted with clear benefits for preserving biodiversity. On the other hand this will require higher agricultural productivity on a global scale and afforestation on marginal lands which in itself could lead to negative impacts on biodiversity.

A worse outcome would be a world that does not undertake global action and where EU action and the resulting increase in bio-energy needs would lead to negative impacts from indirect land use change in other parts of the world, due to EU bio-energy imports. In part this will require monitoring of imports of bio-energy and their corresponding impacts. An important element of the solution would be a global mechanism to reduce emissions from deforestation and forest degradation, as being discussed in the ongoing international climate negotiations.

Finally, reversing trends away from more carbon intensive food consumption, such as meat consumption, can also contribute, but this has not been analysed in this impact assessment.

5.1.5. EU action and global action, the likelihood of meeting the 2ºC objective

The figure below combines the global mitigation scenarios from the POLES model for energy and industry scenarios (chapter 5.1.2) with those for agriculture and land use (chapter 5.1.4). Global GHG emissions peak between 2010 and 2020 and reduce by -49% by 2050[116].

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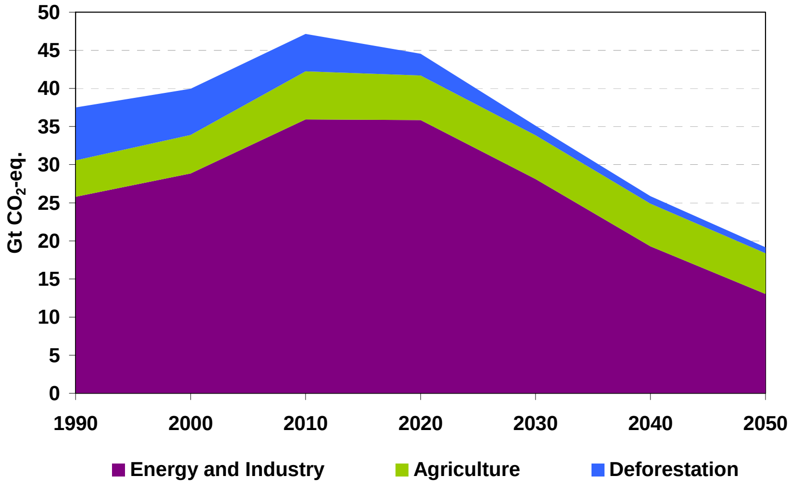
[116] If the absorptions from additional afforestation in GLOBIOM and G4M would be included then total net emissions and absorptions would see a decrease greater than 50% below 1990 levels.

Figure 16: GHG emission pathway in case of Global Action, all sectors and gases



Source: POLES, G4M, GLOBIOM

Likelihood of achieving the 2ºC objective

Figure 17 compares the emission pathways of this Global action scenario for all sectors with coloured bands that show emission pathways modelled by other Integrated Assessment Models that correspond to different temperature increases. It does so also for the Fragmented action and Baseline scenarios. It demonstrates that the Global action emission pathway, which sees global emissions halve by 2050, is in line with the 2ºC objective[117]. But the Fragmented action scenario (with the EU the only large region taking action in line wit the 2ºC objective) sees temperatures already by the end of this century increase with 3ºC or more and the Baseline even with 4ºC or more. This actually would represent a situation where the 2ºC objective is already crossed by 2050.

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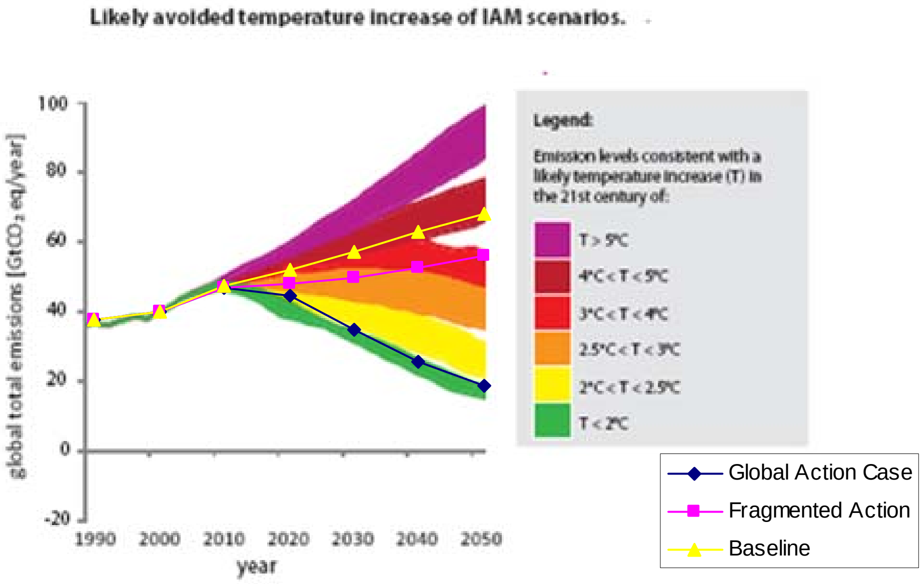
[117] This is also confirmed using the tool '2ºC Check', see http://www.primap.org/primap2Ccode/, the emission pathway is indicated to have a likelihood of around 60% to meet the 2ºC objective.

Figure 17: Temperature increases associated with emission pathways



Source: Adapted from 'UNEP, The Emissions Gap Report: Are the Copenhagen Accord pledges sufficient to limit global warming to 2 or 1.5°C?, Technical Summary, November 2010, figure 2 + total GHG emission pathways of Baseline, Fragmented Action and Global Action cases of the POLES + GLOBIOM + G4M modelling setup (JRC, IPTS, IIASA)

The current 2020 mitigation pledges, as represented in the Fragmented action scenario, do not meet the 2ºC objective. This is confirmed by a recent UNEP report[118] analysing the existing pledges under the Copenhagen Accord and concluding that these pledges represent 60% of the required reduction by 2020 to be in line with the 2° C objective[119].

5.2. Analysis of the EU perspective towards a low carbon economy by 2050

The different scenarios to achieve GHG emissions as described in chapter 4.3 are assessed in this chapter. This is done by looking at the different topics or sectors at a time, assessing impacts across projected scenarios.

5.2.1. Greenhouse gas emission reductions over time and sectoral split

Decarbonisation scenarios

The decarbonisation scenarios show that EU internal emission reductions of 80% by 2050 are feasible, if sufficiently stringent carbon price incentives across sectors can be put in place. Most of the emission reductions are enabled by changes in technology. Price-induced changes of behaviour also make a modest contribution.

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[118] UNEP 2010

[119] Assessing the high end pledges which are often conditional and assuming that no “lenient” accounting rules are applied to land use sectors, surplus emission units (AAUs) and there is no “double counting” of pledges through offset credits.

Cost-effective emissions reductions alone are around 40% by 2030, except in the case of an oil price shock which would see reductions of up to 45%. Stepping up to a low cost pathway would see decreases by 25 to 26% by 2020 and 59 to 62% by 2040.

The contributions of different sectors, in scenarios with equal carbon prices across sectors and with emissions reductions leading towards an 80% trajectory[120] is represented in the table below. For an overview of the results per sector in each scenario see annex 7.10.

Table 8: EU Greenhouse gas emission reductions overall and in different economic sectors in different decarbonisation scenarios

GHG reductions compared to 1990 in %	**2005**	**2030**	**2050**
Total	-7%	-40 to -44%	-79 to -82%
Sectors			
Power (CO2)	-7%	-54 to -68%	-93 to -99%
Industry (CO2)	-20%	-34 to -40%	-83 to -87%
Transport (incl. aviation, excl. maritime)[121] (CO2)	+30%	+20 to -9%	-54 to -67%
Transport (excl. aviation, excl. maritime)	*+25%*	*+8 to -17%*	*-61 to -74%*
Residential and services (CO2)	-12%	-37 to -53%	-88 to-91%
Agriculture (Non CO2)	-20%	-36 to -37%	-42 to -49%
Other Non CO2 emissions	-30%	-71.5 to -72.5%	-70 to -78%

Source: PRIMES, GAINS

The highest absolute and relative reductions come from the power sector. Under similar carbon price incentives across sectors, it decarbonises fast, reaching usually well above 60% emission reductions by 2030 (except in the high fossil fuel price or oil shock scenarios, which see sectors that consume a lot of oil and gas contribute more to total reductions). By 2050, decarbonisation of the power sector is practically complete (for further analysis see chapter 5.2.5).

Above average contributions in the medium and long term are achieved by the residential and service sectors, due to significant reductions in required heating from improved insulation and greater use of electricity and renewables for building heating as well more energy efficient appliances. Industry decarbonises slightly less than the overall economy in the medium term. However industry CCS opens significant further reduction options, although later than in the power sector, which in the context of global climate action are economically viable (see also chapter 5.2.7).

Transport and agriculture are the main sectors where no full carbonisation in the longer term is achieved. In transport, the increasing trend of the last 20 years is reversed, with emissions (excluding aviation and maritime transport) by 2030 getting back to levels below 1990 in most scenarios. It has also the largest range of potential reduction by 2050, depending on the degree of electrification and the level of oil prices (for further analysis see chapter 5.2.6). For agriculture the pattern is inverted. Its contributions by 2030 are significant, but then further decarbonisation steps are more difficult (see chapter 5.2.9).

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[120] i.e. covering both contexts of global and fragmented climate action but excluding scenarios with delayed action and specific treatment for industry exposed to global competition

[121] Excludes international maritime bunker fuels, includes inland navigation in the EU

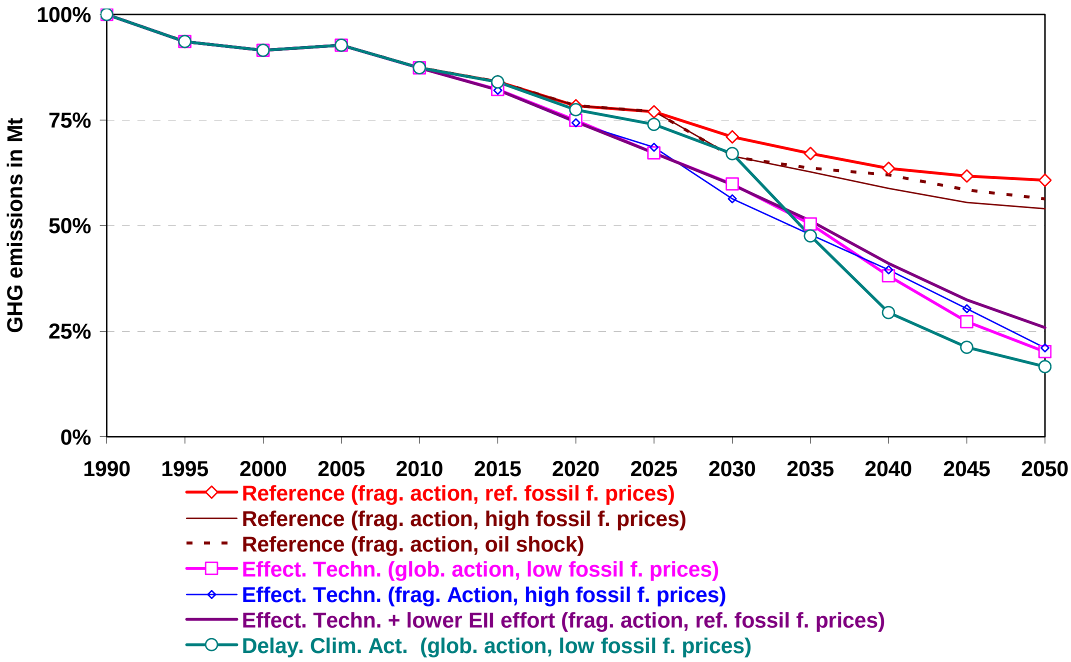
With global action, energy import prices are lower and carbon prices need to be higher to achieve the required decarbonisation. The reverse is the case for fragmented action that requires more moderate carbon prices to decarbonise because of higher energy prices (see chapter 5.2.4). However this only has a limited relevance for the sectoral split of contributions[122]. Some meaningful differences exist for those sectors that use relatively large amounts of oil and gas, like transport and buildings. With higher energy prices these sectors contribute more in the fragmented action scenarios, with corresponding lower contributions by the power sector.

Even if important mitigation options such as CCS or electric cars contributed less (delayed CCS and delayed Electrification), an EU emissions pathway leading to -80% by 2050 is still achievable. However, if several important mitigation options fail to materialise it would become very difficult to reach such low emission levels.

Figure 18 represents total GHG emissions over time for scenarios with specific pathways that differentiate from the Effective Technologies Scenario and the Reference scenario for reasons other than a different enabling for a certain technology such as the delayed electrification and delayed CCS scenarios.

As to be expected, compared to the reference case, high fossil fuel prices or an oil shock decreases emissions. But this does not decarbonise the economy to the extent seen in the effective technologies scenario. If further emission reduction policies were delayed until 2030, stronger mitigation efforts would be required to catch up afterwards. Finally, if there is special treatment for industry in the context of fragmented action, emissions are higher than the effective technologies scenario (for more details see chapter 5.2.7).

Figure 18: EU GHG emissions over time for selected scenarios



Source: PRIMES, GAINS

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[122] Of course this is not the case for the option with specific treatment for energy intensive industries, requiring less reductions from this sector in case of fragmented action.

The reduction in GHG emissions is in part achieved through the increased use of bio-energy (biomass and biofuels). In the PRIMES – GAINS model setup bio-energy is assumed to be neutral in carbon content. But bio-energy production can have an impact on the emissions or absorptions of the land use sector, typically putting pressure on the net sink that Land Use, Land Use Change and Forestry (LULUCF) is at present in the EU. For a more detailed analysis see chapter 5.2.10.

5.2.2. Greenhouse gas emission reductions in ETS and Non ETS

If currently implemented ETS and Non ETS policies are projected until 2050, sectors covered by the EU emissions trading system would provide the bulk of the emissions reductions in line with the agreed continuously decreasing emissions cap. With the applied assumptions on additional use of international credits, a significant emission reduction of nearly 50% is achieved between 2005 and 2050. Without additional policies, oil shocks or high fossil fuel prices, Non ETS sectors would only reduce slightly more than 20% compared to 2005, with contributions beyond the implementation of the existing -10% non-ETS target (by 2020) driven by the impacts of current energy efficiency and renewable heat and transport policies, continued impact of water and waste policies, as well as existing F-Gas measures.

In a decarbonised EU, with equal economic incentives across sectors, a larger contribution by the sectors covered by the ETS would continue to be cost-effective. With emission reductions of already around 45% by 2030 and around 90% compared to 2005 in 2050 in the ETS, except if high fossil fuel prices or a significant oil shock would occur which would result in less reductions in the ETS by 2050, and more in Non ETS sectors (transport, heating).

The range of the contribution in the GHG reduction scenarios[123] which lead towards -80% is shown in the following table:

Table 9: Emissions in ETS and Non ETS sectors

Reductions compared to 2005	**2030**	**2050**
Overall	-35 to -40%	-77 to -81%
ETS sectors	-43 to -48%	-88 to -92%
Non ETS sectors	-24 to -36%	-66 to -71%

Source: PRIMES, GAINS

Non ETS sectors would also contribute significantly and reduce their emissions by nearly 70% emissions compared to 2005 in 2050. By 2030 the Non ETS sector's contribution would be between 24% and 36%. After 2030 further emission reductions are in line with those of the ETS sectors. This pattern is mainly due to the limited number of short-term cost-effective reduction options in transport, while in the long term the smaller reductions are related to the limited potentials for Non CO2 emissions, in particular of agriculture (see chapter 5.2.9).

In the medium term, more than in the long term, also the relative level of oil and gas prices compared to other energy sources plays a role for the ETS/Non ETS split. For example, comparing the Effective Technologies scenarios with different oil prices, the ETS/ Non ETS contributions in 2030 are; 45%/27% in the context of global climate action with low oil prices

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[123] Covering both contexts of global and fragmented climate action but excluding scenarios with delayed climate action and specific treatment for industry exposed to global competition

and 44%/29% in case of fragmented action with reference energy prices. However, they change to 43%/36% with an oil shock or high fossil fuel prices occurring in 2030.

5.2.3. Energy resources and security of fossil fuel supply

Implemented policies already reflected in the reference scenario halt the trend of an ever increasing gross energy demand and lead to a slightly decreasing overall use of energy resources. The projected gross inland consumption is around 1770 Mtoe in 2020, around 1720 Mtoe in 2030 and around 1750 Mtoe in 2050 compared to 1826 Mtoe in 2005. This is brought about by significant increases in energy efficiency. This means that energy intensity of GDP would reduce significantly, by more than 50% in 2050 compared to 2005, but absolute primary energy savings remain limited.

In a decarbonised EU, energy consumption would change substantially. The overall use of energy resources would decrease significantly across all scenarios, reducing to 1740 Mtoe in 2020 and going to around 1650 Mtoe by 2030. Decreases would be even steeper after 2030, resulting in a projected gross inland energy consumption of between 1300 and 1350 Mtoe by 2050.

According to the impact assessment for the Energy Efficiency Plan, the effects of the crisis and implemented policies until December 2009 will deliver 164 Mtoe of energy savings compared to the 2007 Baseline, whereas full implementation of the energy savings objective would require a reduction of primary energy use by 368 Mtoe in 2020. Thus, the remaining gap to achieve the 20% energy efficiency target in 2020 is a further reduction of primary energy use equivalent to around 200 Mtoe. Translating this into additional GHG emissions reductions indicates that around a further 400 Mt CO_2 would be reduced in 2020 if the energy efficiency target is fully achieved[124], or the equivalent of a further 7% reductions of GHG emissions compared to 1990. If this is achieved on top of the GHG reductions in reference by 2020, this would enable the EU to reduce internal emissions by 25% or more by 2020.

It is important to note that these levels of reduced primary energy demand do not come from reduced activity levels. Instead they are mainly the result of technological changes on the demand side: firstly from more efficient buildings, heating systems and vehicles and secondly (most prominently in the last 2 decades to 2050) by electrification in transport and heating, which combines very efficient demand side technologies (plug-in hybrids, electric vehicles and heat pumps) with a largely decarbonised power sector. Energy intensity of GDP reduces by around 65%, resulting in significant absolute energy savings of around 30% compared to 2005.

Energy resource use is quite similar across scenarios in the context of global climate action. If important technological mitigation options like CCS or electrification contribute less, this is compensated by higher energy efficiency gains and hence still slightly lower resource use. As to be expected this effect is strongly correlated to fossil fuel prices and is enhanced in the context of fragmented climate action, in particular during oil shocks or high fossil fuel prices.

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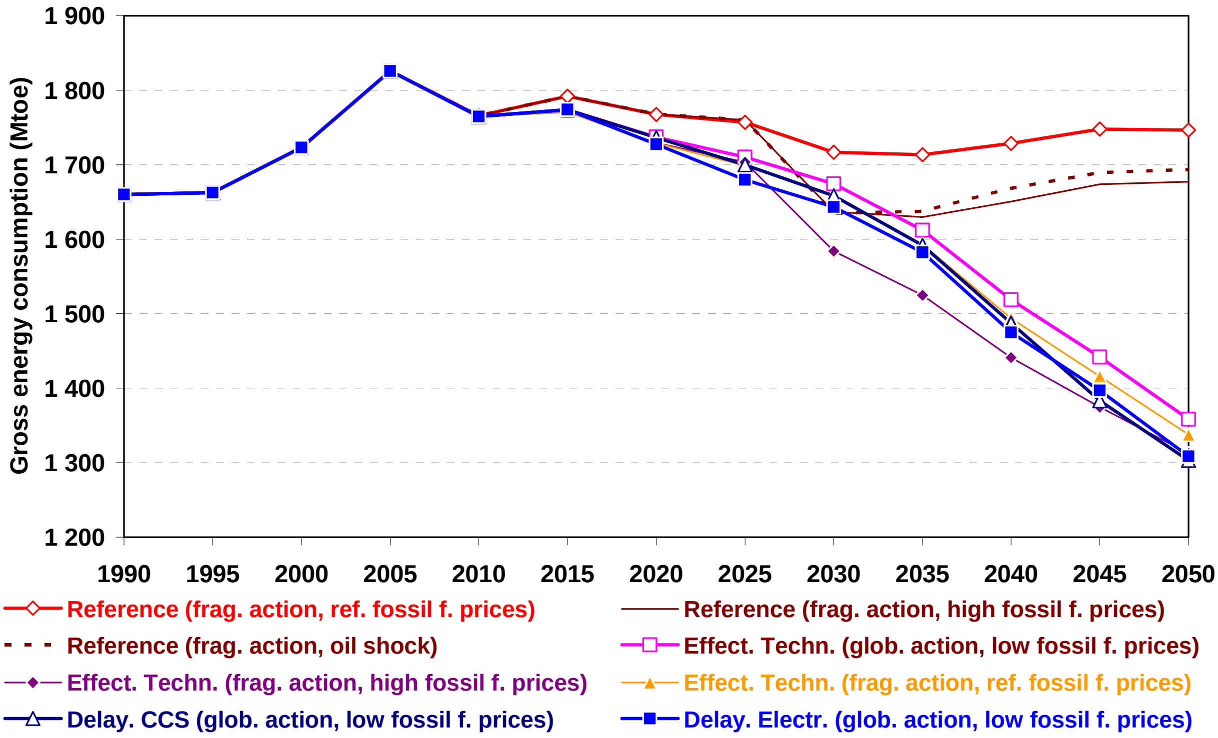
[124] 2 tCO2/toe (based on general CO2 intensity in 2020, PRIMES 2009 energy efficiency scenario, see impact assessment of the Energy Efficiency Plan, SEC(2011) 277).

Figure 19: Gross energy consumption in relevant scenarios over time



Source: PRIMES

Not only the amount, but also the composition of energy resource use would be very different in a decarbonised world. If the current energy policies are implemented and maintained net energy imports (mainly oil and gas) would continue to increase over time, reaching around 1050 Mtoe in 2050. They would need to cover an increasing share of total energy supply and the already high fuel import dependency of the EU (55% in 2008) would reach 58% in 2050.

In a decarbonised EU, security of fossil fuel supply, which is a key dimension of energy security concerns[125], would improve substantially. More domestic energy resources would be used, in particular renewables, total energy imports would more than halve compared to 2005 and be around 60% lower in 2050 than in the reference scenario. From 2025, there would be a complete reversal of the trend of fuel import dependency increases, decreasing significantly to less than 35% by 2050 (see Table 10). Of course, higher fossil fuel prices or oil shocks, as probable in the context of fragmented action, would make this pattern even more pronounced.

Table 10: Fuel import dependency across scenarios

Fuel import dependency (in %)	**2030**	**2050**
Reference (frag. action, ref. fossil f. prices)	57%	58%

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[125] It should be noted that a transition to a low carbon economy, while significantly mitigating energy security issues related to oil and gas supply, may give higher profile to energy security issues related to electricity. Demand for electricity increases, which needs to be available in exactly the demanded quantity at any time. Having much more dispersed sources of supply – also geographically - requires grid expansion, building of smart grids, demand side management, energy storage and back-up. Moreover, new forms of waste management related to remaining CO_2 emissions (CCS) need to be ensured. However, these issues are more under EU control as the oil and gas supply. The 2050 Energy Roadmap will address these issues in more detail.

Reference (frag. action, high fossil f. prices / oil shock)	52.5%	49 / 53%
Effect. Techn. (glob. action, low fossil f. prices)	52%	33%
Delay. CCS (glob. action, low fossil f. prices)	52.5%	31%
Delay. Electr. (glob. action, low fossil f. prices)	53%	34%
Effect. Techn. (frag. action, ref. fossil f. prices)	50.5%	31%
Effect. Techn. (frag. action, high fossil f. prices / oil shock)	47%	29 / 30.5%

Source: PRIMES

This changing pattern in decarbonisation scenarios is the result of a combination of energy efficiency initiatives, the use of a wide range of domestic low carbon options in power generation and the move away from fossil fuels in transport, heating and industry. For example, across the different decarbonisation scenarios renewables cover more than 50% of final energy demand in 2050. The import of oil would reduce between 65 and 70% compared to reference in 2050, while gas imports would be 36 to 43% lower. Total imports of oil and gas would decline by more than half compared to today. With an oil shock or high fossil fuel prices, oil import reductions by 2050 would still be more pronounced.

In the global action scenarios, the combined impact of lower oil and gas imports and the reduced oil and gas price would reduce our oil import bill by around 400bn € (2008) and our gas import bill by more than 120bn € (2008) compared to the reference in 2050 (see Table 11), representing together more than 2% of EU GDP in 2050, and more than halve expenses for oil imports compared to today. This is broadly in line with the findings of the POLES model (see also annex 7.8 for the POLES results).

Table 11: Imports of oil and gas and corresponding expenses in 2050[126]

Oil and gas imports in 2050	Reference	Scenarios in the context of global climate action	Change vs reference (%)
Net oil imports (Mtoe)	547	163-193	-65% to -70%
Net gas imports (Mtoe)	340	196-217	-36% to -42%
Expenses for oil imports (€bn 2008)	474	78-92	-81% to -84%
Expense for gas imports (€bn 2008)	224	65-71	-68% to -71%

Source: PRIMES

Decarbonisation will significantly reduce fossil fuel security risks. But large scale electrification combined with more decentralised generation from variable sources involves other challenges and opportunities for providing high quality energy services at any time. The 2050 Energy Roadmap will address these issues in more detail.

5.2.4. System costs: Investments, fossil fuel expenses and carbon prices

Carbon prices in the reference scenario are around 50 € per ton of $CO_{2\text{-eq.}}$ from 2030 onwards. Of course to achieve reductions well beyond the reference level, higher carbon prices are required with a range of around € 100 to €370 per ton of $CO_{2\text{-eq.}}$ by 2050 (see figure below,

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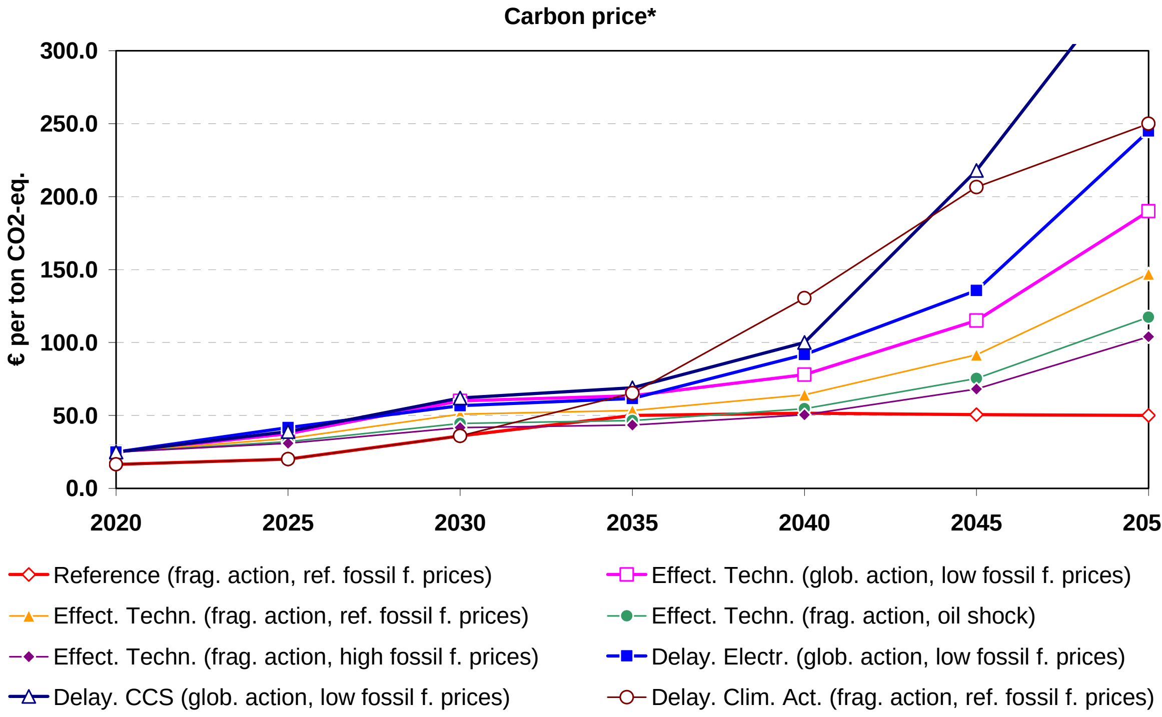
[126] For reasons of consistency with the POLES based global analysis of the impacts on EU oil and gas imports of global action (see annex 7.8) and the scope of the EU level analysis which excludes maritime bunkers, the latter are not included in the presented results. The decarbonisation scenarios covered are Effective Technology, Delayed CCS and Delayed Electrification.

for table with carbon prices see annex 7.10). In particular delayed action increases carbon prices later on, as well as those scenarios that foresee the delayed deployment of a key technology, with the delayed CCS scenario being most outspoken.

