Review of the Impact Assessment for a 2030 climate and energy policy framework

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Summary

On January 22, 2014, the European Commission (EC) published its proposal for a 2030 framework for climate and energy policies in Europe. Early decision making about the long-term framework would give certainty to investors and stimulate long-term innovation and demand for low-carbon technologies, thus supporting progress towards building a more competitive, sustainable and energy-secure European economy. In addition, elements of the 2030 framework are important in the upcoming international climate negotiations and will provide an important contribution to the 2015 UN conference in Paris (known as the 21st Conference of the Parties, or COP21), where countries will join negotiations around a new international climate agreement.

The EC proposes to use a single greenhouse gas target in 2030 of -40% reduction domestically compared to 1990. The sectors covered by the EU Emissions Trading System (ETS) would have to deliver a reduction of 43% in GHG in 2030 and the non-ETS sector a reduction of 30% compared to 2005. The EC further proposes to accompany the single GHG target with a renewable energy target for the EU as a whole of 27% renewable energy in gross final energy consumption. Each EU Member State would make clear in so-called National Energy Plans its commitment towards renewable energy, indicating how this would be delivered, taking into account the need to comply with competition and State Aid rules to avoid market distortions and ensure cost-effectiveness. The EC proposed the formulation of new energy efficiency policies later in 2014 when the evaluation of the current Energy Efficiency Directive has been finalized. Finally, the EC has proposed some additional new features, such as a market stability reserve for the ETS and the development of new indicators regarding energy security, the internal energy market, and energy costs for energy-intensive industries.

The EC proposal rests, amongst others, on the Impact Assessment that accompanies it. This research paper reviews the Impact Assessment with special emphasis on:
- methods employed;
- impacts covered;
- coverage of scenarios;
- comparison of costs and benefits.

The Impact Assessment (IA) is an impressive piece of work and is superior in detail of analysis and quantification of impacts compared to previous impact assessments such as the one accompanying the 2008 20-20-20 framework or the Low Carbon Roadmap. In this report we analyse the IA in detail. Despite the overall good quality of the work, we identified three major weaknesses, which we explore in more detail throughout this report:

1. In Chapter 2 we analyse the linkages between the various models used in the IA. In our view these have been poorly developed and/or are not well described. We suspect the IA is the result of an analysis of 9 different models with limited attention to feedback loops between these models. The IA is not clear on the extent to which various feedback mechanisms have properly been modelled. For example, CO_2 reduction efforts (unilateral or global) will have an impact on energy prices, but these seem to be exogenous to the models used. Similarly, adaptation costs should be considered to have an economic impact contingent on the climate action taken.

2. In Chapter 3 we analyse the cost and benefits of different scenarios in a standardised way. The IA does compare costs and benefits to identify the impacts, but does not use a standardised cost-benefit framework to compare costs with benefits. This makes it hard for policy makers to decide on the overall welfare effects of different scenarios. In our analysis we have compared the costs and benefits of each of the scenarios and this indicates that the most ambitious scenario resulting in 45% GHG reduction is actually the scenarios generating the highest benefits for social welfare.[1]

3. In Chapter 4 we assess a ‘balanced scenario’ that consists of a combination of elements of the analysed scenarios in the IA. The IA seems to have chosen scenarios that may not reflect the full (economic and technological) potential to reduce CO_2 emissions. Our analysis shows that the most ambitious GHG reduction scenario in the present IA actually resembles the ‘cost effective’ scenario in the Low Carbon Roadmap and the range of investigated scenarios in this IA has probably been scaled down in ambition compared to the reduction efforts identified as ‘cost-optimal’ in the Low Carbon Roadmap. This is for example evidenced by the fact that, in this IA, the EU ETS price in several of the more ambitious reduction scenarios are substantially below the € 35/tCO_2 in the Reference Scenario (to values as low as € 11/tCO_2 in the policy option scenarios).

   Based on the results of the IA we have estimated the potential GHG reductions if several elements of various scenarios had been combined in a scenario which we label as the ‘balanced scenario’. Our analysis indicates that a scenario with a 35% renewable energy target, ambitious energy efficiency policies, and a target for the EU ETS that aims to reach a price of € 35/tCO_2 (identical to the Reference Scenario) would result in a GHG emission reduction of almost 49%. As this scenario is constructed using components included in the modelled scenarios this would not imply excessive costs or unreasonable technological (or economic) demands.

   Therefore, we believe that it would be worthwhile for the EC to consider additional scenarios in their IA that will yield larger GHG reductions and at the same time still make sense economically.

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[1] Social welfare is defined in Chapter 3.

1 Introduction

1.1 The 2030 Climate and Energy Framework

The European Commission (EC) is currently developing a 2030 framework for EU climate change and energy policies. Such a framework should outline the headline targets for climate and energy policies in 2030 with the aim of offering investors a long-term time horizon for investments in energy technologies and infrastructures and low-carbon technologies. Providing clarity on the 2030 targets will give certainty to investors and stimulate long-term innovation and demand for low-carbon technologies, thus supporting progress towards building a more competitive, sustainable, and energy-secure European economy. In addition, the 2030 targets are an important element in the upcoming international climate negotiations and will provide an important element in the 2015 UN conference in Paris (known as COP15), where countries will join negotiations for a new international climate agreement.

On January 22, 2014, the EC published its proposal for the 2030 framework (COM 2014/15 final). In this document the EC proposes to use a single GHG target in 2030 of -40% reduction domestically compared to 1990. The EU level target must be shared between the ETS and what the EU Member States must achieve collectively in the sectors outside of the ETS. The ETS sector would have to deliver a reduction of 43% in GHG in 2030 and the non-ETS sector a reduction of 30%.[2] For the ETS, the annual reduction factor would be increased from the present 1.74% to 2.2% after 2020 and a Market Stability Reserve would be created to prevent the oversupply of allowances to continue after 2020.

The single GHG target is backed up by a renewable energy target of 27% renewable energy in gross final energy consumption, set at the EU level. Each Member State would describe in National Energy Plans its commitment towards renewable energy, indicating how this would be delivered taking into account the need to comply with competition and State Aid rules to avoid market distortions and ensure cost-effectiveness.

Energy efficiency, as part of the 2030 policy framework, would be formulated later in 2014 when the evaluation of the Energy Efficiency Directive (EED) has been finalized. Finally, some additional new features have been introduced, such as a market stability reserve for the ETS and the development of new indicators regarding energy security, the internal energy market, and energy costs for energy-intensive industries.

1.2 Embedding the 2030 framework in EU politics

The 2030 framework is built on two pillars. First, there is the experience of, and lessons learnt from, the 2020 framework that should feed into a more effective 2030 framework in which, for example, the EU ETS will be secured against a potential oversupply of allowances. Second, the 2030 framework should fit in the longer-term perspective set out by the EC in 2011 in three separate documents: i) the Low Carbon Roadmap 2050; ii) the Energy Roadmap

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[2] Both figures compared to 2005.

2050; and iii) the Transport White Paper. The scenarios in these roadmaps suggested that by 2030 the EU's GHG emissions would need to be reduced by 40% to be on track to reach a GHG reduction of 80-95% by 2050, consistent with the internationally agreed target to limit atmospheric warming to below 2°C.

The 2030 framework has thus not been developed in isolation but is the outcome of a long process of intensive interaction with EU Member States and the European Parliament that started in 2010 with the preparation of the 2050 Roadmaps. These Roadmaps therefore form the background for the construction of the 2030 framework. The Low Carbon Roadmap (COM (2011) 112 final) shows that prolongation of the current policies up to 2020 to 2050 would yield a reduction of -40% in 2050 compared to 1990. Moreover, current policies would already imply a reduction of -25% in 2020, thus outperforming the target of a -20% reduction. For the 2030 intermediate targets, the Low Carbon Roadmap shows that a target of -40% would be more cost-efficient than a target of -30%.