There is a clear inverse correlation between energy prices and carbon prices. Higher energy prices require lower carbon prices for decarbonisation. With fragmented action, which means energy prices roughly equivalent to those found in the reference scenario, the carbon prices remain around 20% below the level required for global action.

Figure 20: Carbon price evolution



*For reference only ETS carbon price is represented

Source: PRIMES, GAINS

The lowest carbon price needed to achieve reductions is those needed within the scenarios which include an oil crisis or high fossil fuel prices. Of course this points to the fact that pricing in general, be it through the carbon price or through energy prices themselves is an important driver to reduce emissions due to its impact on energy demand and energy efficiency. The benefit of carbon pricing clearly is that it affects those inputs and processes more which are most carbon intensive. Furthermore revenues are recycled within the EU economy. With high energy prices this is not always the case, certainly not if the high energy price is due to high import prices. If certain key technologies are delayed carbon prices increase significantly. Similarly carbon prices increase significantly if climate action is delayed by 10 years.

The combined effect of carbon prices and energy costs, including changes in fossil fuel prices, is a major driver for the type of investments that will be undertaken in the coming decades. In the reference scenario average yearly investments in all sectors[127] increase from around € 800 billion in the period 2010-2020 to around € 1000 billion in the period 2040-2050 (see Table 12). For the decarbonisation scenario this investment expenditure actually increases by 60% to an annual average just under €1600 billion in the period 2040-2050, which is an increase of just over €550 billion compared with the reference case. Cumulatively over the 40 year period this increase in investment expenditure compared to reference is less pronounced, with an average annual increase of around € 270 billion, for both the global and fragmented action scenarios, without delays in technology penetration.

Taking action on climate change directly impacts fuel consumption. In the reference scenario fuel costs increase from around € 900 billion on average per annum in the period 2010-2020 to almost € 1400 billion for the period 2040-2050. Fuel costs decrease significantly when action on climate change is taken. In a fragmented world, but with action in the EU, the reduction in fuel costs is around € 350 billion per annum in the 2040-2050. With global action, the reduction in fuel costs compared to reference is even larger, amounting to € 600 billion saved per annum in the period 2040-2050. Over the whole 40 year period average fuel costs decrease compared to reference are between € 175 and € 320 billion per annum, depending on whether fragmented or global action is realised, and provided that technology penetration is not delayed compared with the effective and widely accepted technology cases. Under delayed electricity penetration in transport average fuel cost savings would be considerably smaller.

Delaying climate action causes investment expenditure to increase by around €100 billion per annum for the 20 year period from 2030 to 2050, without comparably decreasing the investment needs before 2030. Also fuel savings are lower over time compared the effective technology scenarios, making the scenario considerably costlier.

Table 12: Average yearly total investments and fuel expenses

Total average yearly investments	**2011-20**	**2021-30**	**2031-40**	**2041-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	816	916	969	1014	929
Effect. Techn. (frag. action, ref. fossil f. prices)	863	1040	1299	1589	1198
Effect. Techn. (glob. action, low fossil f. prices)	858	1040	1309	1592	1200
Delay. Clim. Act. (frag. action, ref. fossil f. prices)	845	1011	1392	1689	1234
Total average yearly fuel expenses	**2011-20**	**2021-30**	**2031-40**	**2041-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	930	1170	1259	1376	1184
Effect. Techn. (frag. action, ref. fossil f. prices)	911	1067	1034	1019	1008
Effect. Techn. (glob. action, low fossil f. prices)	892	968	834	760	863
Delay. Clim. Act. (frag. action, ref. fossil f. prices)	922	1118	1061	993	1023

Source: PRIMES, GAINS

An oil shock or high energy prices result in a similar absolute increase in fuel expenses in case of decarbonisation or no action. But of course this price increase in case of decarbonisation starts from a significantly lower level of fuel expenses than the case where no action was undertaken. This results in fuel expenses over the period after 2020 in case of decarbonisation that remain on average at the levels below or a bit above the original

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

reference case, whereas in case of no climate action these average annual fuel expense increase in a range € 100 (oil shock) to 300 billion (long lasting high prices) on average.

An oil shock or high fossil fuel prices increase the required average investment expenditure after 2020 on average by about € 100 billion per year in case of no action on climate change, however in the decarbonisation scenarios this additional increase is not detectable (see Table 13).

Table 13: Average yearly total investments and fuel expenses in scenarios with an oil shock or high fossil fuel prices

Total average yearly investments	**2011-20**	**2021-30**	**2031-40**	**2041-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	816	916	969	1014	929
Reference (frag. action, oil shock)	813	983	1012	1207	1004
Reference (frag. action, high fossil f. prices)	813	981	1029	1213	1009
Effect. Techn. (frag. action, ref. fossil f. prices)	863	1040	1299	1589	1198
Effect. Techn. (frag. action, oil shock)	863	1119	1258	1538	1194
Effect. Techn. (frag. action, high fossil f. prices)	863	1116	1295	1559	1208
Total average yearly fuel expenses	**2011-20**	**2021-30**	**2031-40**	**2041-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	930	1170	1259	1376	1184
Reference (frag. action, oil shock)	930	1323	1510	1360	1281
Reference (frag. action, high fossil f. prices)	930	1323	1700	1735	1422
Effect. Techn. (frag. action, ref. fossil f. prices)	911	1067	1034	1019	1008
Effect. Techn. (frag. action, oil shock)	911	1204	1281	1087	1121
Effect. Techn. (frag. action, high fossil f. prices)	911	1205	1421	1325	1215

Source: PRIMES, GAINS

Taking action on climate change results in significantly lower fuel expenses compared to investment cost increases in case of global action. This is not the case with only fragmented action globally where more limited reductions in fossil fuel expenses do not fully compensate the investment increases. But this reverses with an oil shock. In case of permanently high oil prices, increases in investment expenditure for climate action are more than compensated for by the reduction in fuel costs over later periods compared to a situation that no action was undertaken.

Costs are thus highest in the case of no action and with high fossil fuel prices and costs are lowest in case of global action on climate change. In contrast to taking no additional action, investing in for instance carbon low buildings and transport in the EU can shield the economy against the worst effects of high energy prices with significantly less costs related to fossil fuel imports.

Costs can increase also if certain technologies are not sufficiently available at competitive costs or if action itself is delayed.

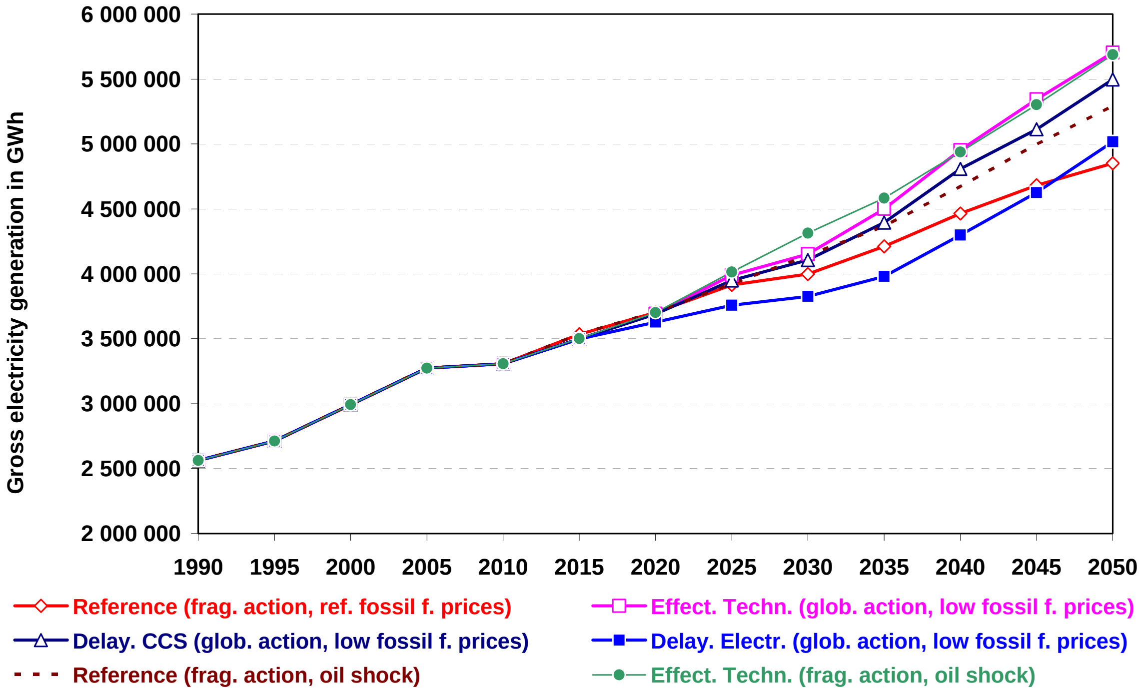
For a more detailed discussion on the separate sectors, see annex 7.11. It is of particular interest to see the relative differences within each sector, that are often more pronounced than the total aggregate data[128]. For more detail on the energy intensive industrial sectors see also chapter 5.2.7.

5.2.5. Sector specific impacts: power

Gross electricity consumption shows a different pattern to the described evolution of gross energy consumption (see chapter 5.2.3). It is projected to continue to increase in all scenarios, albeit for partly different reasons. Hence the importance of the power sector for achieving emission reductions becomes even more important than it is today.

Figure 21 below gives an overview of electricity consumption over time for different scenarios.

Figure 21: Gross electricity consumption in relevant scenarios



Source: PRIMES

In the reference scenario electricity consumption increases by 50% in 2050 compared to 2005, continuing trends observed in the past decades, due to increasing wealth, demand for comfort and more use of electricity in transport (e.g. hybrid cars, electrified railways and metros) and buildings. In the decarbonisation scenarios, carbon pricing leads to higher incentives for electricity savings. However this electricity saving element is overcompensated by:

- Incentives to further electrify demand sectors to reach ambitious emission reductions. For example, gross electricity consumption in 2050 in the Effective Technologies scenario than in the Delayed Electrification scenario and is around 850 TWh higher than in the reference scenario. Plug-in hybrid cars, electric cars and greater use of heat pumps drive this increase

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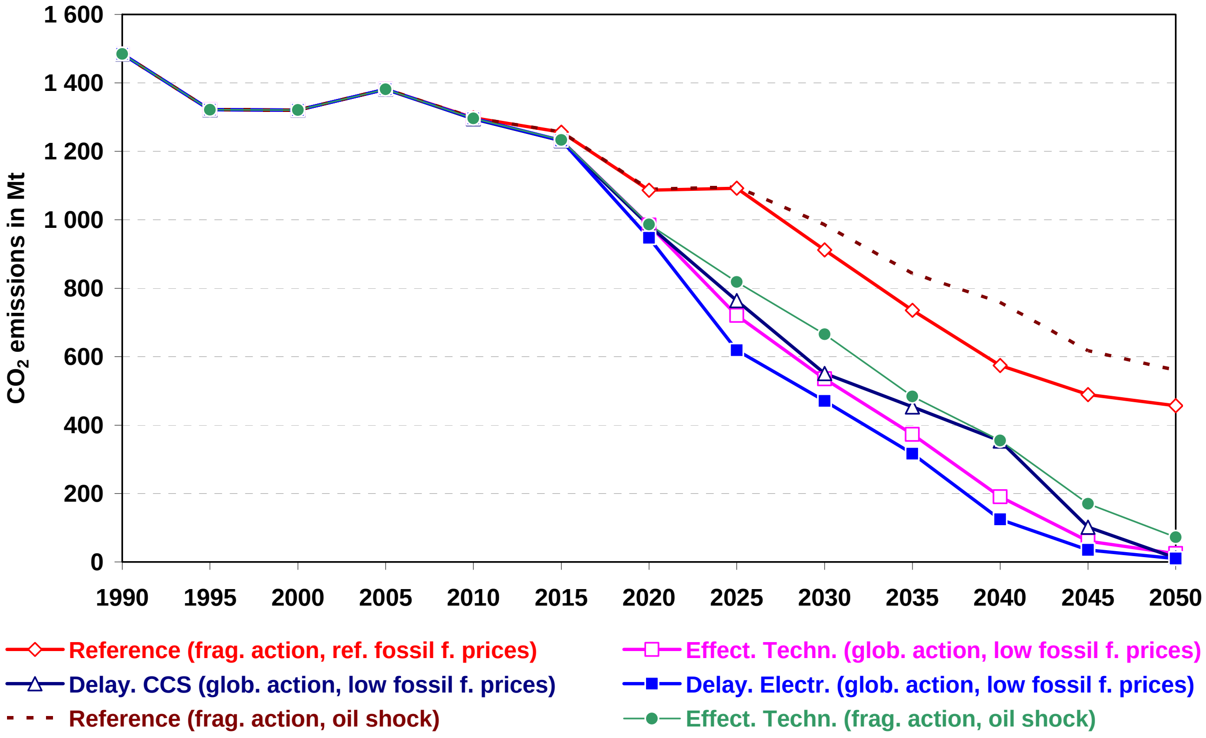
[128] Normally the investments relate to energy part of the investment, not the capital good as a whole. This is not the case for transport and power where the given investment projections relate to the whole capital good. Transport as such represents by far the largest part of investments.

in electricity demand. Delays in transport electrification would result in only moderate electricity demand increase over reference (about 150 TWh) in 2050.

- The higher electricity use of some low carbon technologies (e.g. CCS). For example, the Delayed CCS scenario requires in 2050 around 200 TWh less electricity than the Effective Technologies scenario that has more CCS.

All scenarios project that the power sector is able to cope with ambitious decarbonisation requirements even under conditions of increasing power demand, as Figure 22 shows.

Figure 22: CO2 emissions from power and steam generation and district heating



Source: PRIMES

The cost effective reduction contribution of the power sector exceeds 95% compared to 1990 in most scenarios, hence a more or less complete decarbonisation takes place. For the intermediate time horizon of 2030, this translates into reductions of more than 60% (except in the cases of oil shocks or high fossil fuel prices, resulting in reductions a bit above 50%). Emissions of power plants and district heating are down -64% compared to 1990 in the Effective Technology scenario and -68% lower in the case of delayed electrification due to lower electricity demand from transport and therefore higher emissions in that sector. Under the current trends of the reference case, emissions in 2030 would decrease by less than 40%.

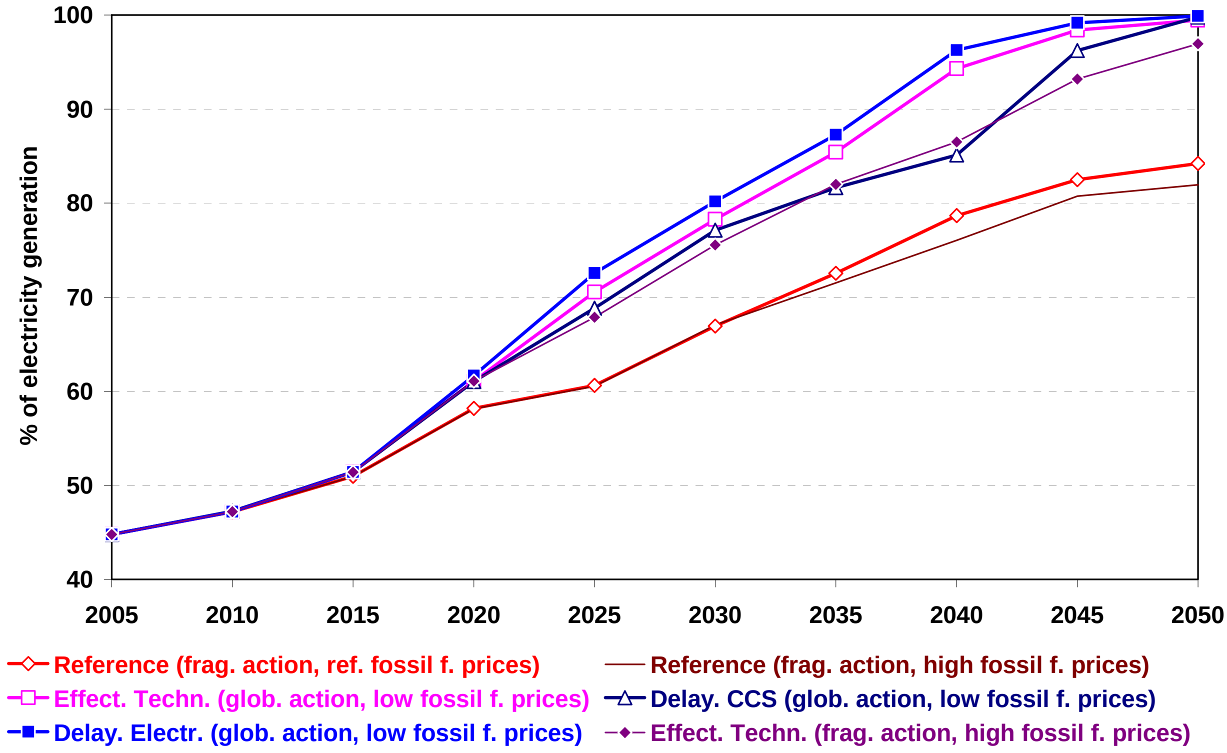
This high rate of decarbonisation of power generation is also the most important driver for the higher reductions in the ETS compared to the Non ETS (see also chapter 5.2.2) and an important driver for improvements in air quality (see also chapter 5.2.14). Furthermore there is a linkage between emissions levels in the transport and power sector for the decarbonisation of the economy. To achieve 80% GHG emission reductions, higher electrification of the transport sector reduces emissions in transport and allows less absolute emission reduction in the power sector and vice versa. See chapter 5.2.6 for further information.

The three main low carbon technologies in the power sector are

- Renewables
- Nuclear
- CCS equipped fossil fuel plants

Near complete decarbonisation is mainly achieved by the combination of these different low carbon technologies, which mainly driven by increasing carbon prices together increase their share in total electricity production from around 45% in 2005 via 75 to 80% in 2030 to practically 100% in 2050 in all scenarios (see Figure 23). Of these three technologies, renewables become the largest source of electricity, seeing its share increase from 15% of electricity production in 2005 to around 50 to 55% 2050, which represents an absolute growth of around 500% reaching 2.7 to 3.0 TWh by 2050. However, the projected shares of single low-carbon technologies should be taken with some caution, in particular given the uncertainty of individual technological progress rates and the difficulty in instigating a possible complete change of the organisation of the power network, which would also enable higher renewable shares than those represented in the modelling[129].

Figure 23: Share of low carbon technologies in power generation



Source: PRIMES

Another difference between the decarbonisation scenarios in the context of global climate action relates to the role of CCS. If the contribution of CCS is lower and comes later, the cost-

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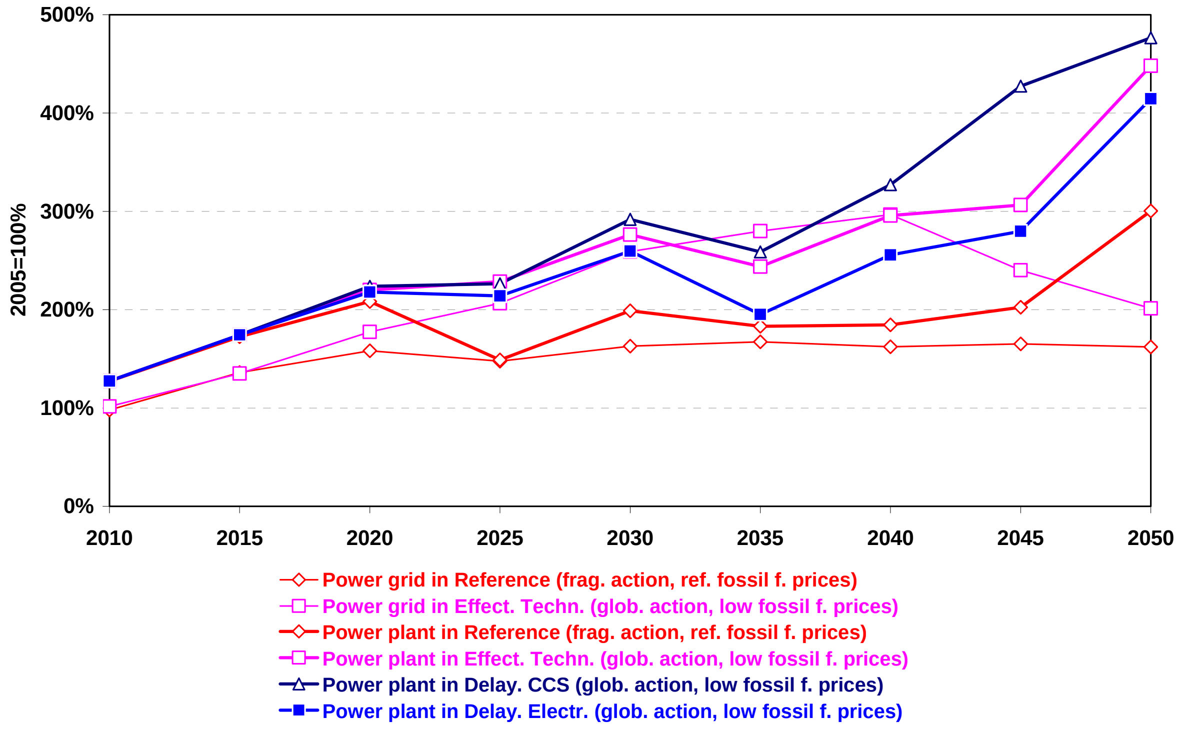
[129] Further developments of the PRIMES model should enable an improved simulation of how grid capacity issues relate to deep decarbonisation scenarios.

effective contributions of other sectors are higher along the pathway. However, carbon prices become significantly higher towards 2050 in this case. This illustrates also the important role of R&D and innovation for a shift towards low carbon technologies at lowest possible costs. But even in the delayed CCS scenario decarbonisation is near complete by 2050 due to the availability of other cost-effective low carbon options in combination with a delayed but still significant CCS contribution

In the context of fragmented action with higher fossil fuel prices or even oil shocks, power demand remains very similar. The corresponding CO2 emissions reduction contribution required by the power sector would then be slightly lower, as shown in Figure 24. The reason for this is that higher fossil fuel prices or oil shocks induce higher contributions from transport and heating.

This significant decarbonisation of the power sector would be achieved with continuously increasing investment expenditures. However, as pointed out in chapter 5.2.4 this increase is less in absolute terms than for instance in the transport, residential and tertiary sectors. The pattern also differs over time for grid investments and power plant investments (see figure below).

Figure 24: Power investments over time



Source: PRIMES

Cumulative investment into the grid from now until 2050 in the reference scenario is projected to be €1.3 trillion and would need to increase to between €1.6 and 2 trillion in the decarbonisation scenarios. The steady increases needed up to 2020 in the reference scenario would need to continue in the decarbonisation scenarios, with this value tripling by 2040 (when compared to 2005), when grid investments would eventually start to decrease and move towards reference levels.

Additional electricity generation plant investments will be needed in the decarbonisation scenarios compared to the reference scenario, reaching cumulatively €2.2 to 2.6 trillion compared to €1.7 trillion in the reference case (excluding CHP). The pattern is similar as for grid investments up until 2040, reaching triple the investment level of 2005, but investments needs further increase after 2040 to 400-450% of 2005 value. As to be expected, delayed electrification requires the lowest amount of power plant investments, while delayed CCS requires the highest cumulative amount.

The impact of decarbonisation in the Power sector will be further assessed in detail for the 'Energy roadmap 2050' which is planned by the Commission for later in 2011.

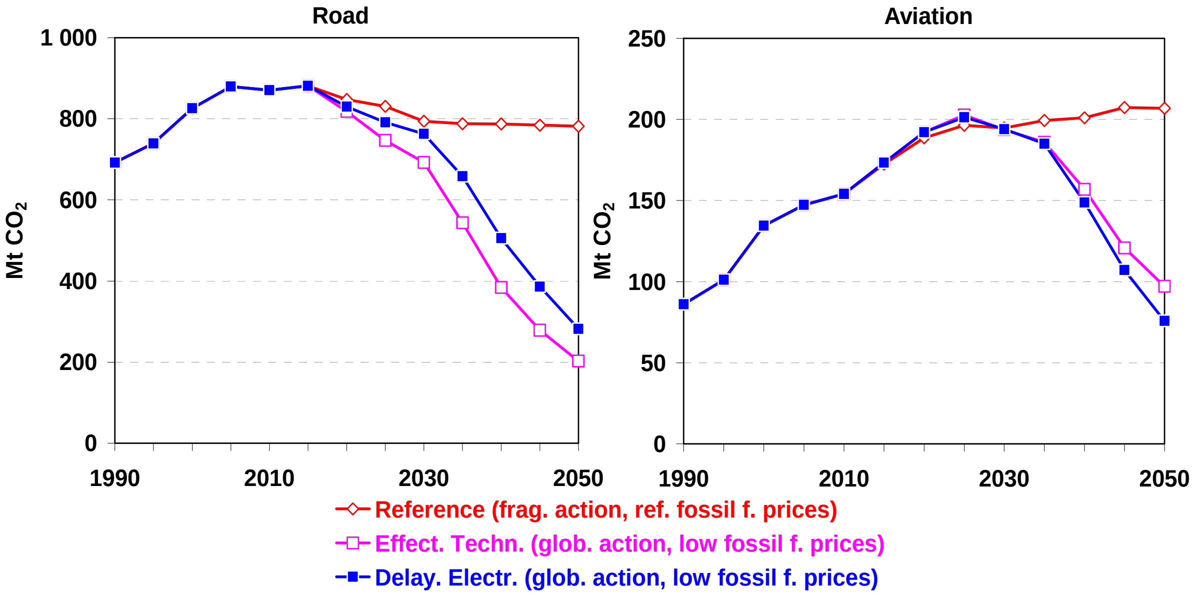
5.2.6. Sector specific impacts: transport

In the reference scenario the total transport CO_2 emissions (excluding maritime bunkers) peak in 2015, decrease to the level of year 2000 by 2030 and stay roughly constant afterwards (see Figure 25 for details on road and aviation). Increased transport activity in the reference scenario is mainly offset by improvements in efficiency. This is in large due to the effect of currently implemented policies on vehicle efficiency (for road transport the CO_2 and Cars Regulation, for aviation the carbon price signal due to the inclusion in the ETS).

In the decarbonisation scenarios analyzed CO_2 emissions reduce significantly in total transport emissions (including aviation, excluding maritime bunkers), in the range of 54 to 70% in 2050 compared to 1990. This translates to the reduction of 65 to 77% in 2050 when compared to 2005.

In 2030 transport emissions (road, rail and inland navigation) are reduced below 1990 levels for all scenarios except those with delayed electrification or delayed action. Emissions from transport (road, rail and inland navigation) reduce back to levels below 1990 with a range of +8% to -17%, with the effective technology scenario at reference prices achieving -5% and the effective technology scenario with low energy prices -2%. %. Including aviation emissions, the reductions would result in emission levels in a range of +20% to -9% by 2030, relative to 1990.

Figure 25: CO$_2$ emissions from transport



Source: PRIMES

Energy efficiency is one of the major contributors to decarbonisation of transport. For instance the average energy efficiency of passenger cars in 1990 was 43.9 toe/Mpkm. By 2050 this improves to 23.9 in the reference scenario and in the Effective Technology scenario it further goes down to 13.6 toe/Mpkm. This is achieved through gradual efficiency improvements of internal combustion engines and subsequently gradual hybridisation leading eventually to high penetration rates for electric propulsion vehicles (such as for example plug-in hybrids and electric vehicles).

The extent of the contribution of electric vehicles, which would have important co-benefits with regard to air pollution (see chapter 5.2.14) is of course dependent on a quick overcoming of barriers to the further development and cost reduction in particular of battery technology. It also assumes availability of the necessary rare materials.

In case of delayed and less widespread electrification, the specific fuel consumption in 2050 is higher (lower efficiency), 19.2 toe/Mpkm, due to a higher remaining share of internal combustion engines. Moreover, carbon prices necessary to achieve decarbonisation are significantly higher. This shows the importance of R&D and innovation in key low carbon technologies for a low cost pathway.

Biofuels are also important to further decarbonise transport but do not result in similar efficiency improvements to electrification.

Growth of biofuels for road transport in the effective technologies scenario is largest before 2020 due to the 20% overall renewables target and the specific 10% renewables target for transport, but after 2020 growth stagnates compared to reference (see Figure 26). In 2050 around 46 Mtoe of biofuels would be used for road transport in case of decarbonisation compared to 37 Mtoe in the reference scenario. Increases are mainly due to an increase in the use of biofuels for heavy duty vehicles. If electrification of road transport is delayed this modest growth after 2020 cannot be kept because biofuels would also be used much more in passenger road transport. This would result in total consumption of biofuel in road transport by 2050 equal to 92 Mtoe.

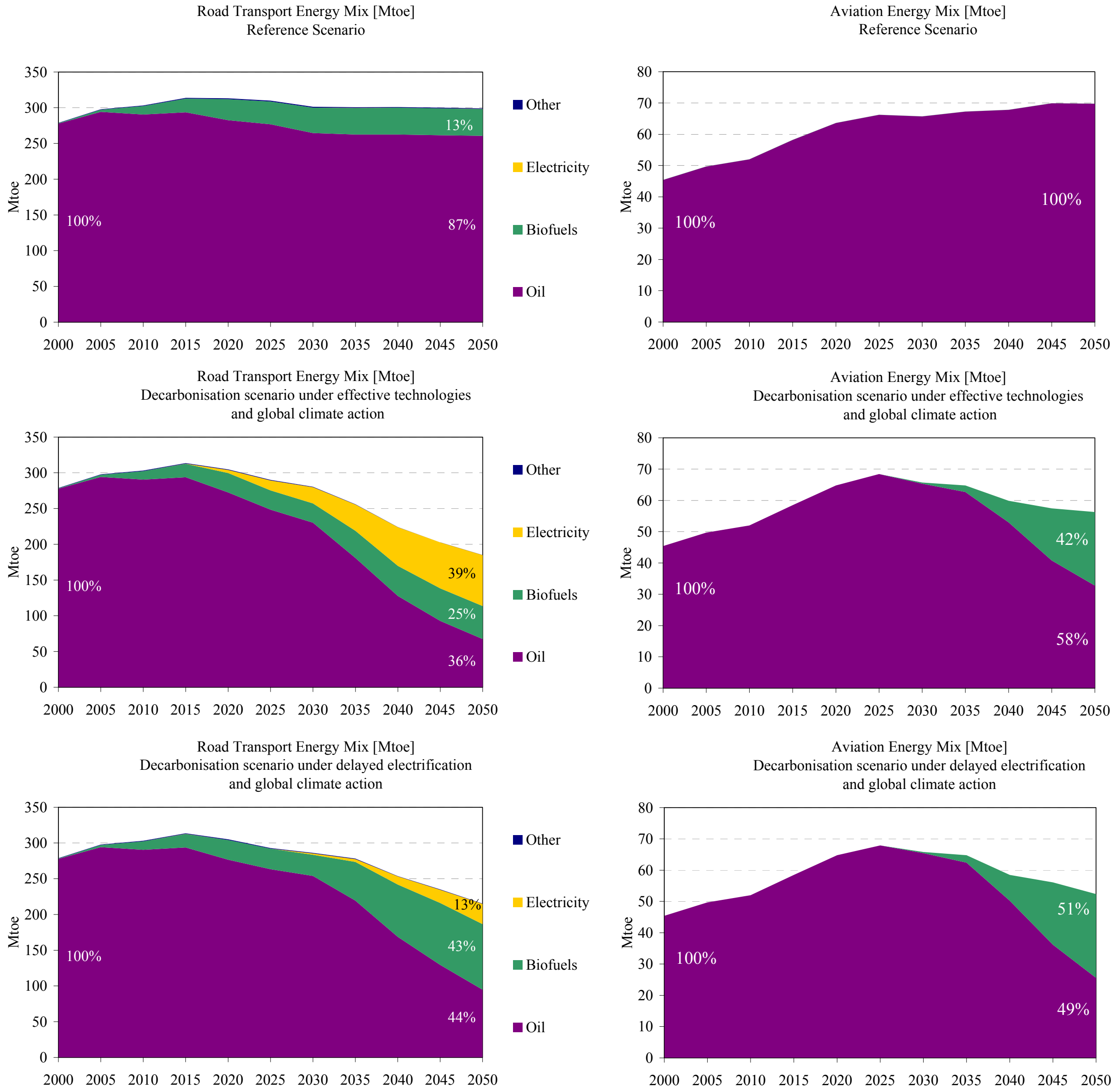
In the aviation sector electrification is not an option, resulting in all decarbonisation scenarios in high growth of biofuel use after 2030 with consumption in 2050 at around 25 Mtoe.

It should also be noted that the modelling did not include the possibility of hydrogen and fuel cells to step in for instance in heavy duty vehicle transport.

This shift translates into an increasing share of aviation in the transport CO_2 emissions. In the reference scenario, the share of road transport sector on the total transport CO_2 emissions decreased from 84% in 2005 to 77% in 2050 and in scenarios with decarbonisation this decreases further to around 65% in 2050 (with exception of delayed electrification where it is around 76%). The share of aviation increases from 14% in 2005 to 20% in 2050 in reference scenarios, but in the decarbonisation scenarios the share of aviation increases to around 31%. In all scenarios, the combined share of aviation and road transport accounts for more than 95% of CO_2 emissions from transport (total excluding maritime bunker fuels). Rail transport is almost totally decarbonised by 2035 (via electrification).

Passenger transport can decarbonise more than freight transport, with passenger transport reductions in the range 69 to 76% compared to the reference scenario, whilst for freight transport reductions are only 54 to 65% compared to the reference scenario.

Figure 26: Energy carriers in the transport sector

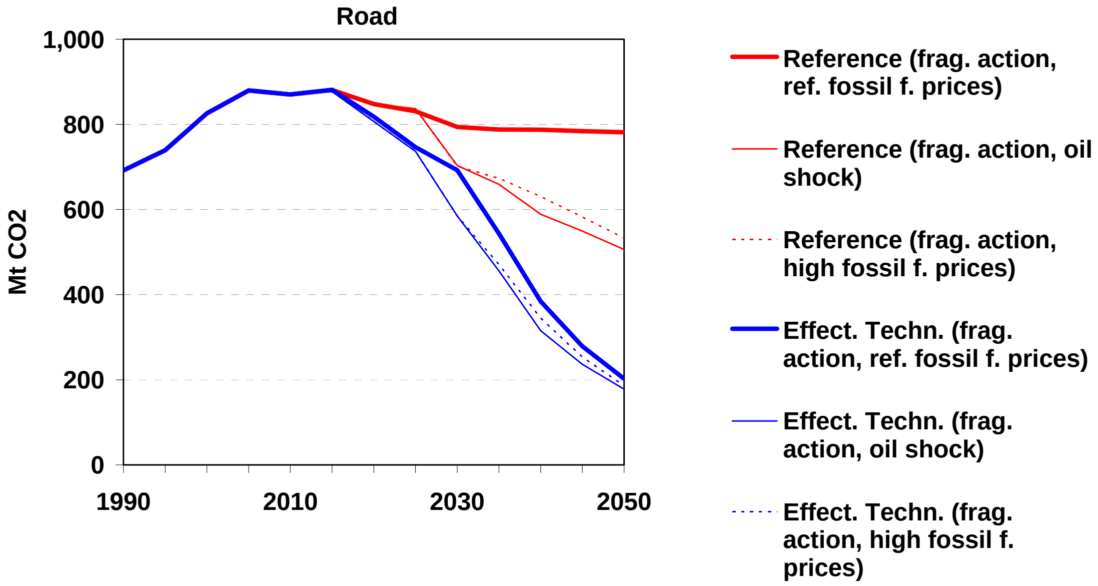


Source: PRIMES

The impact of an oil shock or high fossil fuel price scenario on transportation emissions is much more pronounced in the reference scenarios than it is in the decarbonisation scenarios. Decarbonisation reduces dependency on oil in transport and thus makes the system more robust to changes in oil price.

With an oil shock or high fossil fuel prices road transport reduces CO_2 emissions between 32 and 35% by 2050 compared to the reference scenario without an oil shock or high fossil fuel prices. In the scenario with decarbonisation the impact of an oil shock or high fossil fuel prices is however limited.

Figure 27: CO$_2$ emissions from transport, impact of an oil shock



Source: PRIMES, GAINS

There are only minimal impacts in all the scenarios analysed on the total passenger transport activity in the EU27, measured in passenger-kilometres (pkm). This is in part due to the modelling framework that focuses on GHG reductions and does not include specific transport polices to reduce different kinds of externalities, such as congestion and air pollution which can have effects on demand and produce modal shifts that can lead to additional co-benefits in terms of emission reductions. These aspects are dealt with in more detail in the impact assessment of the White Paper on Transport.

Passenger transport increases in the reference scenario by 94% between 1990 and 2050, decarbonisation causes limited reduction in this increase. In the worst case, the scenario with decarbonisation and a high fossil fuel prices at the same time passenger transport activity increases by 82% by 2050 compared to 1990, only slightly lower than the increase in the reference scenario with the high fossil fuel prices (84% increase).

In a world with global action and low energy prices, activity might even increase slightly more by 99% compared to 1990. By then, the fuel costs represent relatively a lower share of passenger transport costs, while capital costs for electrified cars themselves are higher.

Public road and rail transport is projected to have higher passenger activity in all scenarios compared to reference scenario. Public road transport in reference scenario sees an increase of 26% compared to 1990, while this increase is around 57% with decarbonisation. For rail the increases are 62% and around 114% respectively.

But even these high increases do not significantly change the overall share of cars in passenger transport compared to the reference scenario. Passenger cars reduce their share from 73% in 2005 to around 64% in decarbonisation scenarios.

The average annual distance travelled per person in the EU27 increases from around 10 000 km in 1990 to just below 13 000 km in 2005 and to more than 18 000 km in 2050, with very small variance between scenarios in 2050 (range -3% to +3% difference); with exception of the oil shock or high fossil fuel price scenarios, where it decreases by 5% to 6%.

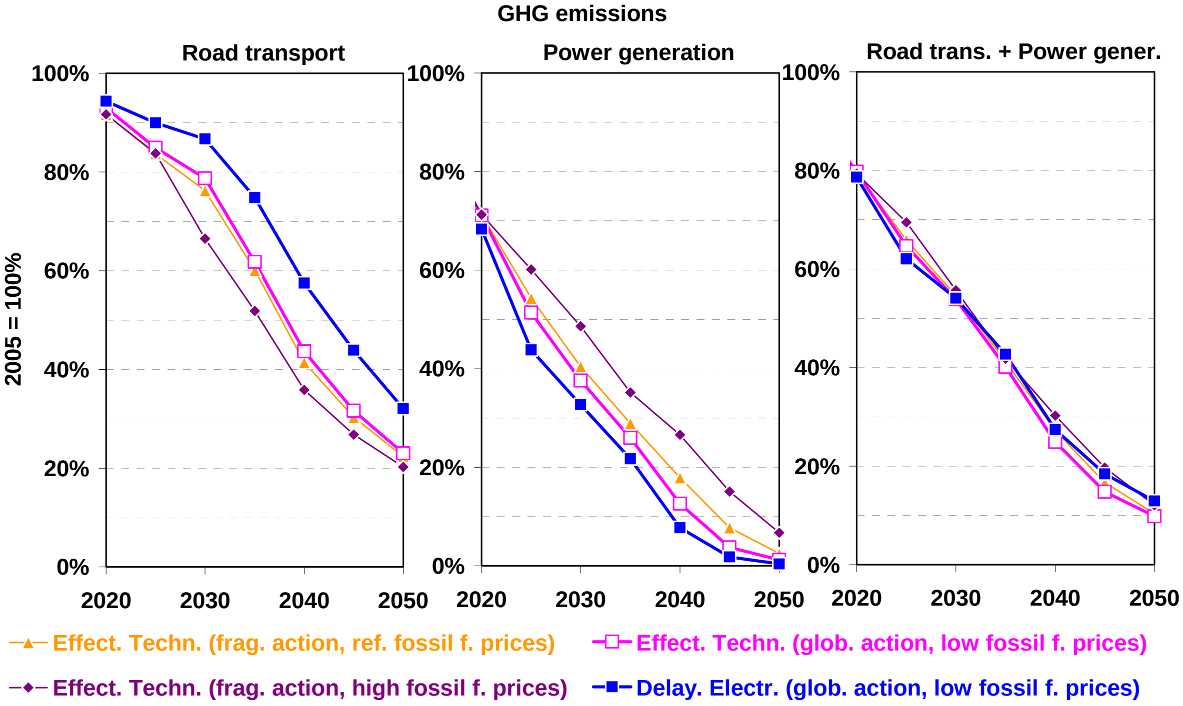
The total freight transport activity, measured in tonne-kilometres (tkm) in 2050 decreases by 1% to 7% in scenarios compared to the reference case, however it still grows by 93% to 106% when compared to 1990 levels (+109% in the reference case). When the scenarios are compared to the reference case in 2050, freight activity on rail is higher by around 28%, on inland waterways is increased by around 14% and freight transport on road decreases by 10% to 15% (in cases with higher oil prices by up to 20%).

There is a strong correlation between what can or should be done in the transport sector, and what can or should be done in the power sector if the economy is to be decarbonised, i.e. reduce GHG emissions with around 80%.

In the case where emissions are highest in the road transport sector (i.e. delayed electrification) emissions in the power sector are at their lowest. And conversely in scenarios where emissions are lowest in the road transport sector (i.e. effective technologies with an oil shock or high fossil fuel prices), emissions in the power sector are at their highest (see Figure 28). This is due to the impact of electrification itself on both the emissions in the transport sector (a lowering effect on emissions) as well as the power sector (an increasing effect on emissions due to the increased demand for electricity).

The sum of emissions from both sectors follows a rather consistent path towards decarbonisation, independent of the scenario chosen. This has implications for the ETS. The ETS sets a fixed reduction target over time for the sectors involved and includes most emissions of the power sector. However in the future all ETS sectors will be impacted by developments in the transport sector, such as electrification, even if the road transport sector is not part of the ETS.

Figure 28: CO_2 emissions from road transport and the power sector in case of decarbonisation



Source: PRIMES

5.2.7. Sector specific impacts: industry

Energy intensive sectors

Industry emitted 20% of the EU's CO_2 emissions and 18% of the EU's GHG emissions in 2005. Of this, 80% were emitted by the 5 energy intensive industries represented separately in the PRIMES model. These are iron and steel, non-ferrous metals, chemicals, non-metallic minerals and the paper and pulp industries.

These 5 industrial sectors contributed 5% to the total value added of the EU economy. They are projected to continue to grow in the reference and decarbonisation scenarios, although in line with historical trends at slightly lower rates than other industrial sectors. Nearly two thirds of their CO_2 emissions are related to energy combustion and a bit more than one third is generated as by-product of various non-energy-related industrial processes (in particular iron and steel, cement and some chemicals).

In addition there are also industrial non-CO_2 process emissions which will be covered to a large extent by the EU ETS from 2013 (see also chapter 5.2.9). These non-CO_2 emissions are expected to reduce rapidly when they are introduced to the ETS, because cheap abatement technology is available, leading to a reduction of some 50Mt of emissions by 2020, reducing them to very low amounts (see also Figure 31 in chapter 5.2.9)[130]. Therefore the focus for further decarbonisation in these sectors remains the industrial CO2 emissions.

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[130] For a more detailed analysis see Höglund-Isaksson et al. (2010).

Energy intensive industries are covered by the EU ETS, but a large range of sectors and subsectors currently benefits from free allocation. This is reflected in the reference scenario reflecting current trends and policies.

The main projected results for the reference scenario are significant increases in energy efficiency per GDP and significant decreases in CO2 emissions of energy intensive industries, continuing the historically observed trends. Energy intensity (energy demand per value added) decreased by 32% by 2005 compared to 1990 and is projected to decrease by 53% by 2030 and by 62% by 2050 compared to 1990. In trends consistent with these energy efficiency increases the CO2 emissions of energy intensive industries already decreased by 18% in 2005 compared to 1990 and are projected to decrease in the reference scenario by 30% in 2030 and by 33% in 2050 compared to 1990.

In the decarbonisation scenarios the cost-effective contribution of energy intensive industries in the Effective Technology scenario would increase to around 35% emission reductions in 2030 and between 85 and 90% in 2050, indicating very similar reduction potentials as for overall CO2 emission reductions (see also chapter 5.2.1 on the contributions of different sectors and Table 14 below). These potentials are a combination of further energy intensity decreases, nearly 75% in 2050 compared to 1990, and the application of CCS for the remaining energy intensive industrial CO2 emissions from 2035 onwards.

Table 14: CO2 emission reductions in energy intensive industries in 2030 and 2050

% emission reduction in 2030/ 2050 compared to 1990	***Reference***	**Effective Technologies scenarios**		
		global action, low fossil fuel prices	**Fragmented action, reference fossil fuel prices**	
			No special treatment EII	**Lower EII effort**
Total CO2 emissions all sectors	*-24/-37%*	*-36/-85%*	*-37/-86%*	*-37/-78%*
CO2 emissions Energy intensive industries	*-30/-33%*	-34/-88%	-34/-87%	-31/-51%

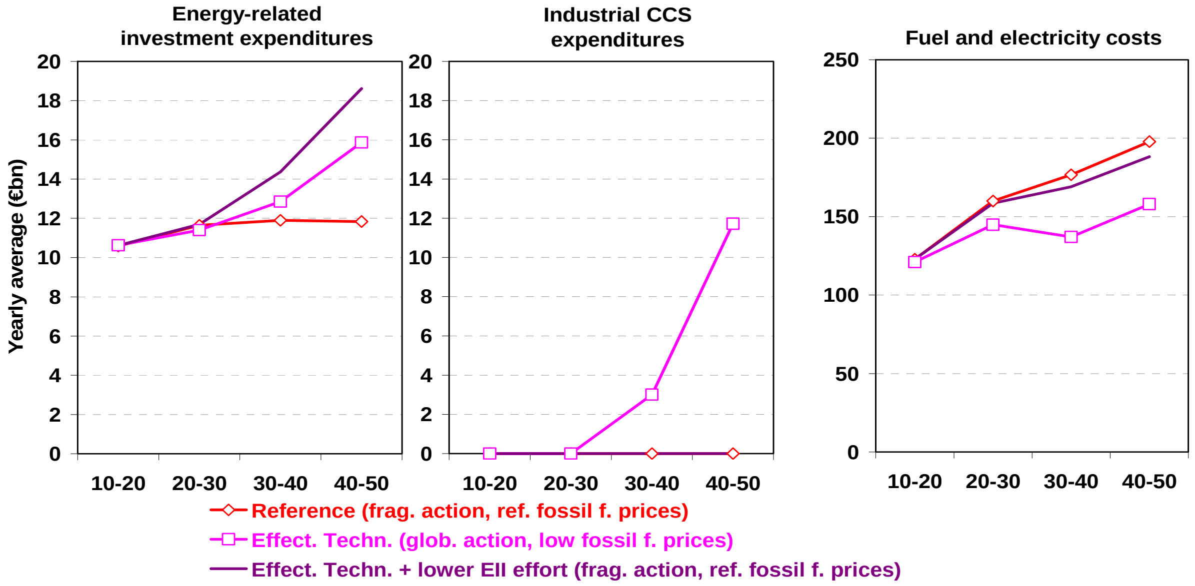
Source: PRIMES, GAINS

In the fragmented action scenario with the EU reducing emissions significantly more than other countries, certain industries supplying low carbon technologies will benefit from improved competitiveness due to higher internal demand and first mover advantages in low carbon technologies to the extent that other world regions will follow climate action or further invest in their energy security. However, for energy intensive industries it would be difficult to realise the described reduction potentials without affecting the economic competitiveness of a large part of these subsectors, in particular if reductions would need to be achieved with CCS, which is a technology that has no other real benefits than reduced GHG emissions.

An alternative scenario is therefore analysed where energy intensive industries would be subject to lower emission reduction requirements. This is simulated by keeping the same carbon prices as in the reference case. This scenario is referred to as the 'Effective Technology with reference energy prices and less efforts for industry' (for results see last column Table 14). In this case industry emissions stay closer to the reference scenario results, producing emissions reductions of around 50% compared to the 86% reductions without the exemptions, mainly because CCS would then not become a mainstream technology for process related emissions.

Results of this scenario for investments in the energy intensive sector, fuel and electricity expenses and CCS expenses are shown in the figures below and compared with Reference and with the Effective technologies Scenarios (with Global Action)[131].

Figure 29: Energy-related investments, fuel and electricity costs and industrial CCS expenditures



Source: PRIMES, GAINS

In the Effective Technology scenario with global action CCS costs are a significant factor, as this is the key technology to achieve very low emissions for certain process related CO_2 emissions. These investments would be driven by a high carbon price. As demonstrated in chapter 5.1.1, global action would mean that other regions would also be subject to similar carbon prices, therefore carbon leakage is not likely to be a problem.

It is however unlikely that these high costs could be borne in a world of 'Fragmented Action', even more so because CCS does not have important co-benefits such as efficiency improvements and reduced fuel costs. In the 'Effective Technology with reference energy prices and less efforts for industry' scenario these investments would not happen. Fuel and electricity costs are reduced compared to the reference scenario but are much higher than in the effective technologies scenarios with global action because of higher energy prices in fragmented action. Fuel and electricity cost increases in the reference and decarbonisation scenarios over the period 2010 -2050 but remain between 1 to 3 percent of total value added of the energy intensive sectors.

An alternative to this approach would be to keep emission reductions at the same level and to protect energy intensive industries by other means. This would imply that energy-intensive industries would require support to compensate for additional costs incurred. After 2030, these annual costs would quickly entail several € billions per year, up to more than € 10 billion on average in the last decade.

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[131] New investments in combined heat and power are included in the power sector.

Impacts on production of energy intensive industries compared to reference of more ambitious action, even if other don't do more than their Copenhagen pledges, up to 2030 were estimated using a macro-economic modelling tool as discussed in chapter 5.1.3 on the macro-economic impacts. For detailed results see Table 7. Overall impacts are limited in 2020, and become a bit larger by 2030 when the EU would reduce emissions by 40%. The results also confirm that free allocation protects energy intensive industry in the ETS, even if the EU would implement more ambitious targets in a world where other regions have more limited ambition.

Impact on total industry

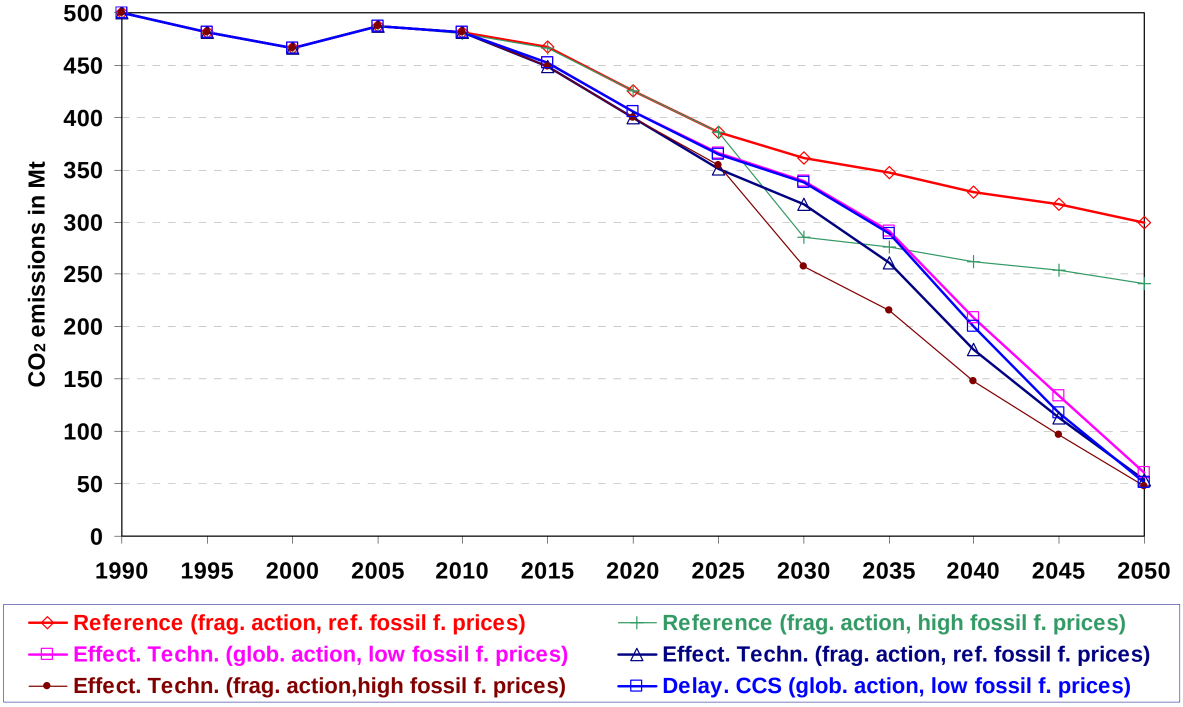
The 5 energy intensive sectors described above take a large part of investments and costs of industry as a whole related to energy. Roughly half of the 2/3rd of investments in energy related capital comes from these 5 industries. For a description of the impact on investments, fuel and electricity expenses of industry as a whole, see annex 7.11.

5.2.8. Sector specific impacts: the built environment

The residential and service sectors contribute above average to emission reductions, as shown in Table 8, chapter 5.2.1. More than 70% of those emissions come currently from the residential sector, and this proportion is projected to be rather stable until 2050.

Figure 30 shows residential emissions over time across a selection of scenarios. In the reference scenario, residential CO2 emissions decrease in 2030 by 25% and in 2050 by nearly 40% compared to 2005 (exactly 40% compared to 1990). These decreases are to a significant extent driven by EU and national energy efficiency legislation. In the decarbonisation scenarios, residential emissions decrease by nearly 90% across all scenarios in 2050 compared to 2005. Clearly higher fossil fuel prices in the context of fragmented climate action lead to higher emission reductions by 2030 in this sector.

Figure 30: Residential emissions over time



Source: PRIMES, GAINS

Currently, two third of the energy use in the residential sector is related to building heating and cooling, more than 20% to water heating and cooking and slightly more than 10% to electrical appliances and lighting. Heating and cooling remains the most important component but its share decreases to less than 60% of residential energy use by 2050. Electrical appliances and lighting, despite significant efficiency improvements, are projected to at least double their share to nearly 25%.

Water heating and cooking energy use is currently marked by a diverse mix of fuels. In the reference scenario, this diversity is projected to pertain, with some composition changes, until 2050. However, in the decarbonisation scenarios it is projected that more than two thirds of final energy demand for water heating and cooking will come from emission free solar heating or from decarbonised electricity, the rest from gas and biomass.

For space heating and cooling, emission trends are determined by the space demand, the efficiency of energy use and by the fuel mix. The modelling assumes an increase in space demand[132] kept constant across scenarios. Emissions thus have to be saved through changes in energy efficiency of the building itself, in particular by improved thermal insulation, and in the efficiency and fuel mix of the heating and cooling equipment for housing.

Table 15 shows results of different scenarios regarding the useful energy requirements of housing over time. While the reference scenario shows continuous increases of useful energy requirements for space heating and cooling compared to 2005, this trend is slowed down and

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[132] In line with current trends household size is assumed to decrease, from 2.4 inhabitants per household in 2005 to 2.0 in 2050 while space per household is assumed to increase from 87 m2 in 2005 to 113 m2 in 2050.

after 2040 even reversed in the decarbonisation scenarios. This reversal is mainly the result of a significantly better thermal insulation of buildings driven by high carbon prices, leading gradually to a replacement of the housing stock with passive housing.

Table 15: Useful energy requirements across scenarios

Compared to 2005 in %	**2030**	**2050**
Reference (frag. action, ref. fossil f. prices)	13.4%	30.7%
Reference (frag. action, high fossil f. prices)	7.0%	23.9%
Effect. Techn. (glob. action, low fossil f. prices)	7.0%	-16.5%
Delay. CCS (glob. action, low fossil f. prices)	6.6%	-21.2%
Effect. Techn. (frag. action, ref. fossil f. prices)	5.9%	-17.6%
Effect. Techn. (frag. action, high fossil f. prices)	1.4%	-18.2%

Source: PRIMES

The other main explanatory factor is a more gradual shift in fuel use towards more energy efficient and less carbon intensive fuels. Efficient heat pumps play an important role by allowing both to increase end-use efficiency of heating and the reduction of the carbon intensity of the energy mix by using geothermal energy and electricity. Renewables are the other important driver.

Currently coal and oil hold still a share of around 25% of final energy used for heating and cooling. Already in the reference scenario this decreases to around 15% in 2050 and would practically disappear in the decarbonisation scenarios. Gas would see a decrease from around 45% today to around 30% by 2050 in the decarbonisation scenarios in the context of global climate action. The share of electricity would increase from currently less than 10% to more than 20% in the decarbonisation scenarios, and the share of biomass from currently over 10% to over 25%. It should be noted that due to the efficiency gains the latter increase corresponds more or less to a stagnation of biomass use for space heating in absolute terms. Finally, distributed heat would maintain its current share of under 10% by 2050.

5.2.9. Sector specific impacts: Agriculture and other Non CO2 emissions

Non-CO_2 emissions represent around 20% of current EU GHG emissions. In 1990 they were around 1175 MtCO2eq and declined to 887 MtCO2eq in 2005. Non-CO2 emissions have historically reduced much faster than CO_2 emissions. In the period 1990-2005 they reduced by almost a quarter, compared to only a 2% reduction in CO_2. In 2005 non-CO_2 emissions represented 17% of total GHG emissions in the EU, with agriculture representing more than half of these, around 9% of EU GHG emissions were agricultural Non-CO_2 emissions.