Based on these studies, the EC published a Green Paper in March 2013, summarizing questions for a public consultation that lasted until July 2013. Taking into account the views expressed by Member States, EU institutions, and stakeholders, the EC conducted an Impact Assessment (IA) to analyse the environmental, economic, and social impacts of a range of 2030 targets. The draft IA was submitted to the Impact Assessment Board (IAB) on 9 October 2013 and was discussed at the IAB hearing of 6 November. The IA was finalized and published on 22 January 2014 alongside the proposal for the 2030 framework.

1.3 Purpose of the present paper

The present paper aims to review and assess the Impact Assessment that forms the empirical basis for the 2030 policy framework. Although the decision to adopt or adjust the 2030 framework is now part of an active policy negotiation between the EU institutions, the formulation of the 2030 framework relies heavily on the accompanying IA. Therefore we review the methods that have been employed in the IA, in order to assess the strength and weaknesses of the IA. In addition, we try to undertake a comparison of costs and benefits of the various scenarios that have been formulated in the IA and investigate what potential alternative scenarios could be useful to investigate that were not included in the IA.

1.4 Content of the present paper

Chapter 2 contains a review of the IA. Chapter 3 compares the costs and benefits. Chapter 4 contains an analysis into the desirability of additional scenarios or viewpoints from the logic of the IA.

2 Review of the IA

2.1 Content of the IA

2.1.1 Set up

The IA starts in Chapter 1 with a description of the process by which it was drafted. Then, in Chapter 2 it presents a fairly extensive policy context in which the IA is embedded in EU policy plans (e.g. the Roadmap for moving to a competitive low carbon economy in 2050 and the Energy Roadmap 2050) and existing policies (e.g. the EU Emission Trading System, the Renewable Energy Directive, Energy Efficiency Directive, Fuel Quality Directive and the Effort Sharing Decision). Moreover, it embeds this into wider development regarding international climate negotiations, renewable energy policies (including capacity markets, priority grid access and revenues), and international developments in energy markets (such as the exploitation of shale gas deposits).

Chapter 2 also identifies the problems that the 2030 framework should address: the EU's medium- to long-term security of energy supplies, ensuring competitiveness (especially for industry) with increasing energy investment needs, and the need for ambitious GHG policies. Moreover, the IA analyses the risk of high-carbon lock-in and short investment horizons in current markets. The EU has the right to act to combat these problems since they affect the internal market and are transboundary in nature.

These problems are then transformed into objectives in Chapter 3.
The general objectives are to ensure progress towards a competitive, sustainable, and secure EU energy system and to meet the EU's objective to reduce GHG emissions by 80-95% in 2050 compared to 1990. The specific objectives are threefold:

- to provide more predictability and certainty for Member States and investors and reduced regulatory risk;
- to agree on the general direction of policies needed to meet climate and energy objectives in in a 2030 perspective;
- to agree on an EU position as regards 2030 GHG reductions in view of the international climate negotiations.

From this, there follows a description of operational objectives and policy coherence. The section on policy coherence is notably less well developed.

Chapter 4 addresses a detailed description of the scenarios that were used in the IA and those that were discarded *a priori* (see below for discussion).
In Chapter 5, the impacts are assessed (see below for discussion). In Chapter 6, the impacts are compared with each other (see below for discussion).
Chapter 7 can be regarded as a collection of annexes and contains, amongst other things, information regarding the Reference Scenarios, stakeholder consultation and enabling conditions.

Next we will describe Chapter 4 and 5 in more detail.

2.1.2 Scenarios in the IA

In Chapter 4 seven policy scenarios are presented, all of which are evaluated against the PRIMES Reference Scenario. The scenarios differ in ambition for greenhouse gas reductions (in 2030), the presence of enabling policies to reach the 2050 target and ambition level of EE policies and RES policies. The seven policy scenarios and the Reference Scenario are summarized in Table 1.

Table 1 Overview of EC IA scenarios

Scenario**	GHG reductions in 2030 vs. 1990	Enabling policies	Ambition level EE policies	Ambition level RES policies	ETS reduction 2030*	Non-ETS Reduction 2030*	Non CO_2 reduction 2030*	Non energy related CO_2 reduction 2030*^	Carbon price (€/tonne)^
REF-R	32.4%	No	2020stand	2020standst.			728	240	35
GHG40	40.6%	Yes	Moderate	Moderate	-11.2%	-12.8%	-26%	-7%	40
GHG40EE	40.3%	Yes	Ambitious	Moderate	-2.9%	-18.0%	-22%	**12%**	**22**
GHG40EERES30	40.7%	Yes	Ambitious	30% in 2030	-7.2%	-16.1%	-17%	**18%**	**11**
GHG45EERES35	45.1%	Yes	Ambitious	35% in 2030	-20.6%	-17.6%	-19%	**17%**	**14**
GHG35R	35.4%	No	Moderate	Moderate	-0.8%	-7.0%	-10%	**9%**	**27**
GHG37R	37.0%	No	Moderate	Moderate	-2,2%	-10.2%	-24%	-6%	35
GHG40R	40.4%	No	Moderate	Moderate	-9.7%	-13.4%	-29%	-7%	53

Source: EC, 2014.

* Relative against the Reference Scenario.

** R at the end of the scenario abbreviation stands for Reference settings, which implies that no enabling policies have been formulated (see text for explanation).

^ Figures in bold present an outcome in the policy scenarios that is less ambitious with respect to GHG reductions than in the Reference scenario.

Table 1 shows that greenhouse gas reductions range from 35 to 45% in the seven policy scenarios (and 32% in the Reference Scenario). Four of the six scenarios contain a target of about 40% reductions. The assessed reduction targets in the other scenarios are 35%, 37%, and 45%. Four of the scenarios assume the presence of enabling policies. Enabling policies are efforts across the economy to ensure a smooth transition towards a low carbon economy in 2050 (Low Carbon Economy Roadmap and the Energy 2050 Roadmap).
In practice, the enabling policies ensure the availability of necessary infrastructure, progress in R&D, and broad social acceptance of decarbonisation technologies, reducing system costs and price impacts.
The scenarios where no enabling policies have been assumed are labelled with a R at the end (Reference settings). It is important to observe that these scenarios are highly unlikely to be compatible with the targets outlined in the 2050 framework since enabling policies are a crucial element of reaching the 2050 targets.

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

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

In the constructed policy scenarios, additional reductions in the ETS (relative to the Reference Scenario) range from 0.8% (GHG35R) to 21% (GHG45EERES35). Outside the EU ETS the largest reduction relative to the reference occurs in the policy scenarios with ambitious EE policies. Two of the scenarios contain explicit targets for RES. The IA states that these scenarios have been formulated to compare the impacts of scenarios with specific RES targets with scenarios where renewables development would be driven by a GHG target. In the other scenarios, deployment of renewables will be largely driven by existing policy instruments and carbon price development.