Table 16: EU GHG share CO_2 – Non-CO_2, 1990-2005

EU 27 GHG emissions (including aviation)	1990	2005	1990-2005
CO2	4467	4368	-2.2%
Non CO2	1175	887	-24.5%
Total	5642	5255	-6.9%

Source: Annual inventory submissions EU Member States to the UNFCCC, 2010, GHG emissions 2008

Reference case

In the reference case, these emissions continue to decrease until 2030, the main reasons for this are:

- Prevailing carbon prices in the ETS, reducing industrial non-CO2 emissions.
- Waste and waste water treatment legislation (e.g. the reduction of methane emissions from landfill sites).
- The Nitrates Directive (on the reduction of N2O emissions).
- F-gas regulation and Directive on air conditioning systems for motor vehicles (contributing to the reduction of F-gas emissions).
- Underlying trends in the CAP (e.g. the decline of livestock numbers EU wide).
- Methane emissions decrease from gas transmissions due to the improvement of infrastructure and from the decline of the coal mining industry. Abatement technologies have also been implemented such as the improved recovery of coal mine gas and reductions in gas transmission losses that come at relative low costs.

After 2030, the reference scenario emissions show a slightly increasing trend. The effects of existing legislation are fading. A second notable effect is the stagnation of non-CO2 emissions in agriculture. In the years up to 2020 the evolution of agricultural production typically stagnates or even declines (in some sectors), however global growth of demand linked to population growth stimulates EU production in the long run. In several cases this implies a turning point in terms of assumed supply and activity levels after 2020 in the agricultural sector. For more details on the model used and the assumptions regarding agriculture production and GHG emissions see annex 7.12.

Summarising, in the reference scenario non-CO2 GHG emissions are expected to decline considerably by one third compared to 2005 in 2030 but then remain more or less stable between 2030 and 2050.

Developments in the effective technology scenario

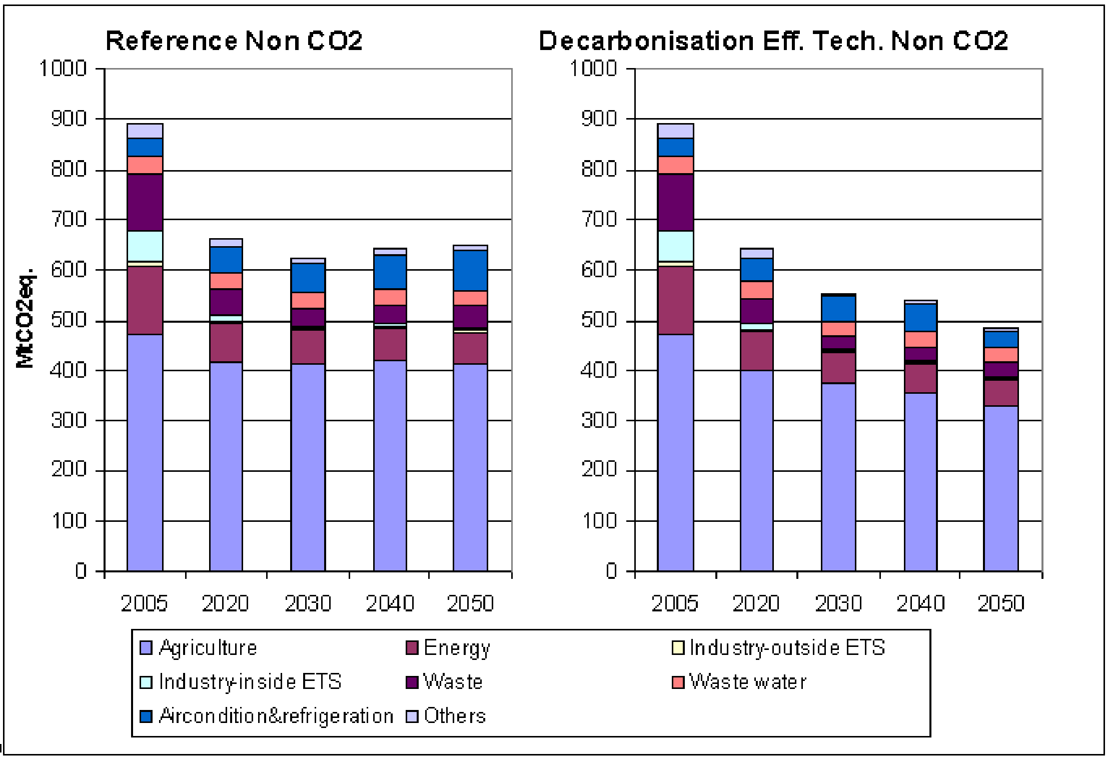
The figure below shows the possible reductions in non-CO2 greenhouse gas emissions in the effective technology decarbonisation case compared to the reference case. Most notable is that in the effective technology decarbonisation case the largest contribution in emission reductions stems from agriculture. In 2020 non-CO2 greenhouse gases could be cut by some 20 Mt $CO_{2\text{-eq}}$ compared to the reference scenario. 60% of this reduction would come from agriculture. Overall (from 2020 to 2050) 50 to 60% of the emissions reductions between the decarbonisation case and the reference case could come from agriculture. The majority of these reductions could come from investments in farm scale anaerobic digestion, mixes of feed changes, the reduced and improved timing of fertilizer use and precision farming.

The air conditioning and refrigeration sector (F-gas emissions) could make the second biggest contribution to further emission reductions over the period 2020 to 2050. At least some 20% of the additional reduction of non-CO2 greenhouse gases between the reference and decarbonisation scenarios could come from this sector. The reductions would be due to using alternative refrigerants and a variety of process modifications.

The remaining emission reductions would come from the waste sector (some 10%), energy (around 7%) and industry outside the ETS. Optimized solid waste treatment systems and anaerobic digestion with biogas recovery could further reduce methane from the waste sector.

In the energy sector mine gas recovery, doubling leak control frequencies and replacement of grey cast iron gas distribution networks could further reduce methane losses. Non-CO2 emissions from industry in ETS and the waste water treatment sector are already significantly reduced due to the carbon prices in the reference scenario and additional potential appears limited.

Figure 31 Non-CO2 GHG emissions in the reference and effective technologies case



Source: adapted from IIASA (Hoglund et al, 2010).

Developments in other scenarios

Reductions in non-CO_2 emissions do not differ substantially between the effective technologies and the delayed CCS and delayed electrification scenarios in 2030, both in the agricultural and non-agricultural sectors. Differences in carbon prices between these reduction scenarios are not significant enough to see large changes in emissions reductions.

Table 17: Non -CO2 emissions total in 2030 (MtCO2eq.)

Mio ton CO2-eq.	2005	2030					
		Ref	Eff. Tech	Delayed CCS	Delayed Electrification	Eff. Tech + Oil shock
Total	879	600	535	535	537	545
Non Agriculture	408	191	160	160	162	164

Agriculture	471	409	375	375	375	380
vs 2005						
Total	0%	-32%	-39%	-39%	-39%	-38%
Non Agriculture	0%	-53%	-61%	-61%	-60%	-60%
Agriculture	0%	-13%	-20%	-20%	-20%	-19%

Source: GAINS

Table 18 shows that by 2050 the differences are more pronounced. In the effective technology case emission reductions from Non CO2 emissions are 46% in 2050 compared to 2005. Delayed CCS increases carbon prices since more expensive technologies are needed. This increases the cost-effective reductions delivered from Non CO2 emissions; to a level of 51% below 2005 levels. Delayed electrification would have a similar impact. In the oil shock decarbonisation scenario emissions are reduced only by 41% compared to 2005 instead of 46% in the effective technologies scenario. The higher oil price implies lower carbon prices to meet the emission reduction targets. This reduces the need to reduce Non CO2 greenhouse gases (41% in 2005 instead of 46% in 2050 compared to 2005.

Table 18: Non -CO2 emissions total in 2050 (MtCO2eq.)

Mio ton CO2-eq.	**2005**	**2050**				
		Ref	**Eff. Tech**	**Delayed CCS**	**Delayed Electrification**	**Eff. Tech + Oil shock**
Total	879	625	475	428	442	520
Non Agriculture	408	216	144	125	133	174
Agriculture	471	410	331	303	309	346
vs 2005						
Total	0%	-29%	-46%	-51%	-50%	-41%
Non Agriculture	0%	-47%	-65%	-69%	-67%	-57%
Agriculture	0%	-13%	-30%	-36%	-34%	-27%

Source: GAINS

Overall, this results in Non CO_2 emissions reductions contributing significantly more than CO_2 to the 40% reduction milestone in 2030 compared to 1990. This reverses by 2050 with CO_2 reducing more compared to 1990 than Non CO_2.

Table 19: CO2 and Non CO2 emissions

Reductions compared to 1990	**2005**	**2030**	**2050**
Overall	-7%	-40 to -44%	-79 to -82%
CO2	-3%	-36 to -42%	-85 to -87%
Non-CO2	-25%	-53.5 to -54%	-56 to -63%

Source: PRIMES, GAINS

With emissions levels at around 330 MtCO2eq. agriculture represents around a third of the remaining total GHG emissions in 2050, tripling in share from 2005.

This points to the important role of agriculture in achieving decarbonisation. If emissions would not continue to decrease by a third by 2050 compared to 2005, then the energy sector would have to reduce even more.

Again, similar to the analysis in chapters 5.2.10 and 5.1.4 this points to the important role of yield improvement in agriculture. The above analysis does not include the feedback effects that abatement costs might have on agricultural prices, yields and demand. It neither assessed potential impact on carbon leakage in this sector. A potentially important element that is neither included in the assessment is the possible impacts of behavioural changes in affecting food consumption patterns.

A transition to more healthy, less fat and meat based diet could reduce methane and nitrous oxides emissions substantially at relatively low cost[133]. Reducing food waste would also improve resource efficiency and reduce greenhouse gas emissions. Such behavioural changes would reduce decarbonisation costs allowing more emissions in other sectors and avoiding the need to use the most expensive options.

Finally, the analysis did not consider alternative, not yet proven, options for the use of F-gases. If by 2050 it has been possible to develop and deploy such alternative gases with much smaller global warming potential, that can replace the F-gases in the air conditioning and refrigeration sector, then that would to a large extent eliminate this sector as a source for greenhouse gases in the long term[134].

5.2.10. Sector specific impacts: Land Use, Land Use Change and Forestry

This chapter addresses the potential impacts of the different scenarios on some land use activities and related greenhouse gas emissions. However, it should be mentioned that this impact analysis is subject to high uncertainties, as land use statistics, land market mapping, land use related greenhouse gas emission accounting, and respective model based quantitative analysis face significant gaps and uncertainties.

Bio-mass is projected to be an important component of the increase in renewable energy projected over the coming decades. In the reference case bio-mass production more than doubles by 2050 (see Table 20). In the decarbonisation case the production of bio mass more than triples in the same period (see Table 21). The sources of this increased bio-mass production would be crucial in assessing the direct and indirect impacts on GHG emissions.

Table 20: Bio-mass production requirements in reference case for energy use

Bio-energy production requirements (Mio toe)			
Domestic production for biomass	2005	2030	2050
Crops	5	76	80
Of which 2nd generation crops	0	57	79
Agricultural residues (including black liquor)	17	31	36
Forestry	40	51	42
Waste	25	63	60
Import	2	9	9

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[133] Stehfest et al., 2009, Popp et al., 2010

[134] In the context of the ongoing review of the F-Gas regulation, a more detailed analysis on the reduction potentials and mitigation options in the F-Gas sector is being carried out.

Total	90	231	228

Source: PRIMES

Table 21: Bio-mass production requirements in effective technologies decarbonisation case for energy use

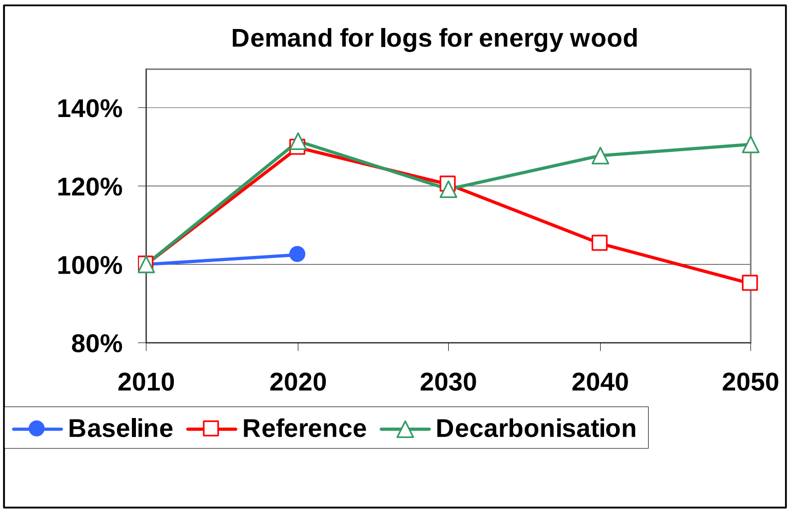
Bio-energy production requirements (Mio toe)			
Domestic production for biomass	2005	2030	2050
Crops	5	53	134
Of which 2nd generation crops	0	40	127
Agricultural residues (including black liquor)	17	32	49
Forestry	40	51	59
Waste	25	63	87
Import	2	12	26
Total	90	212	356

Source: PRIMES

In the reference the increased biomass demand mainly comes to be used to meet increased biofuel production from agricultural crops (increase from 5 to 80 Mtoe). The largest part of this increase happens already in the period 2010-2020 to fulfil the 10% EU renewables target in transport. In the decarbonisation case, a further increase in bio-mass supply of 56% (or 128 Mtoe) is needed by 2050 compared to the reference case. Part of this increase is met through increased imports but the largest absolute increase comes again from crops for biofuels. Table 21 shows that significant increases also occur in residues from the agriculture sector and the waste sector in general. Both increase production of bio-energy by a factor 3 from 2005 to 2050 in the decarbonisation case.

Figure 32 presents impact on demand for wood used for bio-energy as projected by PRIMES and the GLOBIOM model (excluding impact of demand from aviation). It confirms the limited increase forestry products demand for energy purposes over time (see Table 20 and Table 21). By 2050, the projected demand for energy wood from fellings in the decarbonisation scenario is about 35% higher than the demand in the reference scenario. Notable is also the increase in demand for fellings as bio-energy in the coming decade due to the achievement of the 20% renewables target by 2020.

Figure 32: Demand for energy wood in the EU



Source: PRIMES, G4M + GLOBIOM

In other words, modest growth is projected in the long term demand for wood for bio-energy, although in the short term increases are expected to be more considerable.

Still large uncertainties remain. The required inputs in agriculture to produce the crops for biofuel production could increase emissions through for instance increased fertiliser use in agriculture unless substantial progress will be made also in fertilizer efficiency. The agriculture projections presented in chapter 5.2.9 already incorporated the impacts of increases in bio-energy demand in the reference case. But this feedback mechanism was not examined for the decarbonisation scenario.

Furthermore the significant increase in production of crops for biofuels could increase the area used for crop production, which could result in conversion of grassland or even forests into cropland or reduce the expansion of forest that could otherwise occur. This potential impact could not be estimated, neither the potential impact of regulatory provisions that would limit grassland conversion.

Finally the demand for wood could be considerably different in 2050 than represented in Figure 32. Firstly, higher or lower renewables shares would matter. Secondly if other forms of bio mass supply for energy use do not materialise as represented in Table 21, then wood demand could increase with more. Thirdly demand for wood is not only dependent on wood demand for energy use alone, but also on changes in demand of other type of wood uses[135] such as paper, pulp, construction materials and bio-plastics. For instance, the EUwood study has projected that wood demand for other uses than energy will increase with a range of 15 to 35% over the period 2010-2030. This is not unimportant given that today the share of wood felling used for energy production is limited. In the GLOBIOM model around a third of wood production is used for energy purposes whereas the EUwood[136] study seems to indicate that this use might even be lower at present.

The extent to which increased wood demand, both for energy and other purposes, will be met through increased imports or not matters also for the amount of wood production in the EU itself.

Thus large uncertainty remains regarding the magnitude of demand for wood and the related impacts on wood production. To assess the possible impacts on emissions and removals in the Land Use, Land Use Change and Forestry activities (LULUCF) sector, two scenarios were assessed with the GLOBIOM and G4M model[137].

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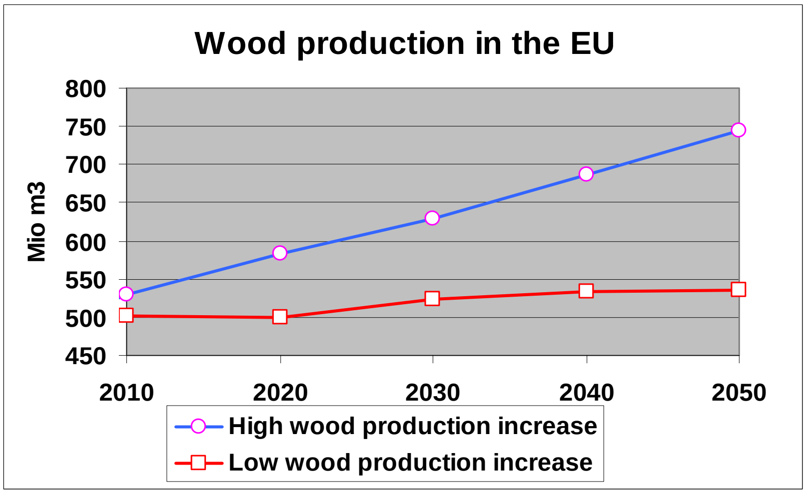
[135] The analysis did not look at the impact on greenhouse gas emissions of using wood products that replace more energy intensive alternatives for instance in construction, that can lower overall lifetime emissions.

[136] See for instance Mantau, U. et al. 2010: EUwood - Real potential for changes in growth and use of EU forests. Final report. Hamburg/Germany, June 2010. 160 p

[137] This are results of ongoing work. First results were reported in chapter 5.3 of the Staff Working Document, Part II, accompanying the Communication 'Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risk of carbon leakage' (SEC(2010) 650/2). The projection represented builds on work by the G4M + EUFASOM models as presented in SEC(2010) 650/2, but extends the time horizon to 2050.

In one scenario, the "low wood production" scenario, increases in EU wood production were assumed to be very limited. The other scenario sees higher overall wood production increases, of around 20% by 2030 and 40% by 2050 compared to 2010.

Figure 33: Changes in wood production in the EU



Source: IIASA, G4M + GLOBIOM

Figure 34 gives an overview of the impacts on the different LULUCF activities from these 2 different wood production levels.

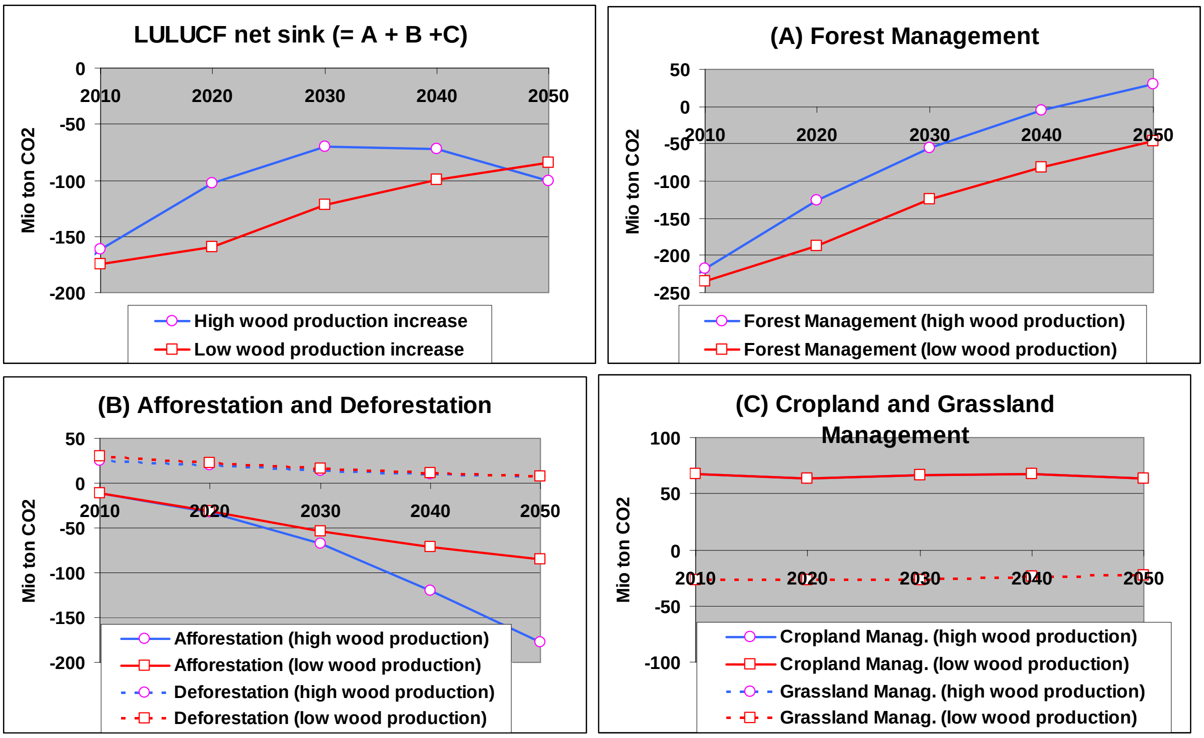
Overall the net sink from LULUCF activities decreases over time, even in the low wood production scenario that sees almost no increase in wood production. This is predominantly due to reduced removals in forest management as a result of maturing European forests. Increased wood demand in the high wood production scenario would however significantly affect the overall LULUCF sink. By 2030 this could result in removals of around 50 million ton CO2 less than in the low wood production scenario. This is equivalent to around 1% of the EU's 1990 GHG emissions.

The largest reduction can be seen in forest management. Instead of a sink, forest management would become a source of CO_2 emissions by 2040. This is mainly due to changes in harvesting cycles and practices to supply more wood.

The other pronounced difference between the 2 wood production scenarios is the impact on afforestation. Afforestation is projected to increase significantly in the high wood production scenario to accommodate increased wood demand. This would actually gradually compensate the loss in sink from changes in forest management. By 2050 this would fully compensate the loss from forest management, bringing net LULUCF removals in the high wood production scenario back to similar levels as the low wood production scenario, albeit at lower levels than at present. This underlines the potential for afforestation as an activity that can increase the sink in the longer term.

Net emissions from deforestation decline to almost zero in both scenarios. They start from a low base (from around 30 Million ton CO_2 in 2010). Overall grassland and cropland management seem more or less stable as a sink and a source of CO_2 but the uncertainty in this area is particularly high, also because the impacts of increased crop production for bio-energy is not estimated with respect to conversion of grassland into cropland.

Figure 34: Impact on LULUCF of different wood production levels



Source: IIASA, G4M

Uncertainties are thus large. The evolution of the LULUCF sink in the EU depends on several elements:

– whether there will be a significant increased demand for wood for bio energy use or not in case of decarbonisation. This depends in part on the development of other sources of bio-energy such as waste and other sources of renewable energy such as hydro, wind and solar.

– the extent to which other wood uses will also grow (note that this demand will be negatively affected if increased wood demand for bio-energy would result in higher overall wood prices). Improving resource efficiency in general through increased recycling rates can also contribute to limit the growth in demand of virgin wood.

– the extent that any of this demand growth will be met by internal production or increased imports. If the latter is the case, attention should be paid whether these imports come from sustainable sources or not and the impact in terms of net GHG emissions.

– the extent that increased production is achieved through changes in forest management or rather through increased afforestation. The most negative impact on the sink would occur if the increased wood production would be met through simple deforestation.

– Increased afforestation can compensate over time the loss of the sink due to increased wood production. Even if wood production would not go up, increased afforestation could compensate in part the reduction in the net sink due to the ageing of EU forests.

Furthermore uncertainty relates to the manner in which these emissions and removals are accounted for and the inherent uncertainty related to the data. Historical estimates of LULUCF by the models used show large differences with the data provided by Member States. Member States report LULUCF net removals of around 400 Mio ton CO2 in 2000 and stable levels in the period 2000-2008[138]. The G4M and GLOBIOM models estimate this to be lower, at around 250 Mio ton CO_2 in 2000, with decreasing trends already in the period up to 2010. Differences are due to the large uncertainties involved, different methodologies and sources used (such as forest inventories, timber supply models and extrapolations), different land coverage, and the fact that reported emissions and harvesting data are incomplete (not all countries report on all types of land uses and carbon pools). Further work to accommodate some of these differences is ongoing.

Chapter 5.1.4 assessed these interrelationships on a global scale; looking at what conditions need to be met in order to deliver increases in bio-energy, reduced deforestation and increased food production.

It is clear that this issue of LULUCF in the EU requires further attention and examination. The Commission will revisit this issue in the context of the assessment regarding the modalities for the inclusion of emissions and removals from activities related to LULUCF in the Community reduction commitment as foreseen under the 2011 Work Programme. Furthermore agricultural policies will also need to give the appropriate incentives to maintain the grassland sinks, tackle emissions from crop land by allowing restoration of wetlands and peat lands and adapting tillage practices, and reduce soil erosion that releases carbon.

5.2.11. Social impacts for households

The overall economic impacts show on the one hand a substantial increase in investment expenditure, also for households in sectors such as transport, energy efficiency in buildings and appliances, and on the other a substantial decreases of overall fuel and electricity costs. It is useful to consider how decarbonisation will influence the yearly costs for energy and transport services for households.

Energy expenditure per household other than transport

Figure 35 shows the expenditure of an average EU household for energy. The costs included are annualised capital[139] and fuel costs related to heating and cooling, insulation of buildings, electricity costs, as well as energy using equipment and appliances. When considering these costs the following elements are of relevance:

- investment costs for energy using equipment over time
- changes in per unit costs of energy input
- overall energy use due to increasing efficiency

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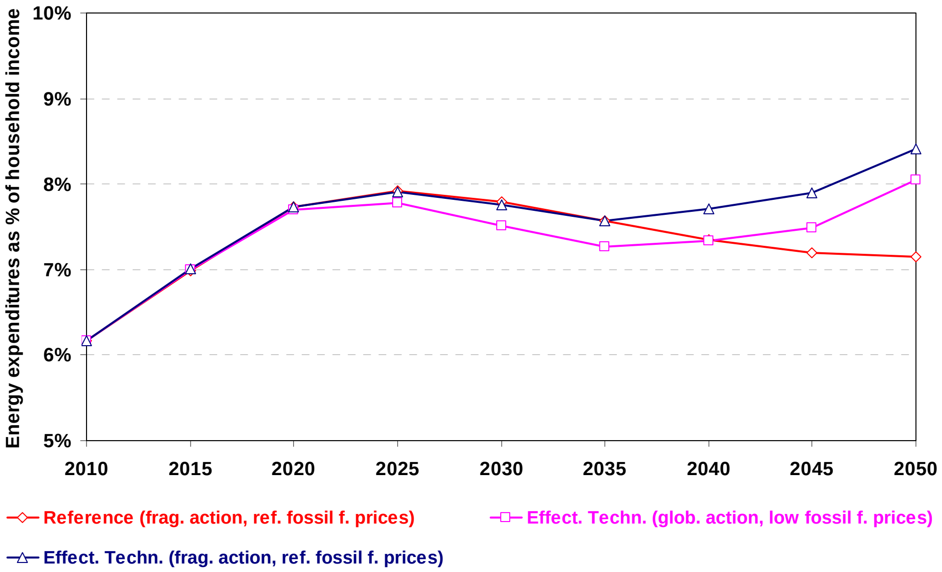
[138] EEA 2010b, Table ES.6

[139] All annualised costs include the return necessary on private sector investments in the housing sector. No social discount rate is applied which would result in lower costs.

Results are displayed in Figure 35. The following conclusions can be drawn:

- Until 2025, increased investments outweigh energy savings
- After 2025, the share of energy expenditures starts to decrease, with fuel savings as a result of energy efficiency investments overcompensating the equipment costs. This leads to a marginally lower annual costs in the decarbonisation scenarios with reference energy prices compared to the reference scenario and a cost well below reference for the global action scenario with low energy prices.
- After 2040 this trend of a lowering share of household income reverses, bringing expenditures in case of decarbonisation back to 2025 levels and above reference levels. This is mainly driven by additional expenditures for thermal insulation in response to further increasing carbon prices, i.e. the shift towards passive housing and similar standards also in refurbishments. Many of the additional energy savings induced by these expenditures will only be reaped after 2050 which is beyond the projection period.
- The impact of international fuel prices is clearly visible when comparing the different decarbonisation scenarios. Household costs are lower in the context of global climate action.

Figure 35: Expenditure of households on energy related equipment, fuels and electricity



Source: PRIMES, GAINS

Overall, it can be concluded that energy expenditures as percentage of household income will increase somewhat compared to today.