The IA assumes in most policy scenarios a uniform carbon price in both EU ETS and non-ETS sectors. In other words, all scenarios except the GHG35R and Reference Scenario assume price equalisation between ETS and non-ETS sectors. The carbon price is dependent on supply (determined primarily by the overall target) and demand. Demand for allowances is driven by the price of allowances and the formulation of complementary RES and EE policies, which reduce demand for allowances. This explains why the carbon price is lower in scenarios with explicit RES and more ambitious EE policies (e.g. GHG40EE, GHG40EERES30 and GHG45EERES35) compared to the Reference Scenario despite the larger CO_2 reductions that are being achieved.[3]

A remarkable conclusion of our analysis is that in four of the seven policy scenarios, key elements of the proposed climate package seem to be less ambitious than in the Reference Scenario. Specifically, non-energy related CO_2 emissions increase and the ETS carbon price decreases compared to the reference values (see values printed in bold in Table 1). This seems to be the result of the definition of complementary RES and energy efficiency policies which reduce demand in for emission allowances (see also discussion in Paragraph 2.2).

2.1.3 Impacts analysed

The impacts are described in Chapter 5 in detail with special emphasis on:

- environmental impacts (GHG impacts including LULUCF and impacts on air pollution);
- energy system impacts (demand, supply, composition of energy mix, imports including import dependency, and the fossil fuel imports bill);
- economic impacts (energy system costs, investment needs, costs for energy intensive industries, overall and limited sectoral GDP impacts);
- social impacts (employment and affordability of energy).

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[3] As all scenarios contain more energy efficiency measures and renewable energy deployment than the reference scenario although the additional energy efficiency measures are very small for the GHG37R and GHG40R scenarios. The GHG35R scenario does assume additional energy efficiency policies, which explains why the price of allowances in the ETS is in the GHG35 scenario are lower than in the reference scenario.

An overview of the most important effects is presented in Table 2.

Table 2 Main effects of scenarios (all numbers are assessed against the Reference Scenario) in 2030

	Air pollution benefits (€bn/yr in 2030)	Impact on LULUCF sinks ($MtCO_2$)	GDP change E3ME (E3MG) (2030)	GDP change GEM E3 (2030)	Employment (% change or REF)	Reduction in annual fossil fuel import bills (avg 2011-2030)^	Additional increase energy costs in % of household budget (2030)
GHG40	7.2-13.5	1.8	0%-0.2% (E3MG)*		0.3%**	-2.0%	0.2%
GHG40EE	17.4-34.8	-0.5	0.55%		0.12%***	-4.3%	0.5%
GHG40EE RES30	16.7-33.2	-0.4	0.46%		0.5%**/0.09%***	-4.8%	0.4%
GHG45EE RES35	21.9-41.5	6.8	0.53%		0.09%***	-5.9%	0.7%
GHG35R	3.8-7.6	1.6				-2.2%	0.0%
GHG37R	4.2-8.8	2.4				-0.4%	0.2%
GHG40R	8.6-17.1	3.1		(-0.45%)-(-0.1%) (GEME3)		-0.9%	0.3%

Source: EC, 2014.

^ These numbers have not been published in the final IA but were calculated by CE Delft from Table 12 (p. 70) of EC (2014) and show the average annual reduction in fossil fuel import bills between 2011-2030.

* The E3MG model outcome does not specify which of the GHG40 scenarios has been chosen, but based on the text we *assume* that the GHG40 scenario was analysed here.

** Assuming revenue recycling to consumers.

*** Assuming revenue recycling to producers to reduce labour costs and investment in energy.

The impacts presented in Table 2 show, not surprisingly, that air pollution benefits are highest in the GHG45 scenario compared to the Reference Scenarios. Impact on LULUCF sinks are in general quite small, although the GHG45 scenario would imply that LULUCF sinks are reduced by about 3% compared to the Reference Scenario, mainly through the higher use of biomass resulting in a reduction in carbon sinks.

Social and economic impacts have been assessed both by E3ME, E3MG and GEM E-3, although not consistently over the various scenarios. In general, E3ME and E3MG shows GDP improvements whereas GEM E-3 shows GDP decreases for the scenarios where no enabling policies have been assumed (see for an elaboration of this issue Paragraph 2.2.2). The range in GDP outcomes from the GEM E-3 and E3MG models relates to the way auction revenues in the ETS have been recycled and the coverage of the ETS. The GEM E-3 model outcomes show that negative impacts on GDP can be mitigated by maintaining the present coverage of the ETS, introducing a tax for non-ETS sectors equalling the price of allowances (EUAs), and recycling the auction revenues to reduce labour costs.

This table shows that the scenarios tend to have net-benefits on employment, which, in the logic of the E3ME model, tends to be stimulated if auction revenues from ETS allowances are recycled to consumers instead of producers to reduce labour taxes.[4] The import bills of fossil fuels would be reduced considerably, albeit much less in the scenarios that assume no-enabling policies with a single GHG target. Reducing import bills is another way of stimulating employment, because the money saved from importing energy (and stimulating employment abroad) will be spent relatively more on products and services within the EU. Finally, the impacts on costs of energy to households are relatively small and do not differ much between the scenarios. In the maximum GHG45 scenario, consumers would spend 0.7% of their incomes additionally on energy products compared to the Reference Scenario.[5]

2.2 Review

In general, the IA is impressive in terms of details covered, depth of analysis, insight in the relationship between economic decision-making and policy impacts and quantification of impacts. Compared to previous IAs in the field of energy and climate policies, such as the IA accompanying the 2020 framework or the IA related to the Low Carbon Roadmap, this IA is in many aspects superior.

Nevertheless, this IA also has some shortcomings. In our review, we have analysed four aspects:
a The coverage of the scenarios.
b The coverage of the impacts.
c The methods that have been employed.
d Comparing the impacts.

These are elaborated in detail below.

2.2.1 Coverage of scenarios

The IA compares a Reference Scenario with seven policy scenarios. Policy scenarios differ with respect to GHG ambition target, the formulation of additional EE and RES policies, and the inclusion or exclusion of 'enabling policies' (see Table 1).

The choice of scenarios themselves has been influenced by the analysis of the Low Carbon Roadmap and the stakeholder meetings, as well as internal discussions. The Low Carbon Roadmap showed that adopting a -30% target would not have any benefits compared to a -40% target until 2030, but rather make the costs of meeting the target much higher between 2030 and 2050. Therefore, the -40% target in 2030 could be determined as cost-efficient from the 2050 Low Carbon Roadmap. The IA states that all scenarios with a reduction below the -35% or above 45% were discarded at an early stage. Reduction below 35% would yield no additional policy efforts compared to the Reference Scenario which already achieves emission reductions of -32.4%. The IA states furthermore that the 45% reduction effort was the highest range

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[4] Recycling to consumers would increase their purchasing power, which would stimulate demand more labour-intensive services and goods (e.g. restaurants and hotels) that tend to stimulate employment.

[5] It is in this light important to notice that in the reference scenario already an increase of the price of energy to consumers is expected. In 2010 consumers spend 12,4% of their incomes on energy products (electricity, heat, transport fuels), which would rise in the reference scenario to 14.6%.

of potential reduction scenarios based on the IA of the 2050 Low Carbon Roadmap.

The seven reported policy scenarios were analysed against the new updated PRIMES Reference Scenario (EC, 2013). The Reference Scenario in this IA is relatively policy-intensive. Although EE policies and RES policies are kept at their 2020 levels, reductions in the EU ETS continue with 1.74% per annum after 2020. Although this formally is probably in line with the revised EU ETS Directive (the annual reduction factor does not stop after 2020) it contains an implicit judgement that politicians regard this factor as a starting point in the negotiations about the 2030 framework. Hence, the Reference Scenario already has factured in a decision about the future of EU ETS. As a result additional efforts from the decarbonisation scenarios are relatively small.[6]

There is, in our opinion, some concern that the choice of scenarios has not been very balanced in this IA. The IA limits the choice of GHG reduction in their scenarios on the Reference Scenario as the lower bound and the 2011 IA of the Low Carbon Roadmap as the upper bound. However, the analysis of the 2011 IA Roadmap was based on the PRIMES 2009 baseline scenarios in which the impact of the economic crisis was not fully reflected. The PRIMES 2009 Reference Scenario assumed that, after the downturn of 2008, sustained economic growth would prevail after 2010, resulting in average EU-27 growth rates of 1% in 2011 and 2012 with full recovery afterwards resulting in a growth forecast of, on average, 2.2% of GDP between 2010 and 2020 and 1.7% between 2020 and 2030 (see EC, 2010). However, the 2013 PRIMES Reference Scenario, which was used in the IA currently under review, assumes a much lower GDP growth forecast at about 1.45% per annum between 2010-2030. As a consequence, GHG emissions are lower in the in the Reference Scenario in the present IA compared to the IA of the Low Carbon Roadmap. Table 3 shows the different development of GDP and emissions in both Reference Scenarios.

Table 3 **Overview of developments in GDP and CO_2 emissions according to PRIMES Reference Scenario 2009 and 2013**

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

Source: Own calculations based on EC, 2014 and EC, 2011. The Primes Reference Scenario 2013 has been based on EU 27, not EU 28 as in the PRIMES documentation, in order to make it comparable to the 2009 PRIMES scenario.

CO_2 emissions in the new PRIMES Reference Scenario are 14% lower compared to the old PRIMES Reference Scenario because of lower GDP growth and a more policy-intensive formulation of energy efficiency measures in the Reference Scenario. Based on our calculations, we conclude that the ‘old’ -40% analysed in the 2050 Roadmap would yield reductions in the order of magnitude as the ‘new’ -45% due to lower GDP forecasts. As such one can dispute the statement that a -45% target was ‘*the highest range of potential reduction scenarios based on the IA of the 2050 Low Carbon Roadmap*’. In fact, a -45% reduction scenario would be in line with the ‘cost-optimal’ reduction scenario from the

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[6] This assumption was also present in the reference scenario of the Low Carbon Roadmap (with the exception of aviation). Compared to the new Reference Scenario, the reference scenario in the Low Carbon Roadmap contained less energy efficiency policies.

Low Carbon Roadmap. In our view the IA of the 2030 framework has extended the scope of the potential 2030 scenarios downwards compared to the Low Carbon Roadmap.

The fact that the scenarios do not exploit the full potential on GHG emission reductions is further evidenced by scrutinizing the results presented in Table 1 in Paragraph 2.1.2. of this review. We see there that in some scenarios, especially in those that show substantial EE improvements, the ambition of EU climate policies seems to lessen compared to in the Reference Scenarios with respect to the price in the EU ETS and the non-energy related process emissions. Such is also exemplified by the role of CCS. It is remarkable that in the most ambitious scenario (GHG45) CCS is assumed to decrease compared to the Reference Scenario in 2050.[7] These results are determined by the way the modelling has been set up but demonstrate that the EC could have chosen more ambitious emission reduction pathways which we believe would have been useful to the institutions negotiating the package.

Moreover, several of the scenarios have indicated that EU ETS prices will be fairly low. For example, the GHG40EERES30 scenario suggests that the price of the EUAs will be € 11/tCO_2 in 2030. This suggests that the scenarios contain the risk of extending the period in which ETS fails to give a proper price signal for low carbon actions up to 2030.[8]

Finally, we observe that the role of enabling policies in the scenarios is rather obscure from this IA. The Reference Scenario does not contain enabling policies but the EC considers these essential to be on track for the 2050 target. As a result only the scenarios with ‘enabling conditions’ are in line with the EUs long-term climate objectives. It is unclear to what extent the costs of these enabling conditions have been included in the IA. Comparing the GHG40 and GHG40R scenarios, it seems that additional investment stemming from the enabling scenarios have been included in this IA and that their impact will materialise mostly after 2030. The implementation of enabling conditions, however, is out of scope of this policy package and depends on societal attitudes as well. From a methodological point of view, it would have been more consistent to compare the scenarios with enabling conditions to a reference scenario that also contains these enabling conditions since these are largely outside the scope of climate- and energy policies and depend on general social attitudes as well. This would have lowered the costs of the scenarios with enabling conditions.

2.2.2 Coverage of the impacts

The coverage of the impacts is focused on end-impacts and fairly extensive. It includes a full analysis on the impact of the prices of electricity for end-users including consumers. However, two particular impacts have been missing in this IA. First, this IA does not contain a specific discussion on impacts for SMEs, which is common in many of the IAs of the EC. While the analysis of impacts is focussed on large energy intensive industries, potential impacts for SMEs have been ignored. Potentially, SMEs could benefit from more ambitious climate policies by providing innovative low-carbon solutions, but such an assessment has not been made in particular for SMEs. Therefore, we conclude that the IA has focused too much on the sectors that might lose from ambitious climate policies while neglecting sectors that potentially would gain from this. Since

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[7] Up to 2030 CCS has a negligible result on the scenarios as the uptake of CCS starts very slowly.

[8] The creation of a market stability reserve would therefore become more urgent under these scenarios.

the overall GDP impacts seem to be positive in the E3ME/E3MG modelling efforts, it would be good to investigate which sectors in the economy would potentially gain from this policy package. This information is missing.

Second, the IA omits the costs of adaptation. One might expect that adaptation costs will be lower in the higher-end reduction scenarios but this is contingent on the rest of the world responding to climate change. In order to frame the issue correctly for politicians, it would be good to include an analysis of the consequences of not adhering to the global efforts of reducing GHG emissions to 50-85% below their 1990 levels. For instance the adverse economic consequences of higher adaptation costs have been extensively explored (see e.g. Stern, 2007).

2.2.3 Methods employed

The IA uses nine models that are all state-of-the-art in their respective fields.[9] However, linkages between these models seems to be underdeveloped.
This may have resulted in biased quantification of the impacts, although we emphasize that poor linkages of models is a general feature of any IA from the EC that we have seen over the last years. PRIMES can be regarded as the main model through which this IA has been shaped and assessed. PRIMES is a partial equilibrium model of EU energy markets. PRIMES is used for forecasting, scenario construction and policy impact analysis up to the year 2050. Basically PRIMES consists of a cost-optimization model where individual consumers of energy (e.g. companies) have choices among fuel inputs, investment of abatement technologies, etc. Optimization is acquired by assuming that marginal costs of energy consumption (including CO_2 taxes or EUAs) equalize among various users.
With respect to the methods that have been employed, we have identified four concerns:

1. Feedback loops between models may have been underdeveloped.
2. The role of discount rates in the PRIMES model.
3. The role of technological innovation which seems to be exogenous.
4. The economic impacts in relation to the functioning of international capital markets.

These will be elaborated below.

Feedback loops

PRIMES has taken economic forecasts from the GEM E-3 model. PRIMES, GEM E-3 and GAINS can model impacts in such a way that they contain a feedback loop so that the impacts are consistent between the three models. If the PRIMES forecasts have not been well linked with GEM E-3 models, there can be some concern if the EUA price development is not overly optimistic and factually lower prices for emission allowances may prevail. For example: a high EUA price resulting from PRIMES in some of the policy scenarios may lead to deteriorating market shares for energy intensive sectors, which should feedback from GEM E-3 to PRIMES. If such feedback loops have not been properly modelled, the EUA price forecast can be regarded as too optimistic. However, it is unclear from this IA if such feedback loops have been applied.