Transport expenditure per household

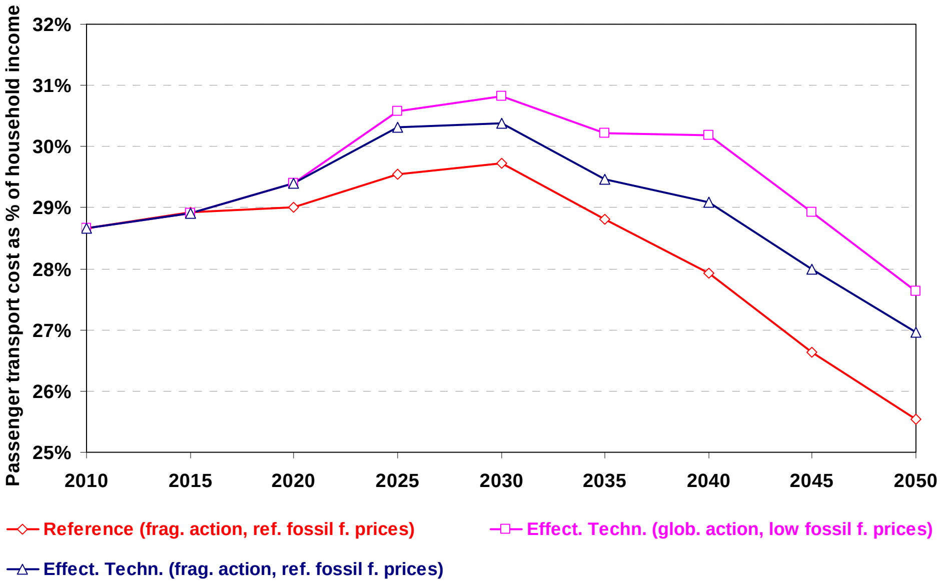
Figure 36 shows the expenditure of an average EU household for transport. The costs included are fuel and electricity costs as well as the annualised total transport equipment costs[140] (e.g. full costs for cars, not only energy-related parts). When considering these costs the following elements are of relevance:

- increased transport activity over time
- investment costs for transport
- changes in per unit costs of energy input
- overall energy use due to increasing efficiency

Results are displayed in Figure 36. The following conclusions can be drawn:

- Until 2030, increased investment expenditure, increased annual mileage, and increasing CO2, fuel and electricity prices outweigh energy savings, after 2030, the energy savings dominate, leading to a situation that overall transport costs per household in 2050 are less important than today.
- Especially after 2020, increased investments costs in the decarbonisation scenarios keep overall transport costs per household above reference levels. This is mainly due to the cost for electrification of road transport, which outweighs the fuel cost savings.
- The impact of different oil prices in the decarbonisation scenarios is counter intuitive. Lower oil prices in the global action scenario leads to higher mileage compared to reference. Instead decarbonisation with reference oil prices leads to lower mileage as the reference case (see also chapter 5.2.6). As a consequence of these effects on mileage the decarbonisation scenario with reference oil prices leads to a lower overall expenditure compared to the decarbonisation scenario with low oil prices.

Figure 36 : Transport costs per household



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[140] All annualised costs include the return necessary on private sector investments in the transport sector. No social discount rate is applied which would result in lower costs.

Source: PRIMES, GAINS

Overall, it can be concluded that transport expenditures as percentage of household income will decrease somewhat compared to today, despite the continuously increasing transport services and mileage that the average household is experiencing.

Overall, the household costs for transport and energy in a decarbonised EU are moderately higher than in the reference scenario, but their combined share in household income in 2050 is not higher than today, with household income projected to increase on average with 90% over the period 2010-2050.

However, in particular the need for high investments upfront to benefit from the fuel and electricity cost savings later on may pose a challenge for households, even more so for the most vulnerable households with lower income which cannot afford increased investment, even if over time compensated by energy savings. Households are not the same, and some might have problems mobilising the necessary resources for the upfront costs. This impact on different types of households was not assessed in this Impact Assessment.

5.2.12. Leveraging finance

Total annual investments over the next 40 years related to the decarbonisation of the economy are projected to be around € 270 billion, for both the global and fragmented action scenarios (see chapter 5.2.4).

Mobilising on average an additional € 270 billion a year in the coming 40 years will require specific attention from a policy perspective. This projected to represents on average 1.5% of our GDP over that period. To put this investment increase in perspective: in 2008 the EU invested[141] 21.1% of its GDP, in 2009 this was reduced to 19.1%. In this context, it is interesting to take note that other economies invest a much larger shares of GDP (e.g. China: 48%, India: 35% and Korea: 26% in 2009)[142].

Given the scarcity of public funds and magnitude of the transition challenge towards a 2050 low-carbon economy, a key question is how to achieve the required level of funding. As the vast majority of financial investments will have to come from the private sector, the role of public funding is to generate the enabling environment for private sector financing to leverage investments into low carbon investments that often will increase long term productivity and to create new markets. Investors might otherwise choose to fund opportunities with the lowest capital intensity rather than the ones with the lowest cost over time. The challenge is to find effective ways to incentivise and finance the additional upfront expenditure and the necessary research and demonstration. It becomes clear that the cheapest abatement opportunities are not always those with the lowest capital spend or the highest productivity increase over the longer time.

This will often involve ensuring access to information on the real costs and benefits of the investments made. This will allow private sector investors to judge better the real long term impact of their investment, thereby indirectly lowering the private discount rate closer to the

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[141] Eurostat, National accounts, Gross fixed capital formation (investments), % of GDP: http://epp.eurostat.ec.europa.eu/portal/page/portal/national_accounts/data/main_tables

[142] World Bank, Indicators, Gross capital formation (% of GDP): http://data.worldbank.org/indicator/NE.GDI.TOTL.ZS/countries

social optimum. An important element is not only information on the technology itself, but also a sufficiently strong long term carbon price signal that gives investment certainty.

But another important tool will be ensuring better access to financing itself. To be equitable it will also be important to ensure that poorer households, that often only have access to high cost credit, can mobilise the resources upfront at more reasonable prices to invest in carbon low investments.

Public funding should only support those investments that are economically efficient but not financially viable. Public funding should not crowd out private investments. Rather, the role of public spending is to "crowd in" investments.

Realising investment can be constrained by practical factors as well, like in the case of the housing sector: While builders and owners refrain from making investment into energy efficiency because they do not benefit from the financial savings, tenants are equally reluctant when they are not certain to stay long enough to get back their investment.

To tackle these barriers to investments, financial and fiscal instruments are part of a policy package, which should include regulatory, facilitation and communication elements. The finance and fiscal instruments essentially fall into different categories: preferential loans, grants that pay back part of a low-energy investment and tax rebates. Different public funding instruments have been introduced along the innovation chain in EU Member States to crowd in private investments and create a leverage effect. See annex 7.13 for a list of examples of such policies.

To achieve this level of leverage, a larger share of regional funding within the EU budget would need to go to low carbon related investments and different policy instruments will need to be applied, with more focus on how this funding can really lead to leverage of national and private sector resources.

At present 30% of the total € 344 billion Regional funding over 2007-2013 is available for activities with a particular impact on sustainable growth, or an average annual amount of €15 Billion of which at this point in time not all investments go to low carbon technologies. By the end of 2009, 22% of this funding for sustainable growth had been allocated to specific projects compared to 27% for the total of Regional funding. In particular, investments for energy-related and environmental programmes were below average, which points out that scope improve the implementation of financing instruments for low carbon development.

Table 22: Cohesion Policy 2007-13 allocations contributing to sustainable growth

Cohesion Policy 2007-13 allocations contributing to sustainable growth			
	Amount of adopted Operational Programs	Amount allocated to selected operations by end 2009	%
	Bn € (rounding)	Bn € (rounding)	
DIRECT	**45.5**	**9.9**	**22%**
Water supply	8.1	1.7	21%
Waste water	13.9	3.8	27%
Waste	7	1.1	16%
Air quality	1	0.1	6%
Nature protection	5.2	1	19%
Climate change adaptation	7.8	1.8	23%

Eco-innovation in SMEs	2.5	0.5	20%
INDIRECT	**59.5**	**13.4 23%**	**23%**
Rail	23.9	5.4	23%
Urban transport	7.8	2.2	28%
Other sustainable transport	4.6	1	22%
Electricity	0.6	0.02	4%
Sustainable energy	9	1.4	15%
Urban & rural regeneration	13.6	3.4	25%
TOTAL	**105**	**23.3**	**22%**

Source: COM(2011) 17 final, Communication 'Regional policy contributing to sustainable growth in EUROPE 2020, Member States Strategic Reports, September 2009 – January 2010.

5.2.13. *Employment impacts*

The transition towards a low-carbon economy will have a significant impact on the structure of the economy since it will affect the demand and supply of energy goods and services and will have an impact in the behaviour of consumers, employees and employers and public authorities. Deep emission reductions have marked effects that redirect investments and impact employment. For instance the renewables sector has already seen a job increase from 230000 in 2005 to 550000 in 2009[143]. Also investments in residential and commercial buildings are projected to increase by around 30% compared to the reference scenario in the next 2 decades, reaching nearly € 70 billion annually instead of nearly € 50 billion annually expected in the reference scenario (see table Table 35). Beyond that they will be even larger. It is clear such additional investments in a labour intensive sector, currently employing around 15 million people[144], will have beneficial impacts on employment. A number of studies have calculated employment effects of green or energy saving building investments in the EU and its Member States[145]. Based on their results, it can be estimated that these additional € 20 billion investment annually in the coming decade lead annually to 150.000 to 500.000 direct construction jobs being created or maintained, and to 250.000 to 750.000 jobs if also indirect employment effects in other sectors are 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.

Also investments in the power sector, both for grids and power plants, are projected to increase by more than €30 billion annually in the decarbonisation scenarios compared to the reference scenario by 2020-2030 (see Table 39). A recent study with the macroeconomic E3ME model for the European Commission has estimated, that additional €50 billion investment in this sector over the coming decade would lead cumulatively to around 400 000 additional jobs, if indirect and induced effects are included[146].

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[143] Source: European Renewable Energy Council, http://www.erec.org/statistics/jobs.html

[144] Eurostat: The EU-27 construction sector: from boom to gloom - Issue number 7/2010, Catalogue number: KS-SF-10-007-EN-N

[145] See e.g. Ürge-Vorsatz, Diana et al. (2010), Clausnitzer, Klaus-Dieter et al. (2010), Klinckenberg Consultants (2010) and European Commission (2008): Summary of the impact assessment of the proposal for a recast of the energy performance of buildings directive, SEC(2008)2865.

[146] European Commission (2010): Impact assessment for the Communication Energy infrastructure priorities for 2020 and beyond - A Blueprint for an integrated European energy network. SEC(2010) 1395 final.

But impacts on employment are not only driven by direct impacts in the concerned sectors. There are indirect effects economy-wide that to a large extent depend on the type of policy implemented to achieve the emission reduction. The Staff Working Document accompanying the COM (2010) 265 'Analysis of options to move beyond 20% GHG emission reductions'[147] underlined already that different mitigation policies can have different impact on employment. For example raising revenue through carbon pricing (auctioning in the ETS or taxation in the non-ETS) and directing this to lowering taxation on labour can have positive effects, most notably for employment. This analysis was revisited and extended to the 2030 time horizon for this impact assessment (see chapter 5.1.3), confirming that full recycling of revenues to reduce the costs of labour potentially could increase employment in the EU with around 0.7% by 2020 compared to reference, or around 1.5 million jobs (see Table 6).

Even if impacts can be positive overall, significant shifts in employment among or within sectors are expected[148]. The development of accommodating policies will matter a lot to ensure for an orderly transition of job prospects between sectors. This is particularly significant in the energy sector with sectors that experience growth and decline as a result of major shifts in investments and changes in production and consumptions patterns. The main need will be to revise and upgrade the 'green' skills of existing workers in all sectors. This is the case even where there have been major increases in demand, such as workers in the building renovation sector to improve energy efficiency and in sectors that are only indirectly involved such as the banking sector that needs to approve the loans for the relevant investments[149].

Beyond specific 'green' know how, there is a need to reinforce human capital in general because of the changes in production methods and adoption of new business models in a resource constrained world. Skills needs are also compounded by general weaknesses in the labour force and in particular the lack of interest in science and engineering, leading to a deficit in available technical skills. The issue is further tackled in the Europe 2020 flagship initiative ‘An Agenda for new skills and jobs’[150].

But not only re-skilling will be important, mainstreaming climate change objectives in the overall policy framework will be beneficial for overall employment. For instance, according to recent estimates, achieving the EU target of spending 3% of EU GDP on R&D by 2020 could create 3.7 million jobs and increase annual GDP by close to €800 billion by 2025[151]. As such there is a particular need to lift barriers on R&D on climate issues, and when accompanied with a long term carbon price signal, giving investors more certainty, and improved framework conditions for R&D, this can results in net benefits in job creation and welfare[152].

5.2.14. Co-benefits in terms of air pollution

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[147] SEC(2010) 65

[148] Employment in Europe Report 2009, ISSN 1016-5444

[149] European Centre for the Development of Vocational Training, Thessaloniki, Greece, 2010: Skills for green jobs – European Synthesis Report

[150] COM(2010) 682 final.

[151] P. Zagamé, (2010) The cost of a non-innovative Europe, http://ec.europa.eu/research/socialsciences/policybriefsresearchachievements_en.html

[152] European Economy. Economic Papers. 413. June 2010. Brussels, Andrea Conte, Ariane Labat, János Varga and Žiga Žarnić: What is the Growth Potential of Green Innovation? An Assessment of EU Climate Change Policies.

The reductions in GHG emissions of different decarbonisation scenarios also have positive impacts on air pollution. This is so because of the reduction in energy consumption and a shift to renewable energy sources. For this analysis the same methodology (the GAINS model) was as in the "Analysis of options to move beyond 20% greenhouse gas emissions reductions"[153]. This permits a broad estimation of the changes in air pollution impacts, including air pollution control costs and physical health impacts. The analysis was carried out for the reference scenario, the effective technology scenario and the delayed action scenario. Both the effective technology and the delayed action scenario assume global action and thus low energy prices.

Table 23 shows that reducing GHG emissions in 2020, 2030 and 2050 will further reduce emissions of $PM_{2.5}$, SO_2 and NO_X in the EU compared to the reference case[154]. The reductions are more pronounced for SO2 and NOx. Looking at the sum for the three pollutants the effective technologies case reduces air pollution by nearly 10% in 2030 and some 29% in 2050 compared to reference. Compared to 2005 this would represent a reduction of 68% in 2030 and 67% in 2050. In the delayed action the reductions in 2020 and 2030 are smaller but bigger in 2050.

The reduction in air pollution has positive impacts on human health. The table shows the impacts on mortality. Effective decarbonisation will reduce the number of life year lost due to $PM_{2.5}$ by 2.6 million in 2020, 6.3 million in 2030 and 14.3 million in 2050. Delayed action will have smaller positive effects in 2020 and 2030 and larger positive impacts in 2050. With effective decarbonisation the number of premature deaths due to ground level ozone drops by 174 in 2020, 415 in 2030 and 846 in 2050. With delayed action these number are lower in 2020 and 2030 but higher in 2050.

This reduction in emissions can also be expected to further reduce the costs of controlling traditional air pollutants. Table 23 shows that the effective decarbonisation case also cuts the costs of controlling air pollution by €3.6 billion in 2020, nearly €13 billion in 2030 and €46 billion in 2050. With delayed action cost savings are initially lower but higher in 2050.

The reduction in mortality can also be valued economically. The table shows that effective decarbonisation reduces this type of health damage due to air pollution by €3 to 7 billion in 2020 compared to the reference. The largest part comes from $PM_{2.5}$. In 2030 the damage reduction increases to around €7-17 billion and in 2050 to €17-38 billion. Delayed action will lead to smaller reductions in damage in 2020 (€1 to 2 billion) and 2030 and more pronounced impacts in 2050 (around €18 to 42 billion/year).

Table 23 shows that effective decarbonisation can reduce air pollution cost (of both damage and air pollution control) by some €11 billion in 2020, €29 billion in 2030 and €85 billion in 2050. With delayed action the savings are smaller in 2020 (€3 - €4 billion) and 2030 and higher later (€66-89 billion in 2050).

Table 23: Impacts on air pollution and air pollution control costs (change compared to the reference)

Change compared to the reference	2020		2030		2050	
	Effective	Delayed	Effective	Delayed	Effective	Delayed

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[153] SEC (210)650

[154] Note that the reference scenario on air emissions (in particular NOx) from the transport sector has some uncertainties due to the difference between "real world emissions" and estimated emissions and the assumptions regarding fleet turnover These effects may influence the air pollution benefits

SO_2 emission (1000t)	-106	-3	-314	-159	-877	-944
NOx emission (1000t)	-161	-48	-369	-222	-1089	-1155
$PM_{2.5}$ emissions (1000t)	-19	-6	-36	-29	-43	-54
Air pollution reduction (%)(sum SO_2, NO_X, PM2.5)	-3.2	-0.6	-9.8	-5.6	-28.5	-30.5
Reduction in health impacts (million life years lost due to $PM_{2.5}$)	2.6	0.8	6.3	4.5	14.3	15.6
Reduction in premature deaths ozone (cases/year)	174	53	415	288	846	870
ECONOMIC IMPLICATIONS						
Reduced air pollution control cost (€billion/year)	3.6	1.9	12.6	8.1	46.3	48.0
Reduced damage health PM2.5 (billion €/yr).	2.9-6.6	0.9-2	6.9-15.9	5-11.4	15.7-36.3	17.1-39.5
Reduced damage health ozone (€billion/year)	0.2-0.4	0.1-0.1	0.4-0.9	0.3-0.6	0.9-1.8	0.9-1.8
SUM of reduced health damage (€billion/year)	3-7	0.9-2.1	7.3-16.8	5.3-12	16.6-38.1	18-41.4
SUM of reduced control costs & damage savings (billion/yr)	6.6-10.6	2.8-4.0	20-29.4	13.8-20.6	62.9-84.4	66-89.4

Source: IIASA (2011) based on GAINS for emissions, health impacts and air pollution control costs (in €2008). Benefit valuation uses valuation of mortality used for the Climate and Energy package.[155]

The reduction in greenhouse gas emissions will also reduce morbidity. A recent study shows that a reduction of the EU's GHG emissions by 25% (in 2020 compared to 1990) could have significant health implications: it would reduce chronic bronchitis, hospital admissions, restricted activity days, medications use, days with lower respiratory symptoms and consultations for asthma and breathing problems[156]. The study valued the benefits of these improvements at around €1.5 billion per year in 2020. Given the more significant reduction in emissions of air pollution in 2030 (6 to 10%) and 2050 with decarbonisation, morbidity benefits can be higher in 2030 and 2050 than in 2020.

These gains will be important also in the light of the comprehensive review of the EU Air Quality Policy foreseen for 2013 at the latest where the aim is to maximise co-benefits with climate policy and minimise trade-offs.

Furthermore, damage to materials, crops and sensitive ecosystems (due to acidification, excess nitrogen deposition and ground level ozone) can be expected to be reduced. Table 24 shows the reduction in ecosystem areas in the EU27 were acidification and euthrophication exceed critical loads. I.e. in 2050 the impacts of effective and delayed decarbonisation are significant.

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[155] Commission Staff Working Document, Part II (SEC(2010) 650.

[156] Holland, M. (2010)

Table 24: Impacts on sensitive ecosystem

Reduction compared to the reference	2020		2030		2050	
	Effective	Delayed	Effective	Delayed	Effective	Delayed
Acidification - Forest area exceeded (1000 km^2)	4	1	9	6	22	24
Acidification - Catchment area exceeded (1000 km^2)	1	0	1	1	3	3
Eutrophication - Ecosystems area exceeded (1000 km^2)	11	4	17	10	63	67

Source: IIASA (2011).

6. CONCLUSIONS

The European Council and Parliament have endorsed a target of 80 to 95% greenhouse gas emission reductions below 1990 by 2050 in the context of necessary reductions by developed countries as a group according to the IPCC to limit global climate change to a temperature increase of 2ºC. The global analysis has shown that for cost-effectiveness reasons the EU would need to achieve most of these emission reductions internally by 2050, and can thus not expect to reach this target range by 2050 using a large amount of international credits.

With no global action on climate change but rather fragmented action future fossil fuel prices are expected to continue to increase significantly and the risk for oil crisis or permanently high oil prices remains. Instead with global action in line with the 2ºC target much lower fossil fuel prices are projected, with prices in 2050 roughly similar to today.

In all EU decarbonisation scenarios, the EU's energy resource efficiency would improve substantially. More domestic energy resources would be used, in particular renewables, and total energy imports would more than halve compared to 2005. Thus the policy objectives of reaching long term climate targets and increasing energy supply security go hand in hand, also if other regions in the world would not fully decarbonise and the risk of oil crises remain.

The assessment shows that by 2050, a 80% EU internal reduction compared to 1990 is technically feasible with proven technologies if a sufficiently strong carbon price incentive is applied across all sectors. Despite significant variations in technological and fossil fuel price assumptions, results are quite robust in terms of the speed and magnitude of emission reductions over time.

Milestones of a cost effective path towards -80% by 2050 are emission reductions by around 25% in 2020, around 40% in 2030 and around 60% in 2040. Reaching these emission levels will require further action, given that our current policies are projected to reduce emissions to -20% in 2020, -30% in 2030 and around -40% in 2050. Given that investments often have long lead times, delaying climate action would lead to significantly higher needed reduction steps later and significantly higher carbon prices and costs. Current policies in place (20% GHG target by 2020, 20% renewables target, a number of EU energy efficiency measures) would lead to reductions of -20% by 2020. To increase reductions to -25% additional energy efficiency policies are important. Full achievement the 20% energy savings target by 2020 would enable the EU to reduce internally emissions by 25% or more.

Shifting towards a low carbon pathway leads to a massive shift from fuel expenses to investment expenditure. Averaged out over the 40 year period, this increase in investment expenditure amounts to around € 270 billion annually, both in case of global and fragmented action. This represents on average 1.5% of our GDP over that period. These costs are largely compensated by reduced fuel costs over time, with largest cost reductions in case of global action that sees the costs for remaining fossil fuel imports also decrease.

As shown this offers opportunities for sustainable growth and jobs given that investments are to a large extent expenditures in the domestic economy, requiring increased added value and output from a wide range of manufacturing industries as well as the construction sector, whereas no action would continue to see increasing import expenses flowing to third countries considering the EU's strong reliance of fossil fuel imports. Furthermore, policies that introduce a carbon price signal through taxation or auctioning can allow for revenue recycling that can increase economic growth and employment.

Climate and energy policies in the coming decade will thus require a combination of smart pricing policies as well as instruments that can unlock private investment. Given the scarcity of public funds and the magnitude of the transition challenge towards a 2050 low-carbon economy, the role of public policy is to generate the enabling environment for private sector financing to leverage investments into low carbon investments that often will increase long term productivity and to create new markets. This will involve improving the access to information for private investors on the real costs and benefits of the investments made on the longer term but also ensuring better access to financing itself. Member States have already introduced policies such as preferential loans schemes, grants that pay back part of a low-energy investment and tax rebates, with the aim to unlock private investment in low carbon technologies. These type of policies will need to continue and be expanded. Also a larger share of regional funding within the EU budget would need to go to policy instruments that leverage private sector resources.

Currently, the EU Emissions Trading System (ETS) is the main policy instrument setting carbon price incentives. A larger contribution by the sectors covered by the ETS would continue to be cost-effective. Emission reductions of already nearly 50% by 2030 and around 90% compared to 2005 in 2050 would be achieved. The highest reductions would occur in the power sector, but in the longer term also the industry sector would provide above average contributions. The existing ETS target, even though continuing after 2020, will not lead to the level of reductions projected for 2030 or afterwards. Current prices in the ETS seem not sufficient to see large scale deployment of CCS in the power sector from 2020 onwards. A delay in the deployment of CCS could see costs increase later on to reduce emissions.

But also the non-ETS sectors would reduce their emissions with more than the current target of -10% by 2020 compared to 2005. By 2030 emissions would be at around -30% and by 2050 nearly at -70% compared to 2005. All sectors would contribute, but to a varying degree. Above average contributions can also be achieved by the residential and service sector, while transport and agriculture are the main sectors where no full decarbonisation in the longer term is achieved. Electrification can play an important role in making transport and heating low carbon, reducing emissions of land based transport back to or below 1990 levels by 2030.

The agriculture sector continues to decrease its emissions, but after 2030 reductions slow down. By 2050 it reduces emissions by up to 50% compared to 1990. It then would represent a third of total EU emissions, tripling its share compared to today. Its importance in terms of climate policy is therefore bound to increase: if it does not achieve the projected emissions, other sectors would need to reduce even more, which would come at a high cost. Given that changes in this sector are gradual, with no major technological solutions available, it is crucial that European agricultural policies focus on further efficiency gains, such as more efficient fertiliser use, improved manure management and improved livestock productivity. Globally, increases in productivity of agriculture to meet a number of competing goals (increased food and bio-energy demand, the need to reduce deforestation) will be crucial. Reversing existing global trends by reducing food waste and re-orienting consumption towards less carbon intensive food could also contribute.

The forestry sector and land use sectors are expected to see their sink function decrease over time, in part due to increased bio-energy and other wood demand. Over time this can be compensated through afforestation. Also imports could in part compensate for any wood demand increase, but of course this should not lead to carbon leakage in to form of unsustainable forestry practices in third countries. Furthermore other land uses can also contribute such as the maintaining of grasslands, the restoration of wetlands and peat lands and the reduction of soil erosion. This underscores the need to consider all land use in a holistic manner, and the importance to address Land Use, Land Use Change and Forestry in EU climate policy in a holistic manner, recognising that uncertainties remain high and improved monitoring and reporting of emissions and absorptions are crucial.

An EU internal reduction of -80% will require continued innovation in technologies through efficiency and cost improvements, and the provision of the corresponding infrastructure. This can benefit from demonstration at industrial scale of key technologies, also to improve public acceptability. Effective R&D and infrastructure policies for key low carbon technologies can facilitate this innovation process. The SET plan has the objective to address this and should thus be fully executed. R&D and innovation can also further spur job growth in the overall economy.

The shift towards investments and the decrease in household fuel expenditures result in costs for households for transport and energy to moderately increases in a decarbonised EU compared to the reference scenario. But their combined share in household income in 2050 is not higher as today. To be equitable it will also be important to ensure that poorer households, that often only have access to high cost credit, can mobilise the resources upfront at more reasonable prices to invest in carbon low investments. Government policies that try to leverage finance should address this.

Employment effects are estimated to be overall positive due to the increased focus on investments often associated with production industries and services localised in the EU. Furthermore pricing policies can allow for smart recycling of revenues, with employment benefiting most from reductions in labour costs. Even if impacts can be positive overall, significant shifts in employment among or within sectors are expected. The development of accommodating policies will matter. The main need will be to revise and upgrade the 'green' skills of existing workers in all sectors. This is not only limited to sectors that see growth decrease or increase but also in sectors that are indirectly involved such as the banking sector.

Overall action on climate change is expected to drive innovation in the EU and improve the competitive position of EU manufacturing industry . The impact of a more ambitious climate policy on energy intensive industries was also assessed. The results of the macro-economic modelling presented in the Staff Working Document accompanying the Communication

'Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risk of carbon leakage' of 26 May 2010 was revisited and refined up to 2030. It confirmed that the impact on the production levels of energy intensive industries were limited and that free allocation protects energy intensive industry in the ETS, even if the EU would implement more ambitious targets in a world where other regions have more limited ambition. But climate action would not only require the application of more advanced industrial processes and equipment, that results in fuel cost reductions. Also carbon capture and storage would be needed on a broad scale as an end-of the-pipe technology after 2035, notably to capture industrial process emissions (e.g. in the cement and steel sector). This would entail an annual investment of more than € 10 billion. In a world of global climate action, this would not raise competitiveness concerns. But if the EU's main competitors would not engage in a similar manner, the EU would need to consider how to address the risks for carbon leakage.

7. ANNEXES

7.1. 2010 Global Climate Highlights

The US National Oceanic and Atmospheric Administration, National Climatic Data Center, listed to following highlights for 2010 in relationship to the global climate[157]:

- Combined global land and ocean annual surface temperatures for 2010 tied with 2005 as the warmest such period on record at 0.62 ºC above the 20th century average. The range of confidence (to the 95 percent level) associated with the combined surface temperature is +/- 0.07 ºC.

- The global land surface temperatures for 2010 were tied for the second warmest on record at 0.96 ºC above the 20th century average. The range of confidence associated with the land surface temperature is +/- 0.11 ºC.

- Global ocean surface temperatures for 2010 tied with 2005 as the third warmest on record, at 0.49 ºC above the 20th century average. The range of confidence associated with the ocean surface temperature is +/- 0.06 ºC.