There are two issues where clearly no feedback loops have been included, which relates to the oil price developments and adaptation costs. Oil price

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[9] These models are: PRIMES as the basis model for modelling demand and supply for energy. GEM E-3, E3MG and E3ME models for modelling economic impacts. POLES for modelling economic impacts of unilateral or conditional international climate policies, GAINS for modelling non-CO_2 GHG and air pollution co-benefit; TREMOVE for modelling transport and GLOBIOM/G4M and CAPRI for modelling LULUCF impacts.

developments seem to be exogenous to the scenarios, which implies that all scenarios contain the same oil price developments as the Reference Scenario. However, fossil fuel consumption is considerable lower in the policy scenarios. As the EU is currently consuming about 12% of global fossil fuels, reduction in EU demand would likely have a price impact in the global energy markets. This impact will be more pronounced when the EU is successful in persuading other countries to reduce GHG emissions in international climate negotiations. For example: the Low Carbon Roadmap assumes that prices of energy may fall by 8% in 2030 if the EU alone undertakes climate action (and other countries stick to their Copenhagen pledges) and by 20% if the rest of the world undertakes similar efforts to limit the global temperature increase below the 2 degrees Celsius. This implies that the substantial savings in energy import bills in the higher end reduction scenarios may not materialize to the extent that they have been presented in this IA.

The other issue relates to adaptation costs. Especially in scenarios not in line with the aim to (have an acceptable degree of chance to) stabilize global temperature increase at 2 degrees Celsius, adaptation costs are expected to increase. The major part of these adaptation costs will occur after 2030, although some of them would materialize even before 2030. Adaptation costs are not taking into account in this IA, and therefore the impact from lowering the adaptation costs in scenarios with substantial GHG reductions has not been quantified. This may have resulted in an underestimation of the costs for the lower end reduction scenarios.

Discount rates

Another issue is the discount rates that are assumed in PRIMES optimization. PRIMES uses very high discount rates, reflecting some assumptions on the pure rate of time-preferences of economic agents[10]. PRIMES uses such high discount rates to reflect market barriers that explain why certain ‘profitable’ energy efficiency policies are not being implemented in the market. This relates to the notion that consumers buying a car tend to take into consideration the total cost of ownership (including fuel consumption) for only a limited number of years. Such ‘irrational’ behaviour tends to have negative GDP impacts: total output of the economy could have been higher if consumers behaved more rationally and included these cost-savings in their purchasing decisions.[11]
In general: the more discount rates come to the social optimum, the higher GDP output will be.

In the IA, policies affecting energy savings are assume to lower the interest rates to final energy end-users. The choice how much they would lower interest rates seems, however, to be arbitrary in the PRIMES modelling.[12] Moreover, even in the scenarios with ambitious EE policies, still a high potential of energy savings for end-users would not be realized due to the discount rates still being higher than the social optimum. Of course, one can argue here that consumers show irrational behaviour and that therefore the PRIMES high discount rates do reflect current behaviour of energy consumers.

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[10] Large power utilities: 8%; heavy industry: 10-12%; service sector: 11-14%; households: 17.5%.

[11] For example: labour costs can be lower if consumers would have more purchasing power, or alternatively other sectors of the economy (hotels, restaurants) could benefit from the increased consumer purchasing power from reducing their energy consumption.

[12] In the reference scenario, discount rates for households are being reduced from the present 17.5% to 12% from 2020 and onwards, while in the scenarios with ambitious EE policies discount rates are being reduced further to 10% in 2030.

Technological innovation

The third issue with PRIMES is that technological innovation is included but is, as far as we can deduce, exogenous to the model. That means that higher CO_2 reduction scenarios do not necessarily lead to technological innovation that lower costs to achieve these reduction scenarios. From the scientific empirical literature, we regard the 'weak variant' of the Porter hypothesis, i.e. environmental policy will stimulate environmental innovation resulting in reduced compliance costs, to be generally correct (see e.g. Lanoie et al., 2011). If innovation is not reflected in the PRIMES model, energy system costs of the policy scenarios may have been overstated. However, we recognize that innovation is difficult to measure and to predict.

Economic impacts in relation to capital markets

Next to GEM E-3 (which may or may have not been included in a feedback loop with PRIMES), the economic forecasts reflect modelling with E3MG and E3ME from Cambridge Econometrics. The impacts modelled with E3MG show more positive GDP impacts than with GEM E-3. The differences between the outcomes of E3ME/E3MG and GEM E-3 can be explained as follows. GEM E-3 is a general equilibrium model that assumes that at present markets are in equilibrium because economic agents are well informed and behave rational. Any movement away from equilibrium will normally entail costs to the economy. With respect to energy savings we clearly see that this does not correspond to empirical observations, which showed that there is a substantive energy savings potential. Therefore we regard E3ME/E3MG as a better model explaining the benefits when non-rational economic agents are forced through policies to undertake energy savings. The other difference between both models is related to the capital market. While GEM E-3 modelling assumes a capital market, capital market behaviour is not adequately covered in E3ME which explains why investments in general tend to be relatively positively evaluated compared to traditional general equilibrium models where higher investment needs from the scenarios would impact on GDP by raising interest rates. Here we regard GEM E-3 as a better model to handle the capital market dimension.

A similar issue may apply to exchange rates. It is unclear to what extent exchange rates changes have been included in the modelling but we observe that if the EU would save a substantial amount of money on the energy import bills, in economic terms this would have consequences for the balance of trade and through that on the exchange rates. Therefore, the reduction on energy import bills may have economic consequences due to a stronger position of the Euro on the international capital markets. For EU companies operating on international markets this would be a loss: they would lose competitive power against foreign competitors. For EU consumers this would be a gain since imported products would be more cheaply available and they would have more purchasing power (or lower labour cost increases).

2.2.4 Possibility to compare the costs and benefits from further GHG reductions

Comparison of costs and benefits is presented in Chapter 6 of the IA.
We notice here that the comparison is limited to the a table presenting the main impacts of the scenarios. No attempt has been made to compare costs and benefits in monetary terms, as is common in social cost-benefit analysis (SCBA). Therefore the benefits cannot be very well compared to the costs by policy makers since they have to compare apples and oranges. For example: how must we compare the reduced energy imports (benefits) in the higher end reduction scenarios with the higher energy costs (costs)? How must we

compare the reduced health damage from air pollution against the higher investment costs?

In a SCBA such costs and benefits are compared to each other in a structured way. Although a SCBA is frequently applied in the EU in evaluation of projects and programs in e.g. the Cohesion Funds (see EC, 2008), it's application in impact assessments has been very limited up till now. However, as we will argue in Chapter 3, it is feasible to compare the costs and benefits of the policy packages in the IA in a SCBA-framework which will answer the question which policy package is to be preferred from a societal perspective.

3 Comparing benefits and costs

3.1 Introduction

A Social Cost-Benefit Analysis (SCBA) is an integrated approach, often used by governments and other organizations, to evaluate the desirability of a given policy or project. It is an analysis of the expected balance of all welfare effects of the policy or project. Welfare is broadly defined. It covers both financial (e.g. tangible costs) and non-financial effects (such as environmental effects). All the effects are expressed in euros as far as possible, in order to compare them and determine the overall welfare effect of the policy.
For research undertaken in the EU, guidelines of cost-benefit analysis have been established.

In an SCBA for the investigated scenarios in the IA, the following costs and benefits have to be included (see Table 4). Costs include investment and O&M costs for technical measures (renewable energy technologies, energy efficiency investments). In addition, policy costs are an important category (e.g. wage of government officials, permit application processes, etc.). Benefits of climate policies are GHG reduction, improved air quality, reduced import dependency, reduced energy costs, and more employment and innovation.