- In 2010 there was a dramatic shift in the El Niño-Southern Oscillation, which influences global temperature and precipitation patterns — when a moderate-to-strong El Niño transitioned to La Niña conditions by July. At the end of November, La Niña was moderate-to-strong.

- According to the Global Historical Climatology Network, 2010 was the wettest year on record, in terms of global average precipitation. As with any year, precipitation patterns were highly variable from region to region.

- The 2010 Pacific hurricane season had seven named storms and three hurricanes, the fewest on record since the mid-1960s when scientists started using satellite observations. By contrast, the Atlantic season was extremely active, with 19 named storms and 12 hurricanes. The year tied for third- and second-most storms and hurricanes on record, respectively.

- The Arctic sea ice extent had a record long growing season, with the annual maximum occurring at the latest date, March 31, since records began in 1979. Despite the shorter-than-normal melting season, the Arctic still reached its third smallest annual sea ice minimum on record behind 2007 and 2008. The Antarctic sea ice extent reached its eighth smallest annual maximum extent in March, while in September, the Antarctic sea ice rapidly expanded to its third largest extent on record.

- A negative Arctic Oscillation in January and February helped usher in very cold Arctic air to much of the Northern Hemisphere. Record cold and major snowstorms with heavy accumulations occurred across much of eastern North America, Europe and Asia. The

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[157] http://www.noaanews.noaa.gov/stories2011/20110112_globalstats.html

February Arctic Oscillation index reached -4.266, the largest negative anomaly since records began in 1950.

– From mid-June to mid-August, an unusually strong jet stream shifted northward of western Russia while plunging southward into Pakistan. The jet stream remained locked in place for weeks, bringing an unprecedented two-month heat wave to Russia and contributing to devastating floods in Pakistan at the end of July.

7.2. Overview of studies that look into impacts of climate change in the EU

IPCC AR4 results for Europe[158] show that with increasing temperatures water availability becomes the critical factor in southern Europe and EU-wide both droughts and flood events will occur far more frequently than at present. Changes to both temperature and precipitation rates are estimated to decrease the snow cover and as a consequence the ski season in the Alps will shorten. A reduction in heating demand for buildings coupled with a decrease in cold weather deaths is predicted for northern Europe; however this is counter to the predictions for southern Europe where increases in cooling demand are paired with increases in heat-related deaths.

The IPCC study also predicted that European flora species would be come increasingly vulnerable, with up to 20% becoming critical endangered and some extinctions. Within the agricultural sector crop yield losses are also predicted to far exceed the temperature-related gains.

The PESETA study[159] contains a spatially disaggregated, detailed assessment of the potential impacts of climate change in Europe (with temperature increases in the EU in the range of 2.5ºC and 5.4ºC) for a number of sectors. The research project evaluates the economic effects of the 2080s climate on the current economy[160]. Impacts assessed include the effects of changing temperature and precipitation levels in agriculture, changed in the frequency and severity of river floods, sea level rise in coastal systems as well as impacts on tourism and human health. For agriculture, rivers floods, coastal systems and tourism the study finds total welfare losses in these sectors for the EU that range from 0.2 to 1.0%, depending on the climate scenario. The study does not examine all potential climate losses, e.g. for transport, energy, forest (i.e. biodiversity), winter tourism and catastrophic events. The PESETA study has the benefit of examining specific impacts on the whole economy but it underestimates potentially the impacts of climate change in Europe because it does not assess all impacts; e.g. impact of climate change on transport, energy, forestry, winter tourism and catastrophic events are not considered. In particular this last category is difficult to assess but may lead to high impacts.

The ongoing EU-funded ClimateCost project[161] will add further details to impacts per sector in the EU. The ClimateCost project also estimated that by 2080 between 0.3 and 1.3 million

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[158] IPCC, Europe. Climate Change 2007: Impacts, Adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

[159] Ciscar et al. (2011) and JRC, Final report of the PESETA research project, 2009.

[160] A comparative statics analysis is performed, comparing the economy as of today with the economy as of today subject to the 2080s climate. The analysis of potential impacts, defined as impacts that might occur without considering public adaptation, can allow the identification of priorities in adaptation policies across impact categories and regional areas.

[161] http://www.climatecost.cc/

additional people in Europe would experience flooding due to sea-level rise if no improvements are undertaken in coastal defences.

7.3. Analysis of global emission pathways towards achieving the 2ºC objective

As the climate system is complex, the answer to which GHG emission pathways will achieve the 2ºC objective depend on the value taken by a number of parameters which are uncertain. One of the most important of them is the climate sensitivity parameter, which links the level of GHG concentrations in the atmosphere with the change in temperature. The parameter is defined as the increase in average temperature corresponding to a doubling of emissions concentrations relative to pre industrial levels. However its value cannot be defined in a laboratory setting and is estimated based on past observations as well as on atmospheric and ocean circulation models. Therefore we are confronted with a range of expected outcomes.

The Intergovernmental Panel on Climate Change's Fourth Assessment Report (IPCC AR4) concluded that based on available information, the equilibrium climate sensitivity (temperature increase as a result of a doubling of GHG concentrations) is likely to be in the range 2°C to 4.5°C, with a best estimate value of about 3°C. It is very unlikely to be less than 1.5°C. Values which are substantially higher than 4.5°C cannot be ruled out, but are unlikely. This implies that stabilizing GHG emissions concentrations at a level of 550 ppmv $CO_{2\text{-eq}}$. (equal to double the preindustrial level) would lead to an increase in temperature around 3°C as best estimate. Stabilizing GHG emissions concentrations at around 450 ppmv $CO_{2\text{-eq}}$. increases temperature by 2.1°C as best estimate with a likely range between 1.4 and 3.1°C[162].

The IPCC AR4 on Climate Change Mitigation assessed a large number[163] of long term emission pathways resulting in stabilization scenarios with different levels of stringency in terms of GHG concentrations (in CO2 equivalent). At that time a limited number of 6 scenarios had looked at low stabilisation levels of GHG emissions concentrations in the order of 450 CO2-eq.

Since the release of the IPCC AR4, researchers have made additional projections looking at emission reductions that achieve low stabilisation GHG emission concentrations. A recent review for UNEP[164] looked at the results of a set of recent scenarios that assessed low stabilisation GHG emission concentrations. The exercise included both Integrated Assessment Modelling (IAM) results that look at the economic and technical challenges of emission reduction scenarios across all sectors and gases, and approaches that used climate modelling to see the impacts of stylised emission patterns.

Figure 37 gives an overview of the scenarios projected by the IAMs. The left hand side shows GHG emissions scenarios that have a "likely chance" (i.e. more than 66% chance) of not overshooting the 2ºC temperature increase compared to pre-industrial levels during the 21st century. The right hand side represents the scenarios that have a medium chance (from 50 to 66% chance) of achieving the same outcome. The red lines represent GHG emission reductions of around 50% compared to 1990 by 2050.

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[162] IPCC, 4th Assessment Report, Climate Change 2007: Working Group I: The Physical Science Basis, Technical Summary, chapter 4.5 Climate Response to Radiative Forcing.

[163] IPCC, 4th Assessment Report, Climate Change 2007: Working Group III: Mitigation of Climate Change, chapter 3.3.5 Long-term stabilization scenarios, table 3.5.

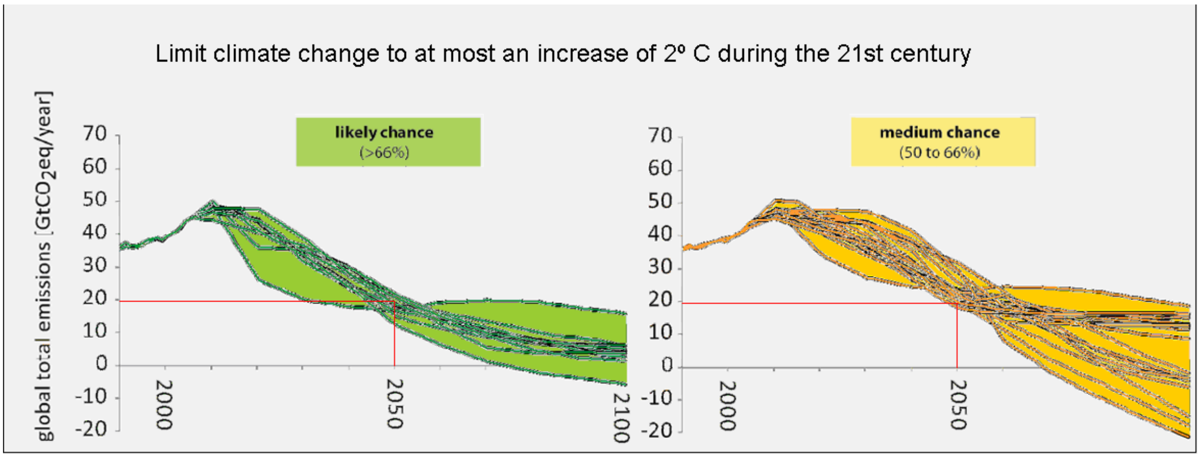
[164] UNEP: The Emissions Gap Report: Are the Copenhagen Accord pledges sufficient to limit global warming to 2 or 1.5°C?, Full Report, 9 November 2010

Scenarios with relatively late or extended global peaking beyond 2020 typically have emissions still well above half of the 1990 level by 2050 (see scenarios right hand side of Figure 37). They typically require near zero or even negative global emissions during the second half of this century to achieve a medium likelihood of keeping within the 2ºC limit during this century.

Instead, scenarios that see their emissions peak before 2020 and then reduce by around 50% or more compared to 1990 by 2050 typically have a "likely chance" (> 66%) meeting the 2ºC limit and require no negative emissions during the second half of this century.

All scenarios see an overshoot of GHG concentration levels above the 450 $CO_{2\text{-eq}}$., with significantly higher peaking in those with a late global GHG peak.

Figure 37: Emissions pathways compatible with a 2°C limit



Source: Adapted from 'UNEP, The Emissions Gap Report: Are the Copenhagen Accord pledges sufficient to limit global warming to 2 or 1.5°C?, 8 November 2010,

Not reaching the global GHG emissions peak soon, clearly increases the risk of seeing temperature increases above the 2ºC limit, and at the same time requires more challenging emission reductions later on in the century or even significant negative emissions on a global scale.

The EU ambition of seeing global emissions peak by 2020 and the reducing by at least 50% by 2050 compared to 1990, is estimated to have a likely chance of limiting global climate change to a 2ºC temperature increase or less compared to pre-industrial levels and to ensure its technical feasibility over the longer term (by lowering the probability that net negative emissions will be required).

7.4. Economic modelling tools used

POLES

The POLES (Prospective Outlook for the Long term Energy System) model is a global sectoral simulation model for the development of energy scenarios until 2050. The dynamics of the model is based on a recursive (year by year) simulation process of energy demand and supply with lagged adjustments to prices and a feedback loop through international energy price. The model is developed in the framework of a hierarchical structure of interconnected modules at the international, regional and national level. It contains technologically-detailed modules for energy-intensive sectors, including power generation, iron and steel, the chemical sector, aluminium production, cement making, non-ferrous minerals and modal transportation sectors (including aviation).

The world is broken down into 47 regions, for which the model delivers detailed energy balances. Emissions of all Kyoto gases are calculated for the sectors covered by the model.

PRIMES

Primes simulates the response of energy consumers and the energy supply systems to different pathways of economic development and exogenous constraints. It is a modelling system that simulates a market equilibrium solution in the European Union and its member states. The model determines the equilibrium by finding the prices of each energy form such that the quantity producers find best to supply match the quantity consumers wish to use. The equilibrium is static (within each time period) but repeated in a time-forward path, under dynamic relationships. The model is behavioural but also represent in an explicit and detailed way the available energy demand and supply technologies and pollution abatement technologies. The system reflects considerations about market economics, industry structure, energy /environmental policies and regulation. These are conceived so as to influence market behaviour of energy system agents. The modular structure of PRIMES reflects a distribution of decision making among agents that decide individually about their supply, demand, combined supply and demand, and prices. Then the market integrating part of PRIMES simulates market clearing. For further information see

http://www.e3mlab.ntua.gr/models_menu.php?title=primes.

GAINS

The GAINS model explores cost-effective multi-pollutant emission control strategies that meet environmental objectives on air quality impacts (on human health and ecosystems) and greenhouse gases. It is an integrated assessment model that brings together information on the sources and impacts of air pollutant and greenhouse gas emissions and their interactions. GAINS brings together data on economic development, the structure, control potential and costs of emission sources, the formation and dispersion of pollutants in the atmosphere and an assessment of environmental impacts of pollution. For further information on the GAINS Europe model which has been used for this analysis, as well as access to background data, see http://gains.iiasa.ac.at/gains/EU/index.login?logout=1.

CAPRI

CAPRI models the response of the European agricultural system towards a range of policy interventions. It is a comparative static equilibrium global agricultural sector model with focus on EU27 and Norway. It is solved by iterating supply and market modules. Its supply module consists of separate, regional, non-linear programming models which cover about 250 regions (NUTS 2 level) or even up to six farm types for each region (in total 1000 farm-regional models). Its market module is a spatial, global multi-commodity model for agricultural products, 40 product, and 40 countries in 18 trade blocks. For further information see http://www.capri-model.org/.

GLOBIOM

The Global Bio-mass Optimization Model (GLOBIOM) is a global recursive dynamic partial equilibrium model integrating the agricultural, bio-energy and forestry sectors with the aim to provide policy analysis on global issues concerning land use competition between the major land-based production sectors. The global agricultural and forest market equilibrium is computed by choosing land use and processing activities to maximize the sum of producer and consumer surplus subject to resource, technological, and policy constraints. Prices and international trade flows are endogenously determined for respective aggregated world regions. It covers 28 regions, representing a disaggregation of the eleven regions adapted to enable linkage with the POLES model.

The market is represented by implicit product supply functions based on detailed, geographically explicit, Leontief production functions, referring to the supply of agriculture and forestry production and explicit, constant elasticity, product demand functions Explicit resource supply functions, i.e. supply function for other inputs than land in the production process of agricultural and forestry products, are used only for water supply.

GLOBIOM can be used to estimate the role of cropland, grassland, and short rotation tree plantations expansion in global land use change projections including forests.

www.globiom.org

G4M

The Global Forest Model (G4M) provides spatially explicit estimates of annual bio-mass increment, development of forest bio-mass and costs of forestry options such as forest management, afforestation and deforestation by comparing the income of alternative land uses. The model is spatially explicit (currently on a 0.5°x0.5° grid). Increment is determined by a global map of potential net primary production (NPP). Such a map shows the biophysical potential of tree growth depending on climate conditions but independently of land cover, i.e. the current presence of forests. At present this NPP map is static but can be changed to a dynamic NPP model which reacts to changes of temperature, precipitation, radiation or CO_2 concentration. Main forest management options are application of thinning and choice of rotation time. The rotation time can be individually chosen but the model can estimate optimal rotation times to maximize increment, maximize stocking bio-mass or maximal bio-mass at harvest time. The model handles also age class dynamics of managed forests.

Calibrated to historic data G4M picks up the land use change trends of the past and projects its future development without explicitly modelling single land use change drivers.

7.5. Drivers assumed in the POLES scenarios

GDP and population assumptions

Main assumptions concerning GDP and population growth by region/country are shown in the table below. These assumptions are maintained across the three scenarios examined.

Table 25: GDP and population assumptions in POLES: yearly growth rates (%)

	2010/2005	2020/2010	2030/2020	2040/2030	2050/2040	Average 2050/2005
World						
GDP (B$2005 in PPP)	3,0	3,5	2,8	2,4	2,2	2,8
Population (Mcap)	1,2	1,1	0,8	0,6	0,4	0,8

Annex I						
GDP (B$2005 in PPP)	0,9	2,5	2,1	1,7	1,5	1,8
Population (Mcap)	0,4	0,3	0,1	0,0	0,0	0,1
N-Annex I						
GDP (B$2005 in PPP)	5,9	4,7	3,6	3,0	2,8	3,8
Population (Mcap)	1,4	1,2	0,9	0,7	0,5	0,9
EU27						
GDP (B$2005 in PPP)	0,7	2,1	1,6	1,3	1,3	1,5
Population (Mcap)	0,3	0,2	0,0	-0,1	-0,1	0,0

7.6. EU sectoral GHG reductions in case of global action

The POLES model project in case of the Global action scenario that in the EU, emissions in the power sector fall 93% by 2050 compared to 1990, while important reductions are achieved in the residential (-79%) and the industrial sector (-72%). As demand for mobility is still growing and decarbonisation options are more limited in the transport sector, the emissions reduction is only 52% with respect to 1990. This result is made possible by higher penetration of hybrid and electric vehicles, as well as by larger use of bio-fuels. Emissions in this sector peak by 2010 and by 2030 are already reduced by about 6% compared to 1990. An important caveat is that figures for transport do not include international aviation or international marine bunkers.

An important role in achieving the results in power generation is played by the increasing contribution of renewables, nuclear and carbon capture and storage (CCS). In the Global action scenario by 2050 the 81% of remaining CO2 emissions in the power sector is captured worldwide and 76% in the EU. It should be kept in mind that a large share of power generation is provided by non-fossil fuel sources. CCS, however, represents a very important source of abatement also in the industrial sector. Renewables represent 50% of power generation worldwide and 44% in the EU, while nuclear provides 22% of total power generation worldwide and 29% in the EU.

Table 26: EU-27 Greenhouse gas emissions by sector in the Global action scenario,

Variable	1990	2000	2005	2010	2020	2030	2040	2050
1990 = 100%								
GHG Total	100	93	95	86	73	55	36	22
GHG Power Sector	100	89	95	82	61	40	20	7
GHG industry	100	89	87	79	65	57	41	28
GHG transport	100	111	118	120	117	94	71	48
GHG residential services	100	90	91	81	77	54	33	21

Source: POLES, JRC, IPTS

7.7. Assessing global GHG emissions using the POLES, GLOBIOM and G4M models

7.7.1. Methodology of the integrated POLES, GLOBIOM and G4M scenarios

The POLES model was used to estimate the supply and demand for energy goods, including bio-energy (both bio-mass and bio-fuels) on a global scale. It did so both for the baseline as well as the Global Action Scenario that sees global GHG emissions from energy and industry reduce by around 50% by 2050 compared to 1990.

The GLOBIOM model (see annex 7.4 for a brief description) was then used to assess what the impact would be on agricultural and forestry production, including land use changes, and subsequent GHG emissions to meet this bio-energy demand together with the demand for food and wood[165].

Subsequently for the Global action case policies were introduced to limit GHG emissions in all sectors, including agriculture and forestry. This reduction scenario in GLOBIOM differs from the baseline through:

– modified bio-energy demand coming from the POLES Global Action Scenario

– introduction of a reduction target for emissions from gross deforestation with the aim to reduce it by half by 2020 and limit it to a minimum by 2030.

– introduction of a reduction target for Non CO2 emissions[166] from agriculture with the aim to stabilise emissions globally

The deforestation rate that is projected in baseline in GLOBIOM is lower than recent historic deforestation rates, indicating that deforestation is happening not only due to permanent replacement by cropland and grassland but also due to other reasons, with significant amounts of deforested land remaining idle and unproductive.

G4M was used to estimate the deforestation in baseline and then the impact of a carbon price on deforestation in the reduction case, taking into account historic deforestation rates. It was ensured that sufficient land for cropland and grass land remains available in G4M to meet the required cropland and grassland needs from the GLOBIOM projections.

As in GLOBIOM, in G4M the target for the Global action case was to reduce gross deforestation by half by 2020 and limit it to a minimum by 2030 through the introduction of a carbon price. Contrary to the projections with GLOBIOM, this carbon price is also a driver for further afforestation.

7.7.2. Sensitivity analysis - exogenous productivity in crop and livestock sectors

Agricultural productivity changes in the future are one of the most important and at the same time the most uncertain parameters.

There may be reasons for optimism. Historically, productivity increases have been higher than expected leading to a steady decrease in real agricultural commodity prices. Significant yield gaps exist still between regions globally. If the institutional framework is properly set up, just catching up of these regions with the rest of the world would lead to considerable productivity increases.

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[165] GLOBIOM operates in partial equilibrium, with wood and food demand driven by gross domestic product (GDP) and population changes. In addition, food demand must meet minimum per capita calorie intake criteria, which are differentiated with respect to the source between crop and livestock calories. Demand is calculated for the different regions on the basis of projections of regional per capita calorie consumption presented in FAO (2006a). The regional population, GDP development and bio-energy demand is the same as the one used for POLES.

[166] The non-CO2 emissions calculated in Globiom have been calibrated to ensure a perfect match with the EPA (2006) numbers for the year 2000.

On the other hand there are also reasons for pessimism in the Malthusian tradition. Some indication exists of a recent deceleration of the productivity gains in developed countries, even though it is unclear to what extent this might be due to economic rather than biophysical drivers. Furthermore, resource (soil and water) depletion and its negative effects on productivity might be of concern in some regions and also climate change could contribute in some regions to negative impacts on yields already in the coming decades.

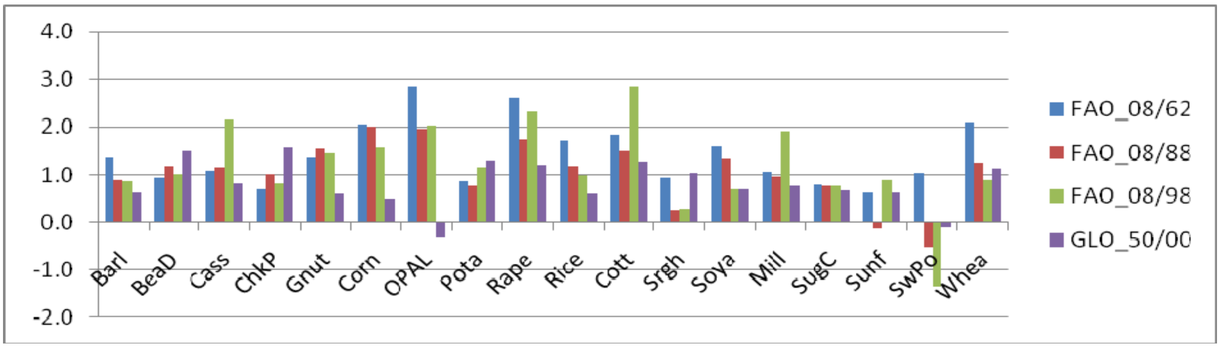
In the GLOBIOM model three factors influence overall yields:

1. Exogenous yield growth representing improvements in yield because of technological changes or more efficient management practices within a given production system
2. A pure yield effect when crops are produced using another type of production system. For instance when intensification is applied, leading usually to higher productivity.
3. An aggregation effect when the production of a specific crop is shifted to more or less fertile soils and climate – with effects that can be positive or negative on productivity

Many models cover quite well the first two effects. Because of GLOBIOM's detailed spatial resolution, the model also can represent the 3rd effect. This in turn gives the model substantial flexibility.

The exogenous yield growth in GLOBIOM for crops is set at 0.5% pa. See figure below comparing historic yield improvements to the "total" yield changes resulting from GLOBIOM. The reasonable match of the two demonstrates that the applied exogenous yield growth in GLOBIOM is in line with historic yield growth, even though historic yield improvements will to some extent also have been influenced by the pure yield and aggregation effects.

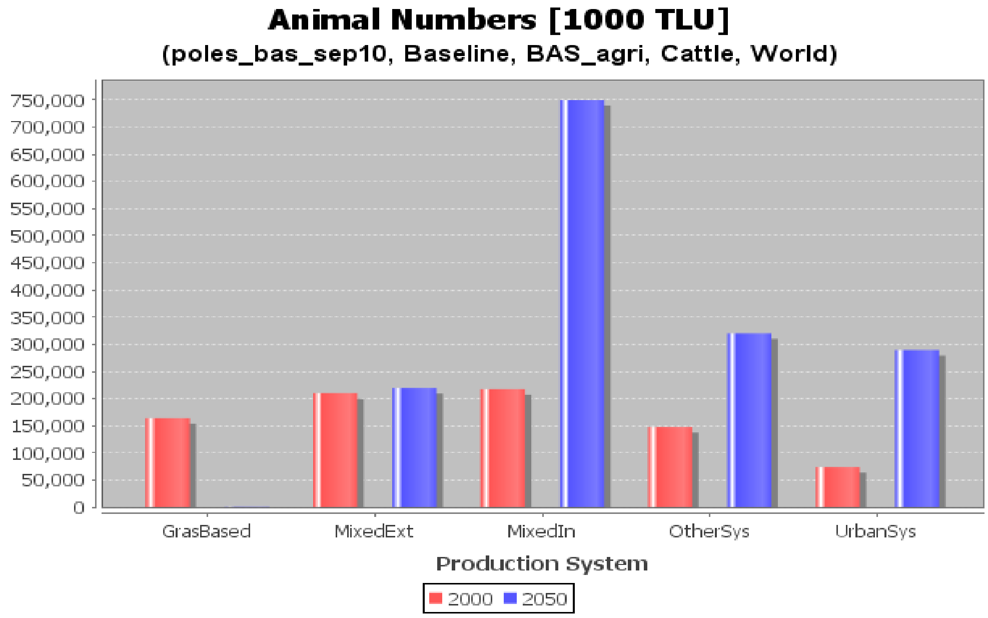
Figure 38: Historic annual rate of yield change (%) compared to the applied on in GLOBIOM



Source: FAO (faostat.fao.org, download 18/11/2010), historic periods assessed are 1962-2008, 1988-2008, 1998-2008.

Livestock production in GLOBIOM is represented through 14 production systems between which the model can endogenously choose. For the baseline, zero exogenous yield growth was assumed but full flexibility across production systems. As a result, the purely grassland based cattle systems nearly disappear by 2050, mixed extensive systems remain stable and there is an important increase in the mixed intensive systems.

Figure 39: Animal numbers per production system in Baseline in Globiom



Source: IIASA, Globiom

Two sensitivity scenarios were assessed regarding the exogenous yield growth:

- A low technological progress scenario with no exogenous crop yield growth (instead of 0.5% pa in the base case). Yield growth for livestock is kept the same as in the base case, at zero % pa
- A high technological progress scenario with yield growth for crops kept the same as in the base case at 0.5% pa but also applying an exogenous yield growth for livestock corresponding to the productivity increases applied with the IMPACT model for the report 'Agriculture at Crossroads' for the International Assessment of Agricultural Knowledge, Science and Technology for Development (Rosegrant 2009).

7.8. Projections of impact on oil and gas imports into the EU of Fragmented and Global Action using the POLES model

Chapter 5.1.2 discusses the results of projections by the POLES model on global and fragmented action, indicating that oil prices will be significantly lower in case of global action by 2050 compared to baseline (69$/barrel in 2050 instead of 138 $/barrel) with a less pronounced impact on oil prices in case of the Fragmented climate action(117$/barrel).

In baseline oil imports in stagnate over time, even though import dependency continues to increases over time, from 74% in 2010, to 84% and almost 90% by 2030 and 2050. At the same time oil prices increase from the assumed 70 $/barrel in 2010 to 138 $/barrel. This results overall in an almost doubling of the oil import bill in the EU.

Taking action on climate change has significant implications for the EU fossil fuel imports and the related bill. The Global action scenario results in 51% lower oil consumption than the baseline level in 2050. In the fragmented action case this reduction in consumption is even more outspoken due to the remaining high oil price in this scenario. Resulting decreases in oil imports are more than 50%, even higher in case of fragmented action because the remaining high oil price keeps some EU oil production ongoing. The cost on the oil import reduces with more than 66% compared to the baseline in 2050, and in case of global action the reduction is even higher (-73%) due to the lower resulting oil prices.

In absolute value the reduction in oil consumption in the global action case translates into $ 337 billion of avoided expenditures compared to baseline by 2050.

Table 27: Import dependency Oil and Gas

Oil imports, change vs 2010	2020	2030	2040	2050
Baseline	8%	6%	-2%	-9%
Global	-3%	-15%	-36%	-56%
Fragmented	-2%	-17%	-42%	-63%
Gas imports, change vs 2010	**2020**	**2030**	**2040**	**2050**
Baseline	9%	18%	25%	23%
Global	0%	-8%	-33%	-52%
Fragmented	0%	-18%	-49%	-79%

Source: JRC, IPTS, POLES

Table 28: Oil consumption, expenses and import in the EU

Oil - 2050	Consumption Mtoe	Change vs baseline	Expense in B$2005	Change vs baseline	Imports Mtoe[167]	Change vs baseline	Expense B$2005	Change vs baseline
Baseline	503	0%	512	0%	437	0%	445	0%
Global	248	-51%	126	-75%	211	-52%	107	-76%
Fragmented	234	-54%	202	-61%	175	-60%	151	-66%

Source: JRC, IPTS, POLES

Similarly, for natural gas the Global action scenario would result in halving gas consumption and reducing gas imports about 83% by 2050 compared to baseline or more than 50% compared to today. With gas prices reduced by 63% these reductions translate into reduction of the gas expenditures of up to 82 % compared to baseline, or $ 205 Billion. The import bill would have a more substantial reduction, as some domestic gas production still remains.