Table 4 **Cost and benefits climate policies**

Costs	Benefits
– Investment costs technical measures	– GHG reduction
– Operation and maintenance costs	– Improved air quality
– Technical measures	– Reduced import dependency
– Policy costs	– Energy savings
	– Employment
	– Innovation

In a ‘standard SCBA approach’ these effects are quantified and compared, in order to determine if the benefits outweigh the costs. However, based on the impact assessment it is not possible to quantify all these effects. For instance, it is not possible to calculate the present value of the cost categories (investment costs, O&M costs, policy costs). Furthermore, many of the effects are only determined for the year 2030 instead of the whole time horizon of the policy. Therefore it is not possible to carry out a fully fledged SCBA.
This does however not imply that is not possible to present a comparison of the net overall welfare effect of the scenarios. The reason is that many of the welfare effects in Table 5 are reflected in the GDP impact (which is determined in the IA). The GDP is an overall indicator of the economic activity reflecting the impact of the costs of climate policies, energy saving benefits, benefits of reduced import dependency, employment, and innovation.
The Gross Domestic Product is defined as (Eurostat 2013):

$$\text{GDP} = \underbrace{(\text{value of all goods and services produced})}_{(1)} - \underbrace{(\text{value of any goods or services used in their creation})}_{(2)}$$

An increase of investment and O&M costs of technical measures decreases GDP, as the costs (and thus value) of goods and services used in creation of end products increase (as (2) increases in the formulae GDP decreases).
A reduction of energy costs (including energy imports) decreases the costs goods and services used in creation of end products (2) and has a positive impact on GDP. More employment and innovation has a positive impact on GDP as the value of goods and services produced increases (1).

The GDP therefore reflects most of the welfare effects that are presented in Table 4. Not included are GHG emission reductions and benefits of improved air quality. Although improved air quality and GHG emission reduction may also impact GDP, it is very unlikely that possible impacts have been included in the economic models. Monetising these welfare effects and comparing them with GDP impacts would therefore present a good indication of the overall welfare effects of the various scenarios.

3.2 GDP Impacts

GDP impacts have been determined with different models and under different assumptions in the IA (see Table 5).

Table 5 GDP Impacts

Model	Scenario	GDP impact in 2030	Difference to Reference Scenario (€2010 bn)[13]
GEM E-3	40% reduction	-0.45% to -0.10%	-18 to -79
E3MG	40% reduction	0.0% to 0.2%	0 to 35
E3ME	GHG40EE	0.55%	96
E3ME	GHG40EERES30	0.46%	80
E3ME	GHG45EERES35	0.53%	93

The GEM E-3 and E3MG model have been used to calculate GDP impacts of a 40% reduction scenario. In the text it is not further specified if specific renewable energy targets or energy efficiency targets are in place for these scenarios (it seems not because the IA describes them as ‘GHG driven scenarios’ as to indicate that additional policies were not formulated).
The E3ME calculations have been carried out for 40 and 45% reductions, including energy efficiency and renewable energy targets.

The outcomes of the calculations show remarkable differences. Depending on the scenario chosen, applied model, and assumptions on enabling policies, recycling of auctioning revenues and presence of taxes in non EU ETS sectors, GDP impacts range from -0.45% to +0.53% in 2030. While the GEM E-3 model predicts negative GDP impacts, E3ME and E3MG project positive outcomes on GDP. The main reason for these differences is that E3MG and E3ME assume enabling policies, while this is not the case in the GEM E-3 calculations. Enabling policies are efforts across the economy to ensure a smooth transition towards a low carbon economy in 2050 (Low Carbon Economy Roadmap and the Energy 2050 Roadmap). In practice, the enabling policies ensure the

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[13] GDP figures in the IA have been expressed in euros for the year 2005, while monetary values for air quality have been expressed in 2010 euros. In order to make figures comparable, GDP data have been corrected for inflation based on Eurostat (2014) and are expressed in 2010 euros.

availability of necessary infrastructure, progress in R&D and broad social acceptance of decarbonisation technologies, reducing system costs and price impacts. However, another important factor is related to the methodological differences between both models (see the analysis in Paragraph 2.2.2).

Other factors that determine the GDP impact of climate policies are recycling methods of auctioning revenues and the presence of tax in non-ETS sectors. Using auctioning revenues to reduce labour costs has a more positive impact on GDP than providing subsidies for consumers.[14] Taxes in non-EU ETS sectors have a positive influence as well.

The GDP impact (in monetary values) ranges from -€ 79 bn to +€ 96 bn in 2030. The monetary values of air quality benefits and GHG emission reductions will be added up in the following sections to determine the overall welfare effect of the different scenarios.

3.3 Air quality benefits

To include the benefits of greenhouse gas emission reduction and improved air quality in cost benefit analyses, these effects need to be expressed in monetary values based on so-called shadow prices. Shadow prices are artificial prices for goods or production factors that are not traded in markets. These prices provide an indication of the value of a particular good – in this case the environment – to society. In general, there are two methods to determine shadow prices. The first method determines shadow prices based on the costs that need to be incurred to secure environmental policy targets (abatement cost method). The second method assigns value to environmental quality based on the estimated damage occurring as a result of emissions and other changes in natural capital (damage cost method). In the IA the effects of improved air quality have been monetized on a combination of reduced health damage and pollution control costs. The benefits calculated in the IA are presented in Table 6.

Table 6 **Air quality benefits (against Reference Scenario)**

	GHG -40%	GHG -40% + EE	GHG -40% + RES 30% + EE	GHG -45% + RES 35% + EE
SO_2 (kton)	-100	-140	-143	-266
NO_x (kton)	-193	-328	-326	-371
PM (kton)	-25	-115	-97	-91
Benefits (€2010 bn/year)	7.2 to 13.5	17.4 to 34.8	16.7 to 33.2	21.9 to 41.5

The effects are expressed in €billion per year for the year 2030. The value of mortality (value of life year lost) is € 57,000 to € 133,000 per life year lost based on the Thematic Strategy on Air Pollution. However, it is unclear if this value is corrected for the year 2030 in the IA. In economic terms, air quality benefits increase with increased welfare. In other words, people tend to value environmental quality higher when they become richer. If we assume that air quality benefits have not been corrected for increased welfare, and taking into account the assumed income growth of 1.5% (GDP growth until 2030 in Reference Scenario), air quality benefits would increase with a factor 1.27.

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[14] Of course, this rests on the bedrock of assuming the governments recycle revenues in a non-distortionary manner – something that can be questioned here.

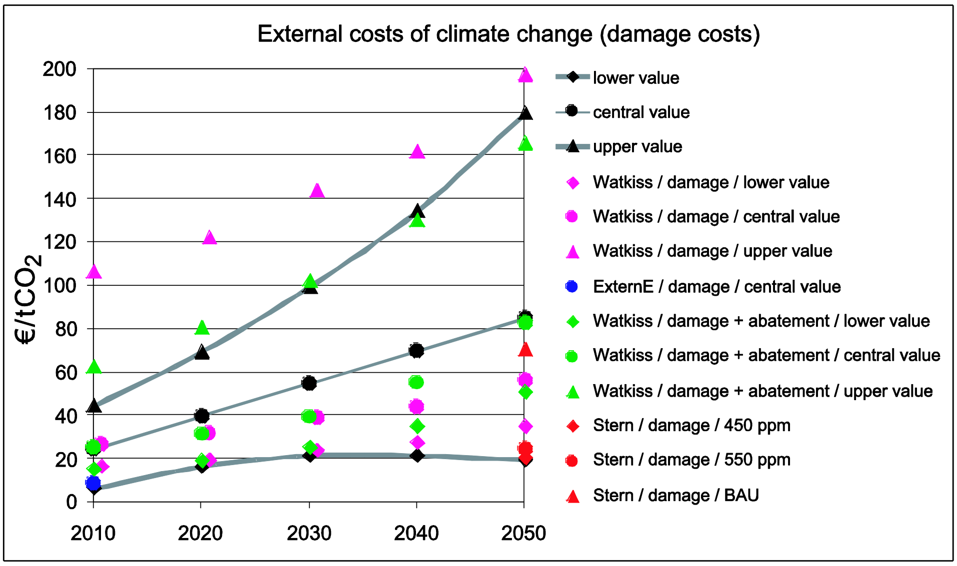
Table 7 Impact income growth on air quality (€2010 bn/year)

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

3.4 GHG reduction benefits

Climate change damages include a broad range of effects related to temperature rise, such as changes in global precipitation, sea level rise, increased risk of extreme events such as drought and severe storms, and in the longer term possibly alteration of ocean currents. The benefits of climate policies are a reduction of these damages. The damage from GHG emissions rises over time, as the negative effects of global warming become more severe as the global temperature rises. Based on a broad literature review, CE Delft has determined damage costs for CO_2 (CE Delft, 2010).