Table 29: Gas consumption, expenses and import in the EU

Gas – 2050	Consumption Mtoe	Change vs baseline	Expense in B$2005	Change vs baseline	Imports Mtoe	Change vs baseline	Expense B$2005	Change vs baseline
Baseline	405	0%	251	0%	276	0%	171	0%
Global	201	-50%	46	-82%	111	-60%	25	-85%
Fragmented	173	-57%	97	-61%	47	-83%	26	-85%

Source: JRC, IPTS, POLES

While oil and gas savings are most significant in 2050, their magnitude is projected to be substantial already by 2030. On top of the direct reductions from reduced volumes of oil and gas, there would be indirect cost reductions in the oil and gas sector due to lower need for capital investments in energy production and transport infrastructure within the EU.

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[167] The POLES projections assume higher remaining potentials for domestic oil and gas production by 2050 as PRIMES, resulting in lower relatively imports in baseline in POLES than in PRIMES.

7.9. Further information on the main assumptions and drivers of the PRIMES scenarios

7.9.1. Assumptions in relation to all scenarios for the EU in the PRIMES – GAINS modelling setup

The following drivers remain constant across all scenarios:

The **Gross Domestic Product** (GDP) increases in line with the 2009 Ageing Report developments; depicting declining growth rates over time as well as great variation among Member States[168]. Recovering from the crisis (fully reflected in the scenarios by only 0.6% pa GDP growth in 2005-2010 and slowly recovering growth 2010-15[169]), EU-27 GDP is expected to rise by 1.7% pa from 2010 to 2050, 2.0% up to 2030 and only 1.5% after 2030. Over time, labour productivity will become the only driver of growth in the EU. Nonetheless, given the recent juncture there remain considerable uncertainty concerning the medium-term economic developments.

These GDP assumptions have been used to project **sectoral activity data**, e.g. sectoral value added, with the help of GEM E3 multi-sector modelling.

The **population** projections for EU27 are based on the EUROPOP2008 convergence scenario from Eurostat, which is also the basis for the 2009 Ageing Report. The key drivers for demographic change are higher life expectancy, low fertility and inward migration. The EU-27 population is expected to grow by 0.2% per year by until 2035 and slightly decline afterwards, remaining fairly stable in number at around 500 million in the next 40 years.

The PRIMES model includes details on a great number of **technologies both for energy demand and energy supply sectors.** The technological representation is particularly rich for the power sector (more than 150 technologies represented), for which data on future investment costs, efficiencies, operation and maintenance costs are included, so that power plant investments can be determined endogenously on the basis of long run marginal costs. The model includes all technologies that are relevant for the energy system, including main demand side technology options and carbon capture and storage. Technology features in the model draw on energy technology related work from JRC-IPTS and other sources having benefited from support by e.g. DG RTD over many years. Technology cost assumptions have been compared with assumptions of other projections, in particular the IEA Energy Technology Perspectives 2010. Overall, cost assumptions can be described as moderate.

The technical-economic characteristics of existing and new energy technologies used in the demand and the supply sectors evolve over time and improve according to exogenously specified trends in line with literature results. These take into account public policies (through campaigns, industrial policy, R&D support and other means) that aim at pushing more rapid

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[168] European Commission, DG Economic and Financial Affairs: 2009 Ageing Report: Economic and budgetary projections for the EU-27 Member States (2008-2060). EUROPEAN ECONOMY 2|2009, http://ec.europa.eu/economy_finance/publications/publication14992_en.pdf. The "baseline" scenario of this report has been established by the DG Economic and Financial Affairs, the Economic Policy Committee, with the support of Member States experts, and has been endorsed by the ECOFIN Council.

[169] The short to medium growth pattern of the reference scenario is hence consistent with the intermediate scenario 2 "sluggish recovery" presented in the Europe 2020 strategy: Communication from the Commission: Europe 2020. A strategy for smart, sustainable and inclusive growth. COM(2010)2020, Brussels, 3.3.2010.

adoption of new technologies by removing uncertainties associated with their use. Non-maturity of technologies is reflected by temporary risk premium. Overall, technical progress assumptions can be described as moderately optimistic. For example, capital costs of already mature technologies decrease by 3% between 2010 and 2050, capital costs of new technologies decrease between 30% and 70% between 2010 and 2050 depending on technological potential and expected use. Also solar PV investment costs are projected to decrease by 60% in 2030 and by 70% in 2050 from today's levels as a result of strong learning by doing associated with strong RES supporting policies. Resource and other availability constraints are reflected by non linear potential cost curves (e.g. renewable source availability, nuclear site availability, CCS storage availability).

Consumers and suppliers are generally hesitant to adopt new technologies before they become sufficiently mature. They behave as if they perceive a high cost (higher than engineering estimations) when deciding upon adoption of new technologies. Agents decisions on trade-offs between capital and variable costs depend on weighted average costs of capital rates which vary between 17.5% for households and cars, 12% for other private transport, industry and services and 8% in public transport.

Nuclear investment in the longer term is endogenous, but Member State restrictions are respected where applicable. Nuclear investments are determined on economic grounds in the PRIMES model unless a country excludes the use of nuclear (e.g. Austria and Ireland) or there are other restrictions on nuclear use. Costs of nuclear waste are taken into account in the variable costs.

CCS penetration is determined on economic grounds and depend on ETS prices (apart from EU funding for demonstration plants). It is generally assumed that CCS infrastructure, regulation and legislation develops in all countries in a synchronous manner as CCS competitiveness vis-à-vis other power sources, assuming (except in the delayed CCS scenario) that there are no regulatory and acceptance issues, especially on transport and storage. Costs of infrastructure are recovered as variable payment by power producers for transportation and storage. For capture technologies significant potential for technological progress is assumed, leading to capital cost reductions per kW by 40 to 50% until 2050, depending on the capture technology. CO2 transportation and storage infrastructure is assumed to develop under public regulation. Data on CO2 storage and transportation were compiled from various research projects. Total EU potential storage capacity is roughly 250,000 million tCO2. This compares to 190,000 million tCO2 cumulative emissions until 2050 in the worst CO2 projection. Transportation and storage services are priced by regulation reflecting total long-term average costs. Storage prices increase significantly with total cumulative volume of CO2 to be stored.

Renewables are represented in significant detail and for various categories of renewable source intensity (for intermittent sources). Technological progress assumptions differ according to maturity, ranging between 10% (e.g. offshore wind, geothermal) and 70% (PV) capital cost reduction per KW between 2010 and 2050, It should be noted that these costs include standardized grid connection costs (including for example costs of DC links for offshore wind farms). Grid parity for PV is expected before 2030 in southern part of Europe.

With respect to **grids**, 250 interconnectors (existing and new) are modelled. Costs increase nonlinearly with the share of intermittent RES. Smart grid effects are represented to some extent, covering smart metering enabling efficiency, flexible controls preventing problems from variable RES operations, enabling deployment of small scale RES in low voltage and smart metering for electro mobility. However, the HV-MV-LV hierarchy of the grid is maintained but auto-production is included in the modelling. The power sector model includes a detailed representation of cogeneration.

The **demand side** sub-models of PRIMES decompose energy consumption in nine industrial sectors, five types of households, four tertiary sectors and transport by type of transportation mode. Each sector is decomposed in sub-sectors, further more in energy uses and energy processes. At the bottom level of this decomposition tree a specific generic technology operates and consumes energy forms. The technologies are represented as vintages and their characteristics change over time. The consumer may change energy mix for a technology, or change technology mix across the future vintages or change energy process mix, depending on costs, technical possibilities and useful energy requirements. Energy consumption is reduced through increased energy efficiency as a result of adopting more advanced technology vintages, investing in overall energy savings (e.g. thermal integrity of buildings) and/or reducing useful energy requirements, the latter being in competition with non energy uses and materials.

The **technologies** represented are identifiable, including a series of electric appliances used by households, specific furnaces and kilns in industry, motors, air compressors, drying systems, buildings (in categories), houses (in categories), renewable production devices (e.g. thermal solar collectors), heat pumps, etc. Industrial boilers and CHP by sector are also represented and are included in the power/steam sub-model which also represents steam and heat distribution networks in a simplified way. The industrial sub-models represent the production of most basic processing materials and include endogenous choices about recycling. The transport model represents a series of technologies for the various transport means, including electric cars, plug-in hybrids, simple hybrids, fuel cells. The transport model also keeps track of technology vintages for all transportation means. The technological detail in the demand sector models of PRIMES is sufficient to associate information on possible policy measures for energy efficiency (e.g. eco-design) and standards.

The PRIMES model is based on individual decision making of agents demanding or supplying energy and on price-driven interactions in markets. Correspondingly, **discount rates** pertaining to individual agents play an important role in their decision behaviour. Agents' economic decisions are usually based on the concept of cost of capital, which is depending on the sector - weighted average cost of capital (for firms) or subjective discount rate (for individuals). In both cases, the rate used to discount future costs and revenues involves a risk premium which reflects business practices, various risk factors or even the perceived cost of lending. The discount rate for individuals also reflects an element of risk averseness. For a more detailed background, see chapter 2 of 'EU energy trends to 2030 — UPDATE 2009'.

7.9.2. Specific assumptions in relation to the reference scenario for the EU in the PRIMES – GAINS modelling setup

The reference scenario for 2050 is consistent with the reference scenario until 2030 published in September 2010[170] (which has been used, amongst others, in the analysis of implications of

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[170] European Commission, DG Energy: EU energy trends to 2030 - UPDATE 2009, September 2010. http://ec.europa.eu/energy/observatory/trends_2030/doc/trends_to_2030_update_2009.pdf , Member States have been consulted during preparation of this 2009 energy trends baseline that include projections for all GHG emissions.

a move beyond 20% greenhouse gas emission reductions[171]). The detailed macroeconomic assumptions on GDP and population are consistent with the 2009 Ageing Report[172].

A key policy that is assumed to be implemented is the amended EU Emission Trading System (ETS)[173]. The ETS cap continues to decline by the adopted linear factor after 2020[174], resulting in a cap of nearly 70% below 2005 emission levels by 2050 (except for aviation, where the default reduction beyond 2020 continues to be 5% below 2004-6 levels). But given the agreed review of the linear factor after 2025 as well as the unspecified use of international credits after 2020, it is assumed to result only in a 50% internal reduction of ETS emissions by 2050 compared to 1990. This may be interpreted as a generous assumption of the use of international credits given that at present the legislation only foresees a certain amount of international credits up to 2020.

ETS prices are derived endogenously on the basis of the above defined domestic emission constraint, while taking account of existing ETS flexibility, in particular with regard to banking. The ETS carbon price needed to comply with the ETS directive rises from 36 € per ton CO2 in 2030 (in constant prices of 2008) to 51.5 € in 2040 and flattens out to 50 € in 2050[175].

Non ETS and renewable energy legislations[176] have set legally binding national targets for 2020, of which full implementation is assumed. There is no assumption on specific targets for later years, but rather a continuation of a policy incentive of similar strength for the Non ETS sectors[177] and similar facilitation but declining subsidy intensity for renewables, expressed in a Renewables (RES) values as shown in the Table 30 below.

Table 30: Policy drivers in the reference scenario

	2020	2030	2040	2050
ETS carbon price (€/tCO2eq)	16.5	36	51.5	50
Non ETS carbon value (€/tCO2eq)	5	5	5	5
RES value (€/MWh)	49.5	35	35	35

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[171] European Commission: Communication 'Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risk of carbon leakage' (COM(2010) 265 final). Background information and analysis, Part II (SEC(2010) 650). http://ec.europa.eu/clima/documentation/international/docs/26-05-2010working_doc2_en.pdf

[172] European Commission, DG Economic and Financial Affairs: 2009 Ageing Report: Economic and budgetary projections for the EU-27 Member States (2008-2060). EUROPEAN ECONOMY 2|2009, http://ec.europa.eu/economy_finance/publications/publication14992_en.pdf. The "baseline" scenario of this report has been established by the DG Economic and Financial Affairs, the Economic Policy Committee, with the support of Member States experts, and has been endorsed by the ECOFIN Council.

[173] Directive 2009/29/EC amending Directive 2003/87/EC.

[174] The ETS cap decrease at a rate equal to a linear factor of 1,74 % compared to the average annual total quantity of allowances issued by Member States in accordance with the Commission Decisions on their national allocation plans for the period from 2008 to 2012

[175] The ETS price in 2030 in this reference scenario going up to 2050 is significantly higher than carbon price for 2030 in the reference case presented in the staff working document accompanying the Communication 'Analysis of options to move beyond 20% greenhouse gas emission reductions and assessing the risk of carbon leakage' (SEC(2010) 650}. The main cause is additional action and banking over a longer period of time motivated by expectations on increases of allowance prices in the future due to the continuously decreasing ETS cap after 2030 up to 2050.

[176] Effort Sharing Decision 406-2009-EC, Directive 2009/28/EC

[177] By holding the non-ETS carbon value needed to achieve the EU non-ETS target in 2020 constant from 2020 onwards.

Source: PRIMES, GAINS

Non ETS and renewable energy legislations to achieve the binding national targets for 2020 give considerable freedom to Member States on how they can achieve them, allowing for transfers between Member States if some overachieve the national targets.

For the achievement of the **Non ETS emission targets**[178], it is assumed that this flexibility is fully used. Consequently, a uniform Non ETS carbon value across the EU is used. The policy impulse needed to reach the 2020 EU non-ETS target of a 10% emission reduction compared to 2005 equals a carbon value of 5 Euro per ton of CO2, as the reference scenario until 2030 has shown. There is no assumption on targets for later years. Instead it is assumed that the policy impulse will continue at the same strength, represented by constant non-ETS carbon values of 5 Euro per ton of CO2 after 2020, and that at least -10% is maintained as minimum reduction for the whole period until 2050.

For the achievement of the **renewable energy targets**[179], only limited trade is assumed in 2020 for those Member States that have indicated that they plan to make use of the so called co-operation mechanisms that allows for such transfers to achieve the renewable energy targets. National support measures are assumed to be of similar level in all renewable energy sectors within a country, provided that the transport specific target is met. For reaching the targets, on average a renewable energy incentive of around €50 per MWh and a biofuel support of €55 per MWh in 2020 are necessary, with considerable differences between countries. With a 20% average renewable energy share for the EU as a whole, average shares are around 32% in the electricity sector, 20% in heating and cooling and 10% in transport. There is no assumption on targets for later years. RES subsidies decline after 2020 starting with the phasing out of operational aid to new onshore wind by 2025; Also other RES aids declines substantially by 2050 at different rates according to technology. For example, aid to solar PV remains important until 2035 and becomes insignificant for new installations in a great number of Member States from 2040 onwards. Increasing use of RES co-operation mechanisms will also help to reduce RES costs. Policies on facilitating RES penetration will continue at an average level of €35/MWh, reflecting greater use of trade between Member States after 2020. Decarbonisation scenarios see the same phase-out of operational aids to renewables, but an intensification of enabling policies (e.g. quicker authorisation).

National **nuclear policies** as of mid 2010 are assumed to continue. Member States that have no nuclear power production remain so, except for Italy and Poland where national plans envision nuclear use. Nuclear in Belgium and Germany is phased out according to legislation as of mid 2010. Sweden continues to use and invest in nuclear.

Other policy assumptions are identical to those described for the reference scenario until 2030 in the 2009 update of the European Energy Trends until 2030[180]. Notably the reference scenario includes the Regulation on CO_2 emissions of new passenger cars, the implementing measures of the Eco-Design and Labelling Directives (e.g. energy services, stand-by, lighting), the CCS demonstration plants which are part of the European Energy Programme for Recovery (EEPR), and the recast of the Energy Performance in Buildings Directive. For consistency reasons to appropriately represent the integrated approach taken by the

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[178] Effort Sharing Decision 406-2009-EC.

[179] Directive 2009/28/EC.

[180] European Commission, DG Energy: EU energy trends to 2030 - UPDATE 2009, September 2010. http://ec.europa.eu/energy/observatory/trends_2030/doc/trends_to_2030_update_2009.pdf

Commission on CO2 emissions from vehicles, also the draft legislative proposal to reduce CO2 emissions from light commercial vehicles (vans) is included, which was adopted on 28 October 2009 by the European Commission and politically agreed between Parliament and Council in December 2010.

For Non CO2 emissions, the projections assume full compliance with existing EU Directives as well as national legislation. The EU-wide Directives include the Landfill Directive (1999/31/EC), the Waste Directive (2006/12/EC), the Waste Management Framework Directive (2008/98/EC), the Nitrate Directive (1991/676/EEC), Common Agricultural Policy (CAP) Reform and the CAP Health Check, the F-gas Directive (2006/842/EC) and the Motor vehicles Directive (2006/40/EC).

7.9.3. Detailed description of the different decarbonisation scenarios

Scenarios in the context of Global Climate Action

Effective and widely accepted technology scenario

This option represents a policy environment that enables all mayor low carbon technologies, such as energy efficiency and renewables, carbon capture and storage (CCS), nuclear and electrification of transport. This is reflected by the following additional but realistic assumptions compared to current policies:

- All renewable technologies are facilitated to a larger extent (e.g. by planning and infrastructures, expressed in higher renewable values). The extent of cost saving technological progress in solar technologies is assumed to be larger.

- Energy intensity improvements are brought about in the context of high ETS prices and demand side policies are mirrored through high carbon values; in addition greater penetration of renewables increases the conversion efficiency and hence improves energy intensity.

- It is assumed that CCS is successfully demonstrated and is commercially available after 2020, benefiting from cost improvements driven by carbon prices; it also assumed that there is public acceptance for the technology

- It is assumed that current national nuclear policies are implemented as planned. Nuclear energy is assumed to be enabled by increased public acceptance and higher safety of nuclear waste operations. However, no new nuclear will be built in countries which continue to exclude this.

- Electrification of transport is enabled by R&D and other policies promoting progress in battery-driven vehicles. A decrease of battery costs (EUR/kWh) by a factor of 4 in 30years is in line with current optimistic expectations. Lighter batteries, faster charging and higher power densities are also assumed. An infrastructure enabling full electrification including smart grids is built up so that from 2030 a transition to electric cars can take place. Constraints to electrification only remain in certain parts for non urban long-distance road transport, especially for trucks and busses.

In this enabling context, carbon price equalisation across sectors works as key driver to ensure a cost-effective decarbonisation approach including the selection of technologies and fostering of demand-side energy efficiency. Also additional renewables incentives are assumed but no further specific energy efficiency policies are assumed beyond those driven by the pricing signal

Delayed CCS

This option explores the consequences if CCS as a potential important new low carbon technology is not enabled as successfully as under the "Effective and widely accepted technology" scenario. If effective, CCS allows continued significant use of fossil fuels (coal and gas) for electricity supply even under a strict carbon constraint and enables radical emission reductions of industrial processes. However, the successful deployment presupposes the availability and public acceptance of a new transport and storage infrastructure for CCS. The delayed CCS scenario reflects potential problems in this regard in particular by significant upward shifts in cost curves for CCS transport and storage as well as by more conservative assumptions on related cost improvements over time.

In particular, issues with public acceptance of transporting and storage of substantial amounts of CO2 would impede CCS deployment in this scenario, delaying its effective deployment by 10 to 15 years. As a result of non acceptance issues regarding storage, manufacturers anticipate smaller market for CCS. This causes lower technology learning due to slower development of mass production of the capture technologies, which in turn contributes to such delays. The cost improvement rates catch up partly after 2040. However storage cost effects remain after 2040 in comparison with the effective and widely accepted technology scenario, which is more optimistic on CCS.

Delayed electrification scenario

This option explores the consequences if the currently widely regarded promising key decarbonisation technology in the transport sector, i.e. electrification of transport, is not enabled as successfully as under "Effective and widely accepted technology". As a result of delay in R&D, battery costs remain much higher, reflected by using the lower bound for battery cost improvements estimated by the IEA[181], and the range autonomy of pure electric vehicles develops in a slower pace compared to the "Effective and widely accepted technology" case. This causes a delay of 15 to 20 years in the effective deployment of electrification in transport and in the preparation of the infrastructure needed. Alongside, slower development of mass production for electric vehicles leads to lower technology learning with cost improvement rates of batteries only partly catching up beyond 2040. It is assumed that during the delay period the charging infrastructure develops partially.

Delayed climate action scenario

The scenario 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 (this thus includes the impact of a continued decrease in the ETS cap according to existing legislation). 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

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[181] International Energy Agency (IEA) 2009, Transport, Energy and CO2: Moving Toward Sustainability,

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.

Scenarios in the context of Fragmented Climate Action

Effective and widely accepted technology scenario in the EU

This scenario explores the effects if the EU would continue its action towards an emissions reduction of 80% in a world were others don't act beyond the Fragmented Climate Action scenario. Hence global fossil fuel prices are assumed not to deviate from the reference scenario. All other assumptions are equal to those in the Effective and widely accepted technology scenario in the EU in the context of global action.

Technology assumptions are kept similar as in the same scenario in the context of global action. This can be justified methodologically by the interest to isolate price effects. However, given the size and in many areas also technology leadership of the EU, and the already existing technology efforts in other countries, it is also not obvious that low carbon technology development would be significantly slower in a world in which only the EU increases its actions.

Specific measures for sectors exposed to global competition

Scenarios are considered that can give insights into specific measures for sectors exposed to global competition, given that a level playing field at global level would not exist. The consequences of two possible options with regard to specific measures are explored:

- One option would be to implement exactly the same reduction as the effective and widely accepted technology scenario. But it should then be explored what this means for industry, what type of investment costs would they experience, what kind and extent of R&D support or what level of direct support would be necessary to compensate industry for relevant additional costs incurred that industries in third countries would not or to a lesser extent face?

- Another option would be to have special provisions to allow industry exposed to global competition to reduce less, for instance to stay at the level of the reductions as experienced in the reference scenario. This could for instance be achieved by allowing them increased access to international credits, which might be available at lower prices in such a world. The scenario tries to reflect this by applying reference scenario ETS carbon prices to industrial installations and industrial process emissions of energy intensive industries exposed to global competition. As a direct result of this the overall EU emission reductions effort would be lower.

Oil shock scenario

To assess the impact of an oil shock in case of fragmented action, a scenario is developed that sees the doubling of oil prices in 2030, with lower increases for gas (initially by 50%) and less severe increases for coal. Due to the reaction of demand and/or supply to higher prices, this scenario includes a gradual reduction of high oil prices over time coming rather close to reference case levels by 2050.

High fossil fuel price scenario

Furthermore an even more bleak scenario is assessed that would see continued high fossil fuel prices. It also assumes doubling of prices in 2030 but in this scenario these high oil prices remain at that level over the full period 2030-2050. This scenario is similar as the high oil price scenarios of US EIA[182] which assume that structural changes in the energy markets result in long term high fossil fuel energy prices.

Delayed EU climate action in a world of fragmented climate action

What are the impacts of delay if energy prices remain at levels of the reference scenario? The scenario assumptions to implement the delay are similar as in the above scenario of delayed climate action in a world of global climate action.

7.10. Overall Carbon price and GHG profile of the different reference and decarbonisation scenarios

Table 31Carbon price evolution different scenarios

Carbon price evolution*	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Reference (frag. action, ref. fossil f. prices)	16.5	20	36	50	52	51	50
Effect. Techn. (glob. action, low fossil f. prices)	25	38	60	64	78	115	190
Effect. Techn. (frag. action, ref. fossil f. prices)	25	34	51	53	64	92	147
Effect. Techn. (frag. action, oil shock)	25	32	45	47	55	75	117
Effect. Techn. (frag. action, high fossil f. prices)	25	31	42	43	50	68	104
Delay. Electr. (glob. action, low fossil f. prices)	25	42	57	62	92	136	245
Delay. CCS (glob. action, low fossil f. prices)	25	39	62	69	100	218	370
Delay. Clim. Act. (frag. action, ref. fossil f. prices)	16.5	20	36	65	131	207	250
* For reference only ETS carbon price is represented							

Source: PRIMES, GAINS

Table 32 GHG emission profile per sector different reference and decarbonisation scenarios

Reference (frag. action, ref. fossil f. prices)					
GHG vs 1990	**2005**	**2020**	**2030**	**2040**	**2050**
Total	**-7%**	**-22%**	**-29%**	**-36%**	**-39%**
Sectors					
Power (CO2)	-7%	-27%	-39%	-61%	-69%
Industry (CO2)	-20%	-31%	-33%	-35%	-34%
Transport (incl. aviation, excl. maritime) (CO2)	30%	31%	24%	24%	24%

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[182] US EIA: Annual Energy Outlook 2010

Transport (excl. aviation, excl. maritime) (CO2)	25%	20%	12%	11%	10%
Residential and services (CO2)	-6%	-20%	-33%	-39%	-45%
Non CO2 emissions	-25%	-45%	-49%	-47%	-47%
Effect. Techn. (glob. action, low fossil f. prices)					
GHG vs 1990	**2005**	**2020**	**2030**	**2040**	**2050**
Total	**-7%**	**-25%**	**-40%**	**-62%**	**-80%**
Sectors					
Power (CO2)	-7%	-34%	-64%	-87%	-98%
Industry (CO2)	-20%	-32%	-35%	-59%	-84%
Transport (incl. aviation, excl. maritime) (CO2)	30%	28%	12%	-31%	-61%
Transport (excl. aviation, excl. maritime)	25%	16%	-2%	-45%	-70%
Residential and services (CO2)	-6%	-24%	-37%	-62%	-88%
Non CO2 emissions	-25%	-47%	-54%	-55%	-60%
Effect. Techn. (frag. action, ref. fossil f. prices)					
GHG vs 1990	**2005**	**2020**	**2030**	**2040**	**2050**
Total	**-7%**	**-26%**	**-41%**	**-61%**	**-80%**
Sectors					
Power (CO2)	-7%	-34%	-61%	-82%	-97%
Industry (CO2)	-20%	-32%	-36%	-55%	-84%
Transport (incl. aviation, excl. maritime) (CO2)	30%	25%	7%	-36%	-64%
Transport (excl. aviation, excl. maritime)	25%	15%	-5%	-47%	-71%
Residential and services (CO2)	-6%	-25%	-42%	-67%	-90%
Non CO2 emissions	-25%	-47%	-54%	-53%	-58%
Delay. CCS (glob. action, low fossil f. prices)					
GHG vs 1990	**2005**	**2020**	**2030**	**2040**	**2050**
Total	**-7%**	**-25%**	**-40%**	**-61%**	**-82%**
Sectors					
Power (CO2)	-7%	-34%	-63%	-76%	-99%
Industry (CO2)	-20%	-32%	-34%	-67%	-87%
Transport (incl. aviation, excl. maritime) (CO2)	30%	28%	12%	-33%	-64%
Transport (excl. aviation, excl. maritime)	25%	16%	-2%	-46%	-74%
Residential and services (CO2)	-6%	-24%	-37%	-63%	-90%
Non CO2 emissions	-25%	-47%	-54%	-56%	-63%
Delay. Electr. (glob. action, low fossil f. prices)					
GHG vs 1990	**2005**	**2020**	**2030**	**2040**	**2050**
Total	**-7%**	**-26%**	**-40%**	**-62%**	**-80%**
Sectors					
Power (CO2)	-7%	-36%	-68%	-92%	-99%
Industry (CO2)	-20%	-32%	-35%	-65%	-85%
Transport (incl. aviation, excl. maritime) (CO2)	30%	29%	20%	-17%	-54%
Transport (excl. aviation, excl. maritime)	25%	18%	8%	-28%	-61%
Residential and services (CO2)	-6%	-24%	-37%	-62%	-89%

Non CO2 emissions	-25%	-47%	-54%	-56%	-62%
Effect. Techn. + lower EII effort (frag. action, ref. fossil f. prices)					
GHG vs 1990	**2005**	**2020**	**2030**	**2040**	**2050**
Total	**-7%**	**-25%**	**-40%**	**-59%**	**-74%**
Sectors					
Power (CO2)	-7%	-34%	-62%	-83%	-98%
Industry (CO2)	-20%	-31%	-33%	-44%	-54%
Transport (incl. aviation, excl. maritime) (CO2)	30%	25%	7%	-35%	-64%
Transport (excl. aviation, excl. maritime)	25%	15%	-5%	-47%	-71%
Residential and services (CO2)	-6%	-25%	-42%	-67%	-90%
Non CO2 emissions	-25%	-47%	-54%	-53%	-58%
Reference (frag. action, high fossil f. prices)					
GHG vs 1990	**2005**	**2020**	**2030**	**2040**	**2050**
Total	**-7%**	**-22%**	**-34%**	**-41%**	**-46%**
Sectors					
Power (CO2)	-7%	-27%	-33%	-50%	-61%
Industry (CO2)	-20%	-31%	-37%	-38%	-36%
Transport (incl. aviation, excl. maritime) (CO2)	30%	31%	6%	-9%	-19%
Transport (excl. aviation, excl. maritime) (CO2)	25%	20%	0%	-16%	-28%
Residential and services (CO2)	-6%	-20%	-47%	-53%	-57%
Non CO2 emissions	-25%	-45%	-49%	-47%	-47%
Effect. Techn. (frag. action, high fossil f. prices)					
GHG vs 1990	**2005**	**2020**	**2030**	**2040**	**2050**
Total	**-7%**	**-26%**	**-44%**	**-60%**	**-79%**
Sectors					
Power (CO2)	-7%	-34%	-54%	-74%	-93%
Industry (CO2)	-20%	-32%	-39%	-51%	-84%
Transport (incl. aviation, excl. maritime) (CO2)	30%	25%	-9%	-45%	-67%
Transport (excl. aviation, excl. maritime)	25%	15%	-17%	-54%	-74%
Residential and services (CO2)	-6%	-25%	-53%	-73%	-91%
Non CO2 emissions	-25%	-47%	-54%	-53%	-56%
Reference (frag. action, oil shock)					
GHG vs 1990	**2005**	**2020**	**2030**	**2040**	**2050**
Total	**-7%**	**-22%**	**-34%**	**-38%**	**-44%**
Sectors					
Power (CO2)	-7%	-27%	-34%	-49%	-62%
Industry (CO2)	-20%	-31%	-37%	-34%	-33%
Transport (incl. aviation, excl. maritime) (CO2)	30%	31%	6%	-3%	-14%
Transport (excl. aviation, excl. maritime)	25%	20%	-1%	-10%	-24%
Residential and services (CO2)	-6%	-20%	-47%	-44%	-48%
Non CO2 emissions	-25%	-45%	-49%	-47%	-47%
Effect. Techn. (frag. action, oil shock)					

GHG vs 1990	**2005**	**2020**	**2030**	**2040**	**2050**
Total	**-7%**	**-26%**	**-44%**	**-59%**	**-79%**
Sectors					
Power (CO2)	-7%	-34%	-55%	-76%	-95%
Industry (CO2)	-20%	-32%	-40%	-50%	-83%
Transport (incl. aviation, excl. maritime) (CO2)	30%	25%	-9%	-41%	-66%
Transport (excl. aviation, excl. maritime)	25%	15%	-17%	-50%	-73%
Residential and services (CO2)	-6%	-25%	-53%	-69%	-90%
Non CO2 emissions	-25%	-47%	-54%	-53%	-56%
Delay. Clim. Act. (glob. action, low fossil f. prices)					
GHG vs 1990	**2005**	**2020**	**2030**	**2040**	**2050**
Total	**-7%**	**-23%**	**-33%**	**-71%**	**-83%**
Sectors					
Power (CO2)	-7%	-30%	-53%	-97%	-100%
Industry (CO2)	-20%	-31%	-31%	-74%	-88%
Transport (incl. aviation, excl. maritime) (CO2)	30%	30%	16%	-39%	-70%
Transport (excl. aviation, excl. maritime)	25%	18%	2%	-51%	-76%
Residential and services (CO2)	-6%	-20%	-27%	-68%	-90%
Non CO2 emissions	-25%	-45%	-49%	-59%	-63%
Delay. Clim. Act. (frag. action, ref. fossil f. prices)					
GHG vs 1990	**2005**	**2020**	**2030**	**2040**	**2050**
Total	**-7%**	**-23%**	**-35%**	**-70%**	**-83%**
Sectors					
Power (CO2)	-7%	-30%	-52%	-94%	-99%
Industry (CO2)	-20%	-31%	-33%	-74%	-87%
Transport (incl. aviation, excl. maritime) (CO2)	30%	27%	14%	-38%	-70%
Transport (excl. aviation, excl. maritime)	25%	16%	2%	-48%	-76%
Residential and services (CO2)	-6%	-21%	-34%	-71%	-91%
Non CO2 emissions	-25%	-45%	-49%	-57%	-62%

Source: PRIMES, GAINS

7.11. Sectoral changes in average yearly total investments and fuel expenses

Industry

The 5 energy intensive sectors, as described in chapter 5.2.7 take 2/3rd of investments in energy related capital come from these 5 industries. In total, investments for the whole industry increase in the effective technologies scenarios with less than the achieved reductions through fuel and electricity expenses, certainly in case of global action and low fossil fuel prices. When CCS is included this picture becomes more balanced but on average fuel and electricity expense reductions are higher than investment and CCS expenditures increases.

Table 33: Average yearly total investments in energy related capital goods, CCS expenditures and fuel expenses in industry

Total average yearly energy investments Industry	11-20	21-30	31-40	41-50	Average
Reference (frag. action, ref. fossil f. prices)	19	19	19	20	19
Effect. Techn. (frag. action, ref. fossil f. prices)	19	19	22	31	23
Effect. Techn. (glob. action, low fossil f. prices)	19	18	19	28	21
Delay. Clim. Act. (frag. action, ref. fossil f. prices)	18	19	25	32	23
Total average yearly fuel and electricity expenses Industry	**11-20**	**21-30**	**31-40**	**41-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	209	276	311	356	288
Effect. Techn. (frag. action, ref. fossil f. prices)	210	274	286	338	277
Effect. Techn. (glob. action, low fossil f. prices)	207	255	246	275	246
Delay. Clim. Act. (frag. action, ref. fossil f. prices)	209	272	286	334	275
Total average yearly CCS expenses Industry	**11-20**	**21-30**	**31-40**	**41-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	0	0	0	0	0
Effect. Techn. (frag. action, ref. fossil f. prices)	0	0	1	9	3
Effect. Techn. (glob. action, low fossil f. prices)	0	0	3	12	4
Delay. Clim. Act. (frag. action, ref. fossil f. prices)	0	0	7	14	5

Source: PRIMES, GAINS

With an oil crisis, energy related investments in both reference and decarbonisation scenarios increase sharply by 2030. With the temporary oil shock they decrease later to slightly below reference levels, however in case of remaining high fossil fuel prices they remain higher for the reference case. Relative fuel and electricity savings from decarbonisation become higher in case of an oil shock or high fossil fuel prices compared to the reference case. Finally CCS penetration and related costs are lower due to increased reductions in other fossil fuel intensive sectors which reduce the need for additional reductions in for instance the industry sectors.

Table 34: Average yearly total investments in energy related capital goods, CCS expenditures and fuel expenses in industry in case of an oil shock or high fossil fuel prices

Total average yearly energy investments Industry	11-20	21-30	31-40	41-50	Average
Reference (frag. action, ref. fossil f. prices)	19	19	19	20	19
Reference (frag. action, oil shock)	19	29	18	19	21
Reference (frag. action, high fossil f. prices)	19	29	20	21	22
Effect. Techn. (frag. action, ref. fossil f. prices)	19	19	22	31	23
Effect. Techn. (frag. action, oil shock)	19	29	19	28	24
Effect. Techn. (frag. action, high fossil f. prices)	19	28	22	32	25
Total average yearly fuel and electricity expenses Industry	**11-20**	**21-30**	**31-40**	**41-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	209	276	311	356	288
Reference (frag. action, oil shock)	209	304	363	363	310
Reference (frag. action, high fossil f. prices)	209	303	403	445	340
Effect. Techn. (frag. action, ref. fossil f. prices)	210	274	286	338	277
Effect. Techn. (frag. action, oil shock)	210	301	332	343	296
Effect. Techn. (frag. action, high fossil f. prices)	210	300	362	397	317
Total average yearly CCS expenses Industry	**11-20**	**21-30**	**31-40**	**41-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	0	0	0	0	0
Reference (frag. action, oil shock)	0	0	0	0	0

Reference (frag. action, high fossil f. prices)	0	0	0	0	0
Effect. Techn. (frag. action, ref. fossil f. prices)	0	0	1	9	3
Effect. Techn. (frag. action, oil shock)	0	0	0	7	2
Effect. Techn. (frag. action, high fossil f. prices)	0	0	0	5	1

Source: PRIMES, GAINS

Residential (households) and tertiary

Investments in energy related capital (e.g. boilers and electric appliances) are more or less stable for the reference scenarios, with some increases by the end of the modelled period (see Table 35). This changes dramatically for the effective technology cases, with investment needs increasing by around 30% over the next ten years compared to reference case or almost 200 billion €, and then further multiplying over the period 2020 – 2050 by a factor of 4. In total, the investments required for the effective technology scenarios increase to around € 200 billion per year by 2050 compared to the reference scenario. On average annual investments in this sector over the whole period are around € 80 billion higher than the reference case.

But this in turn drives significant reductions for the expenses of fuel and electricity, by about € 70 to 100 billion for fuels by 2050 and around € 90 to 120 billion for electricity. On average the annual fuel and electricity expenses decrease in the effective technology scenarios over the whole period with around € 70 to 105 billion.

Table 35: Average yearly total investments in energy related goods and fuel expenses in the residential and tertiary sector

Total average yearly energy related investments Residential + Tertiary	**11-20**	**21-30**	**31-40**	**41-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	47	48	47	67	52
Effect. Techn. (frag. action, ref. fossil f. prices)	66	68	123	269	131
Effect. Techn. (glob. action, low fossil f. prices)	65	64	111	263	126
Delay. Clim. Act. (frag. action, ref. fossil f. prices)	50	48	196	258	138
Total average yearly fuel expenses Residential + Tertiary	**11-20**	**21-30**	**31-40**	**41-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	229	275	283	293	270
Effect. Techn. (frag. action, ref. fossil f. prices)	222	253	246	223	236
Effect. Techn. (glob. action, low fossil f. prices)	220	236	211	189	214
Delay. Clim. Act. (frag. action, ref. fossil f. prices)	228	272	243	200	236
Total average yearly electricity expenses Residential + Tertiary	**11-20**	**21-30**	**31-40**	**41-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	294	377	423	459	388
Effect. Techn. (frag. action, ref. fossil f. prices)	291	369	387	368	354
Effect. Techn. (glob. action, low fossil f. prices)	291	361	366	336	339
Delay. Clim. Act. (frag. action, ref. fossil f. prices)	292	371	386	358	352

Source: PRIMES, GAINS

Additional investments due to an oil shock or high fossil fuel prices compared to the reference are similar to the additional investments undertaken in case of climate action with reference fossil fuel prices (see figure below). This of course means that total investments remain significantly higher in case of action on climate change. For fuel and electricity expenses, the increases in the absolute amount of the oil bill on average are similar in case of action or no action no climate on climate change, but remain on average significantly below the reference level in case of action on climate change even with high energy fossil fuel prices, whereas in case of no action they increase significantly above this original reference level.

Table 36: Average yearly total investments in energy related goods and fuel expenses in the residential and tertiary sector in scenarios with an oil shock or high fossil fuel prices

Total average yearly energy related investments Residential + Tertiary	**11-20**	**21-30**	**31-40**	**41-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	47	48	47	67	52
Reference (frag. action, oil shock)	47	80	42	63	58
Reference (frag. action, high fossil f. prices)	47	80	49	71	62
Effect. Techn. (frag. action, ref. fossil f. prices)	66	68	123	269	131
Effect. Techn. (frag. action, oil shock)	66	97	106	255	131
Effect. Techn. (frag. action, high fossil f. prices)	66	94	122	256	135
Total average yearly fuel expenses Residential + Tertiary	**11-20**	**21-30**	**31-40**	**41-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	229	275	283	293	270
Reference (frag. action, oil shock)	229	292	311	292	281
Reference (frag. action, high fossil f. prices)	229	292	339	344	301
Effect. Techn. (frag. action, ref. fossil f. prices)	222	253	246	223	236
Effect. Techn. (frag. action, oil shock)	222	270	274	226	248
Effect. Techn. (frag. action, high fossil f. prices)	222	271	292	245	257
Total average yearly electricity expenses Residential + Tertiary	**11-20**	**21-30**	**31-40**	**41-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	294	377	423	459	388
Reference (frag. action, oil shock)	293	389	439	451	393
Reference (frag. action, high fossil f. prices)	294	389	459	492	408
Effect. Techn. (frag. action, ref. fossil f. prices)	291	369	387	368	354
Effect. Techn. (frag. action, oil shock)	292	379	406	371	362
Effect. Techn. (frag. action, high fossil f. prices)	292	379	420	393	371

Source: PRIMES, GAINS

Transport

Yearly average transport investments increase substantially for the reference case, from less than € 700 billion to more than € 800 billion by 2050. But this increase is magnified for the decarbonisation scenario; with yearly investment requirements upwards of € 1100 billion, or around € 300 billion more than in the reference scenario in 2050.

There are significantly higher reductions in fuel bills compared to the increase in investments within the effective technology decarbonisation scenarios with global action, of around € 430 billion and there are similar reductions in fuel bills compared to the increase in investments for the effective technology decarbonisation scenarios with fragmented action scenarios. However the electricity bill rises for transport after 2030 due to electrification, adding less than € 100 billion per year in the period 2030-2040 and around € 150 billion in the period 2040-2050.

Table 37: Average yearly total investments and fuel expenses in transport

Total average yearly investments Transport	**11-20**	**21-30**	**31-40**	**41-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	669	774	819	830	773
Effect. Techn. (frag. action, ref. fossil f. prices)	693	843	1022	1140	924

Effect. Techn. (glob. action, low fossil f. prices)	690	849	1048	1152	935
Delay. Clim. Act. (frag. action, ref. fossil f. prices)	693	843	1027	1251	953
Total average yearly fuel expenses Transport	**11-20**	**21-30**	**31-40**	**41-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	497	619	667	728	628
Effect. Techn. (frag. action, ref. fossil f. prices)	487	546	493	435	490
Effect. Techn. (glob. action, low fossil f. prices)	473	488	383	296	410
Delay. Clim. Act. (frag. action, ref. fossil f. prices)	491	573	528	444	509
Total average yearly electricity expenses Transport	**11-20**	**21-30**	**31-40**	**41-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	9	10	11	11	10
Effect. Techn. (frag. action, ref. fossil f. prices)	12	46	108	168	84
Effect. Techn. (glob. action, low fossil f. prices)	12	46	103	156	79
Delay. Clim. Act. (frag. action, ref. fossil f. prices)	10	30	90	166	74

Source: PRIMES, GAINS

Investments in the effective technology decarbonisation scenarios do not change significantly when comparing the scenarios with and without an oil shock or high fossil fuel prices. This is not true for the reference scenarios with the oil shock or high fossil fuel prices which incur significant additional investment requirements, amounting to around 170 billion in the period 2040 – 2050, or more than half of what by the would need to be invested additionally in the effective technology scenarios.

Combined fuel and electricity bills increase significantly with an oil shock or high fossil fuel price scenario. In case of no action and high fossil fuel prices, the combined fuel and electricity bill would have increase by the period 2040 – 2050 with more than € 250 billion compared to the reference situation. In case action on climate change would have been taken, this increase compared to reference would have been limited to a bit more than € 80 billion.

Table 38: Average yearly total investments and fuel expenses in transport in scenarios with an oil shock or high fossil fuel prices

Total average yearly investments Transport	**11-20**	**21-30**	**31-40**	**41-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	669	774	819	830	773
Reference (frag. action, oil shock)	666	792	863	1006	832
Reference (frag. action, high fossil f. prices)	666	789	856	999	828
Effect. Techn. (frag. action, ref. fossil f. prices)	693	843	1022	1140	924
Effect. Techn. (frag. action, oil shock)	693	880	1005	1107	921
Effect. Techn. (frag. action, high fossil f. prices)	693	879	1018	1125	929
Total average yearly fuel expenses Transport	**11-20**	**21-30**	**31-40**	**41-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	497	619	667	728	628
Reference (frag. action, oil shock)	497	721	826	693	684
Reference (frag. action, high fossil f. prices)	497	722	945	925	772
Effect. Techn. (frag. action, ref. fossil f. prices)	487	546	493	435	490
Effect. Techn. (frag. action, oil shock)	487	633	656	492	567
Effect. Techn. (frag. action, high fossil f. prices)	487	633	741	647	627
Total average yearly electricity expenses Transport	**11-20**	**21-30**	**31-40**	**41-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	9	10	11	11	10
Reference (frag. action, oil shock)	9	12	32	67	30
Reference (frag. action, high fossil f. prices)	9	12	33	70	31
Effect. Techn. (frag. action, ref. fossil f. prices)	12	46	108	168	84
Effect. Techn. (frag. action, oil shock)	12	47	111	170	85

Effect. Techn. (frag. action, high fossil f. prices)	12	47	114	177	87

Source: PRIMES, GAINS

Power Sector

What is probably most notable from the investments in the power sector is that they are lower than the additional investment requirements in the transport, residential and tertiary sectors. This underlines the crucial importance of energy efficiency measures and fuel switching in these sectors, not just the power sector. Nonetheless investments are still significant, increases of around 40% compared to reference scenario over the whole period or around € 40 billion more by 2050.

By 2050, fuel expenses have decreased by around € 60 billion in the effective technology scenario with global action and by about € 25 billion in the effective technology scenario with fragmented action.

Table 39: Average yearly total investments and fuel expenses in the power sector (includes steam)

Total average yearly investments Power Sector	**11-20**	**21-30**	**31-40**	**41-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	81	75	85	98	85
Effect. Techn. (frag. action, ref. fossil f. prices)	85	110	131	140	116
Effect. Techn. (glob. action, low fossil f. prices)	84	108	128	137	114
Delay. Clim. Act. (frag. action, ref. fossil f. prices)	84	101	140	135	115
Total average yearly fuel expenses Power Sector	**11-20**	**21-30**	**31-40**	**41-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	126	163	178	202	167
Effect. Techn. (frag. action, ref. fossil f. prices)	124	157	165	176	155
Effect. Techn. (glob. action, low fossil f. prices)	124	147	143	141	139
Delay. Clim. Act. (frag. action, ref. fossil f. prices)	125	160	160	167	153

Source: PRIMES, GAINS

Investments are resilient in the effective technology scenario with oil shock or high fossil fuel price scenarios, while they increase in the reference cases with oil shock or high fossil fuel price scenarios. Fuel costs also increase less in the effective technology decarbonisation scenarios than they do in case of no action. Compared to reference, fuel costs remain lower in the effective technology scenarios, even with an oil shock or high fossil fuel price scenarios. This is not the case with no action.

Table 40: Average yearly total investments and fuel expenses in the power sector (includes steam) in scenarios with an oil shock or high fossil fuel prices

Total average yearly investments Power Sector	**11-20**	**21-30**	**31-40**	**41-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	81	75	85	98	85
Reference (frag. action, oil shock)	81	82	89	118	93
Reference (frag. action, high fossil f. prices)	81	83	103	122	98
Effect. Techn. (frag. action, ref. fossil f. prices)	85	110	131	140	116
Effect. Techn. (frag. action, oil shock)	85	113	128	141	117
Effect. Techn. (frag. action, high fossil f. prices)	85	114	133	141	118
Total average yearly fuel expenses Power Sector	**11-20**	**21-30**	**31-40**	**41-50**	**Average**
Reference (frag. action, ref. fossil f. prices)	126	163	178	202	167

Reference (frag. action, oil shock)	126	176	201	211	179
Reference (frag. action, high fossil f. prices)	126	175	215	240	189
Effect. Techn. (frag. action, ref. fossil f. prices)	124	157	165	176	155
Effect. Techn. (frag. action, oil shock)	124	169	183	178	164
Effect. Techn. (frag. action, high fossil f. prices)	124	169	195	197	171

Source: PRIMES, GAINS

7.12. Further information on the main assumptions and drivers of the agriculture scenarios for the EU

The CAPRI model is used to estimate agriculture production. For the purpose of the 2050 roadmap the baseline methodology was revised and specific assumptions were made. As far as the Common Agriculture Policy (CAP) is concerned, the policy tools taken into account are limited to those of the current regime (including changes from 2008 health check), consequently the future changes in the CAP to be introduced and their potential positive impact are not assessed in this modelling exercise. The key revisions compared to the baseline delivered in 2009 were:

- Use of long run expert projections from FAO and IFPRI[183] on the agricultural markets up to 2050

- Extrapolation of fertiliser projections from EFMA up to 2050 and merge of these extrapolations with the information included in historic trends. In EU15 these trends tend to point downwards, reflecting increasing environmental awareness and efficiency improvements. In the New MS, these trends often slope upwards, reflecting the catching up process after the transition phase.

Other changes were a greater weight for national expert information as it was put forward in the consultation process from a subset of MS (all from EU15).

In addition, specific assumptions were made in terms of policy and market assumptions. The most important changes from the CAP Health Check were implemented: abandonment of set aside, expiry of the milk quota in 2015, modifications to pillar 1 payments (increased modulation, further decoupling). The possible premium reallocations according to Article 69 and national preferences have not been implemented (presumably less important). The table below summarizes the **policy assumptions** are the following:

Table 41: Core policy assumptions for the August 2009 CAPRI baseline

Instrument	*Base year*	*Baseline*
Direct payments EU-15	As defined in agenda 2000	Health check implemented
Direct payments EU-10	Partly	Health check implemented
Direct payments BUR	None	Health check implemented
Set aside EU-15	10%	Abolished (Health Check)
Set-aside EU-10 and BUR	None	Abolished (Health Check)
Article 69 payments	None	Implemented
Modulation	None	Health check implemented
Decoupling	Yes	Health check implemented

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[183] FAO (2006) World agriculture: towards 2030/2050, Global Prospective Unit, Rome. IFPRI (2009) Agriculture at a Crossroads, IAASTD global report,.

Sugar Quotas	Yes	Reform 2006 implemented
Dairy quotas	Yes	Expiry 2015 (Health Check)
Tariffs, Tariff Rate Quotas	Yes	Maintained
Export Subsidies	Yes	Maintained

Market assumptions are exogenous macroeconomic developments, but also specific assumptions on biofuel production from agricultural feed stocks or on mineral fertiliser use. Furthermore, the CAPRI baseline *tries* to stay close to the percentage changes of corresponding variables from external sources of information.

1. External projections on agricultural markets and activities as prepared by various agencies:

    a) Most important are for the medium run perspective (up to 2020) the projections from a baseline prepared with the AGLINK model. The CAPRI baseline of September 2010 uses the AGLINK baseline of 2009.

    b) This is supplemented, again for the horizon up to 2020, with projections from FAPRI (also prepared in 2009)

    c) For the long run perspective (up to 2050) increasing weight is given to the projections by FAO (World agriculture: towards 2030/2050, Global Prospective Unit, 2006) and IFPRI (Agriculture at a Crossroads, IAASTD global report, 2009). Whereas the medium run evolution of agriculture was typically stagnating or even declining in some sectors, in the long run the global growth of demand would also stimulate EU production according to FAO and IFPRI. In several cases this implies a turning point in terms of supply and activity levels after 2020.

2. National expert information on animal numbers of several MS (all from EU15) has been considered suitable to supplement the AGLINK projections.

3. Fertiliser projections for the medium run have been aligned with 2009 EFMA projections. These have been extrapolated after 2018 with a logistic extrapolation formula to obtain a historical projection. However, projections after 2020 were increasingly relying on the historical evolution of summary CAPRI indicators for farmers' behaviour (over-fertilisation factor and organic availability factor). It was assumed that underlying efficiency improvements and catching up processes for mineral fertiliser use in the new MS would continue within some limits (minimal efficiency improvement everywhere but not beyond technical frontiers.

4. The PRIMES baseline (the reference projection up to 2050) is the source for macroeconomic assumptions, and biofuel feedstock evolutions. Of these the former only add a small modification to the CAPRI baseline.

The key assumptions under the 'market assumptions' heading are in the table below

Table 42 Core market assumptions for the August 2009 CAPRI baseline

Variable	*Source*	*Determines…*
Macroeconomics	PRIMES for EU,	Adjustments of demand

(inflation, GDP)	FAO/IFPRI elsewhere	relative to external forecasts
Demographics	PRIMES for EU, FAO/IFPRI elsewhere	Adjustments of demand relative to external forecasts
EU market information available from DG Agri (Aglink) or national experts	Aglink / national expert projections	… target values for CAPRI estimator (e.g. beef supply)
EU market information unavailable from DG Agri (Aglink)	Constrained trends	… related variables (e.g. suckler cow herd)
World markets	FAO/IFPRI FAPRI plus data consolidation	… international market variables, position of behavioural functions, starting point for simulations
Yields	Aglink or international agencies merged with historical trends	…market results, position of behavioural functions, starting point for simulations
Fertiliser use	EFMA projections and historical trends	… environmental indicators, farm income

7.13. Examples of innovative policy schemes to spur energy related investments for households[184]

- In France, a 0% interest rate loan for home retrofitting energy efficiency projects up to € 30,000 have been introduced and low VAT rates supported the refurbishments. The ' Green loan for social housing' aims to improve the energy performance of the social housing. From 2009 to 2020 € 1.2 billion of loans with a fixed rate of 1.9% on 15 years is available to finance the restoration of the first 100,000 social housing units. To accelerate the development of the renewable energy market in France, the FIDEME scheme launched in 2003 foresees a €45m public-private fund, addressing the debt-equity gap in the sector to attract lenders. The leverage structure mobilised 20 times the public funding.

- The German public bank KfW operates the German CO2 Building Rehabilitation Programme (1996 – ongoing). The objective is to support investment in building energy renovation. Preferential loans are provided for refurbishment measures aimed at reducing energy consumption, via local commercial banks. An additional repayment grant is given if a more ambitious efficiency standard is achieved. Between 1996 and 2004, € 6bn in loans were provided; 57 million m2 floor area in existing buildings renovated; The budget was € 4bn (in loans) from 2006 to 2009, increasing to € 2bn per year in the 2010-11. Through the implementation of the programme, around 220,000 new jobs were created. It was further estimated that the various KfW programmes for buildings had a combined impact of emission reductions of around 1 Mt CO2 emission reduction per year. From 2007 to 2009

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[184] Sources: UNEP & SEFI (2008), SEF Alliance and Bloomberg New Energy Finance (2010), BASE - Basel Agency for Sustainable Energy (2006), Clausnitzer et al (2010), Klinckenberg Consultants (2010)

the KfW grants offered grants as an alternative to the loans. The support varied between 5% and 17.5% of the renovation costs.

– The Carbon Trust, a not for dividend company created by the UK government, helps businesses and public organisations to reduce their greenhouse gas emissions and to support low carbon technologies. Its Incubator Programme runs technology accelerators through a £20m Carbon Trust Venture Capital Fund that leverages private sector investments. In terms of leverage, 11 companies have raised £14.6 million private sector investment since joining the incubators, two of which are venture capital investments. In total, the Carbon Trust has invested £26.8 million in early stage UK clean energy businesses and has leveraged £138.9 million of private sector investment. This implies a leverage ratio of 1 to 5. A planned UK Green Investment Bank could play a significant role in unlocking further private capital through equity and debt finance. With a capital base of £100-400 million, an additional £3 billion of finance can be unlocked. The Chancellor announced in November 2010 in the spending review that the green investment bank will be funded with £1 billion.

– In the Czech Republic, the Green Savings Programme support equipment installed in 250,000 residential houses. The programme is expected to cost approx. € 1bn over the programme lifetime. By 2012, 250,000 houses should have been improved, 1.1 Mt CO2 emission annually reduced and 30,000 jobs created or retained. The cost effectiveness is expected to be € 20/tCO2.

– In Belgium, energy efficiency measures of private households are supported through a combination of reduced VAT rates, subsidies and income tax reductions. Since 2000, the VAT rate for restoring works and transformation works for all dwellings has been reduced from 21 to 6% for dwellings older than 5 years. This measure may be cumulated with significant yearly the tax reductions of up to 40% of the investment in energy related improvements in housing, with a maximum tax reduction per year of € 2770 in 2010. This is further accommodated with several specific limited subsidies for energy saving investments.

– Bulgaria has introduced a building tax exemption for up to 10 years to owners of buildings who have obtained energy performance certificates of a higher class. The Bulgarian Energy Efficiency and Renewable Energy Credit Line (BEERECL) is an EBRD facility helping seven Bulgarian banks to lend to private sector industrial energy efficiency and renewable energy projects. Besides the credit line, development assistance is also provided for project development services including energy auditing, financial analysis, risk assessment, formulation of loan applications and deal structuring, The facility is partly supported by the nuclear power plant Kozloduy International Decommissioning Support Fund (KIDSF). An innovative component is that the project sponsors (borrowers) receive an incentive grant from the KIDSF upon successful project commissioning, 15% of the loan for efficiency projects and 20% for renewables.

– The Slovenian financial stimulation for energy efficiency renovation and sustainable buildings of new buildings (2008-2016) promotes the implementation of energy audits, feasibility studies, investment and project documentation for energy efficiency and renewable energy. The subsidy is limited to 2.5% of the proposed investment.

– The $163m funds provided by the Global Environmental Facility (GEF) between 2003 and 2006 are estimated to have leveraged seven times more investment through co-financing.

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