Figure 1 Damage costs GHG reduction (€2008 / tonne)



Recommended shadow prices (in €2010 values) are presented in Table 8.

Table 8 Recommended shadow prices (€2010 per tonne)

Year	Lower value	Central value	Upper value
2010	7	26	46
2020	18	41	72
2030	23	57	103
2040	23	72	139
2050	21	88	186

In order to determine the benefits of GHG emission reductions, the damage costs need to be multiplied with GHG reductions in the various scenarios.
In the Reference Scenario, GHG emissions are reduced by 32.4% against 1990 levels, while the investigated scenarios[15] reduce CO_2 emissions by 40.6%, 40.3%, 40.7% and 45.1% respectively in 2030. The corresponding benefits when multiplying physical reductions with damage costs in 2030 are presented in Table 9.

Table 9 **GHG reduction benefits (€2010 bn/year in 2030)**

	Additional CO_2 reduction (mt in 2030)	Benefits lower value (€bn)	Benefits central value (€bn)	Benefits upper value (€bn)
GHG40	465	10,6	26,4	48,0
GHG40EE	448	10,2	25,4	46,2
GHG40EERES30	471	10,7	26,7	48,6
GHG45EERES35	721	16,4	40,9	74,3

Table 9 shows that GHG emission reduction benefits in the 40% reduction scenarios range from € 10,2 bn (lower value GHG40EE scenario) to € 48,6 bn in 2030 (GHG40EERES30). The benefits in the 45% reduction scenario range from € 16,4 bn to € 74,3 bn.

3.5 Overall welfare effect

The overall welfare effects of the various scenarios are determined by adding up GDP impacts, air quality benefits and GHG reductions. As many of the effects are only calculated for the year 2030, we have only been able to determine overall welfare effects for the year 2030.

Table 10 **Overall welfare effect against Reference Scenario (€2010 bn/year in 2030)**

	GHG40	GHG40EE	GHG40EERES30	GHG45EERES35
GDP impact	-79 to 35	96	80	93
Air quality	10,4	26,1	25,0	31,7
GHG reduction	26,4	25,4	26,7	40,9
Total 2030	-42 to 72	147	131	165

The table shows that the scenario with 45% emission reduction scores the most positive in terms of overall welfare. This scenario results in most positive effects on air quality and GHG reduction, while the GDP impact is positive as well and only slightly lower than in in the GHG40EE scenario (and even higher than in the GHG40EERES30 scenario). The substantial increase in energy costs in the GHG45EERES35 scenario seems to be outweighed by economic benefits (reduced import bills, employment and air quality benefits).

As overall welfare seems to increase with more ambitious climate policies, it would be interesting to include scenarios with higher reduction percentages to determine the social optimum where the marginal increase in energy costs would be equal to the marginal social benefits. This social optimum may lie at 45% emission reduction, but we cannot assess this from the present IA since no

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[15] GHG40, GHG40EE, GHG 40EERES30 and GHG45EERES35.

scenarios have been included that analyse more stringent GHG reduction targets.

We also observe that the present formulation of the GHG45EERES35 scenario does not seem optimal by the researchers that have undertaken the IA. They state (p45) that *'A scenario mainly driven by a 45% GHG target and moderate EE and RES policies was analysed but is not evaluated in full in Section 5 in order to keep the number of scenarios assessed manageable. Many of the differential effects can be assessed by comparing the different 40% scenarios. It shows that it would be possible to reach 45% emission reductions in the EU at lower costs and with lower co-benefits as in the GHG45/EE/RES35 scenario.'* Therefore we conclude that scenarios with single GHG targets in the range of -45 to -50 may be more beneficial than the presently analysed GHG45EERES35 scenario.

At the same time it is important to note that calculations for the scenarios with explicit energy efficiency and renewable energy targets have only been determined under the important assumption of enabling policies. Under this assumption, the GDP impact is positive in all scenarios (and thus the overall welfare effect as air quality and GHG reduction are by definition positive). If such enabling policies do not materialize, GDP impacts can be more negative. However, one could defend this approach by pointing to the fact that the scenarios with no enabling policies will not reach the stated goals in 2050 and are therefore not part of the policy options that this IA wants to analyse.

For the GHG40 scenario, impacts have been determined in absence of enabling policies as well. In absence of enabling policies, the results for the GHG40 scenario show that the net overall welfare effect is very dependent on assumptions on taxes in the non-EU ETS sector and recycling methods of auctioning revenues (see Table 11).

Table 11 Overall welfare effect GHG40 scenario under different assumptions (€2010 bn/year in 2030)

Tax in non-EU ETS	**No**	**No**	**Yes**	**Yes**	**No**	**Yes**
Recycling method auctioning revenues	Subsidy for consumers	Labour cost reduction	Labour cost reduction	Labour cost reduction	Labour cost reduction	Labour cost reduction
Enabling policies	No	No	No	No	Yes	Yes
Model applied	GEM E-3	GEM E-3	GEM E-3	GEM E-3	E3MG	E3MG
Auctioning in ETS	Only power sector	Only power sector	Only power sector	All sectors ETS	Only power sector	All sectors EU ETS
GDP Impact	-79	-70	-37	-18	0	35
Air quality benefits	10	10	10	10	10	10
GHG reduction benefits	26	26	26	26	26	26
Overall welfare effect	**-42**	**-33**	**-0,03**	**19**	**37**	**72**

The table shows that in scenarios with no enabling polices, only the scenario with auctioning revenues from all EU ETS sectors (used to reduce labour costs) results in a positive overall welfare effect. The welfare effect is most negative if the recycling method for auctioning revenues is used as a subsidy for consumers.

3.6 Sensitivity analysis

In the absence of enabling policies, only in the scenario in which revenues from all EU ETS sectors are used to reduce labour costs do GHG reductions and air quality benefits outweigh negative GDP impacts. When applying the upper range of air quality benefits (assuming that is not corrected for income growth in the IA) and upper range for GHG reductions, one of the scenarios (fourth column) becomes positive (from being slightly negative). The overall welfare effect in the other scenarios does not change in terms of being positive or negative.

Table 12 Impact upper range air quality and GHG reduction benefits (€2010 bn/year)

Tax in non-EU ETS	**No**	**No**	**Yes**	**Yes**	**No**	**Yes**
Recycling method auctioning revenues	Subsidy consumers	Labour cost reduction	Labour cost reduction	Labour cost reduction	Labour cost reduction	Labour cost reduction
Enabling policies	No	No	No	No	Yes	Yes
Model applied	GEM E-3	GEM E-3	GEM E-3	GEM E-3	E3MG	E3MG
Auctioning in ETS	Only power sector	Only power sector	Only power sector	All sectors ETS	Only power sector	All sectors EU ETS
GDP Impact	-79	-70	-37	-18	0	35
Air quality benefits	17	17	17	17	17	17
GHG reduction benefits	48	48	48	48	48	48
Overall welfare effect	-14	-5	28	48	65	100

4 Formulation of alternatives

4.1 Introduction

We have shown in Chapter 2 that the selection of scenarios in the IA is somewhat imbalanced. Specifically, the highest reduction scenario (45% GHG reduction) is more or less equivalent to the 'optimal' reduction scenario in the Low Carbon Roadmap. In addition, some elements in the formulated policy scenarios are less ambitious than in the chosen Reference Scenario. In Chapter 3 we have furthermore shown that the 45% reduction scenario has the most positive benefit/costs ratio. Therefore, it is remarkable to note that in this IA not more stringent GHG reduction targets were considered.

It is beyond the scope of this analysis to formulate comprehensive alternative scenarios and calculate their economic impacts. However, based on the results of the IA we can assess a scenario that would be logical from a political point of view. This scenario would aim for an acceptable carbon price and reductions in all sectors in line with accepted ambitions from the Low Carbon Roadmap. Such an alternative could be build on elements of each of the formulated policy scenarios in the IA. In this Chapter we define this 'balanced scenario' and discuss its implications

4.2 Formulation of a 'balanced scenario'

The 2030 framework consists of various elements: the EU ETS, energy efficiency and renewable energy policy plans. In Chapter 3 we have seen that the -45% GHG reduction target is economically the most beneficial. However, at the same time the price of emission allowances drops from € 35/tCO_2 in the Reference Scenario to € 15/tCO_2, which indicates that the target may not have been stringent enough as demand for allowances will be seriously reduced by the energy efficiency and renewable energy policies. In the Low Carbon Roadmap, it was indicated that CO_2 prices would range between € 40-€ 60/tCO_2 in the various policy scenarios in 2030 (EC, 2011). Therefore, an estimated price impact of € 15/tCO_2 in the most ambitious policy scenario of the present IA does not seem optimal in the light of the potential CO_2 reductions that must be realized after 2030.

A strategy in which prices in the ETS would rise to higher levels up to 2030 could be beneficial in the long-run for three reasons:
1. Given long investment cycles in industry and power generation, a higher price signal would be more in line with the requirements of the low carbon economy that must be established up to 2050 and beyond. Accepting very low price levels would imply that the EU ETS would fail to deliver such a price signal. This would, in turn, stimulate the demand for additional policies in several member states which would (in all) undermine the level playing field across the EU.
2. In the GHG45EERES35 scenario, the oversupply of allowances in the EU ETS is likely to continue for a longer period of time. If the market stability reserve is created as part of the 2030 framework, this would imply that the size of this reserve would be swollen considerably, which may affect emission reductions beyond 2030.

3. Auction revenues will be much lower in these scenarios. Recycling auction revenues to reduce labour taxes tend to stimulate employment according to the IA, and thus the lower EU ETS price implies that the labour market is less stimulated.

Therefore, it would be interesting to investigate if the elements in the GHG45RES35 scenario could be combined with a tighter EU ETS cap so that the total price of allowances would be equivalent to the Reference Scenario (€ 35/tCO_2). This would also affect the non-energy CO_2 emissions which also tend to rise in the GHG45RES35 scenario compared to the Reference Scenario. We call the scenario in which the GHG45RES35 is combined with a tighter cap for the EU ETS sectors the ‘balanced scenario’.

The ‘balanced scenario’ consists of five elements:
1. Energy efficiency improvements and renewable energy targets in line with the GHG45 scenario – which seems to be beneficial from an economic perspective (see Chapter 3).
2. An EU ETS cap that results in a price of € 35/tCO_2, in line with the Reference Scenario.
3. An implicit price of carbon of € 35/tCO_2 in the non-ETS sectors, so as to limit potential competition and adverse impacts from different price signals in different sectors of the economy (this assumption underlies all the scenarios in the IA except the Reference Scenario).
4. CO_2 emissions from non-energy use in line with the Reference Scenario.
5. Non-CO_2 emissions and the enabling conditions in line with the GHG40 scenario – which forms the basis of current EC proposals for the 2030 framework.

Although a full calculation of the impacts of this ‘balanced scenario’ is not really possible without re-running the models that were used in the IA, it is to some extent possible to assess the impacts on GHG emissions from the five elements above by comparing the results of individual scenarios in the IA.
In this way we have estimated the likely CO_2 reductions in this ‘balanced scenario’.

Note: There is one important caveat in our calculations. We use rough approximations of the difficult realms of the PRIMES model in which every variable depends on a set of other variables and the relationships between the variables are often non-linear.[16] *We have imposed linear ceteris paribus conditions to some of these variables. See Annex A for further explanation on the assumptions on the calculation of the impacts.*

4.3 Elements of the balanced scenario in more detail

The balanced scenario with higher prices of carbon will have impacts in the ETS and non-ETS sectors, which we explain briefly below. In Annex A more detailed calculations are given.

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[16] This especially applies to all cost functions as marginal costs increase along the utilisation of the technologies.

4.3.1 Impacts in the EU ETS for energy related CO_2 emissions

The main mechanism of the 'balanced scenario' for additional GHG reduction compared to the presented GHG45EERES35 scenario is the higher price for emission allowances in the EU ETS. This has to be achieved by reducing the cap so that demand and supply of allowances comes in line with the expectation of the Reference Scenario (with an associated price of € 35/tCO_2).

Now one may observe that the cap in the GHG45EERES35 scenario is already much lower than in the other scenarios. However, the instalment of additional EE and RES policies result in a reduced demand for allowances. Therefore, despite having the lowest cap, the GHG45EERES35 scenario results in a weakened demand for allowances compared to the Reference Scenario – as is evidenced by the lower price of emission allowances.

In the GHG45EERES35, GHG emissions under the ETS decrease from 1.606 Mt CO_2 eq. in the Reference Scenario to 1.275 Mt CO_2 eq. in 2030. Based on our analysis of the outcome of the PRIMES scenario we conclude that all of this reduction is due to energy-related CO_2 emissions.[17] Based on our own calculations from the PRIMES scenarios, we assume that energy related CO_2 emissions (excluding aviation) decrease from about 1.240 Mt in 2030 under the Reference Scenario to about 910 Mt in the GHG45EERES35 scenario.[18] However, the largest part of this decrease is due to three separate impacts:

1. Compared to renewable energy input in the Reference Scenario of 24.4%, the GHGEERES35 scenario assumes an EU-wide target of 35% renewable energy input which reduces the demand for allowances.
2. The GHG45EERES35 scenario assumes enabling policies while the Reference Scenario does not include these scenarios. The enabling scenarios reduce demand for allowances.
3. The GHG45EERES35 assumes ambitious energy efficiency policies that reduce the demand for allowances.

Based on our comparison of scenarios (see Annex A.2) we estimate that the renewable energy target reduces the demand of allowances in the ETS by 280 Mt CO2 compared to the Reference Scenario. The enabling scenarios primarily impact primary energy use. Our best estimate here is that enabling scenarios themselves reduce primary energy use by 34 Mtoe (see Annex A.1) which in turn reduces CO_2 emissions by about 62 Mt compared to the Reference Scenario. We estimate that in total about 35 $MtCO_2$ of these reductions would accrue to the ETS sectors.

The impact of the energy efficiency policies are very difficult to determine from the PRIMES calculations. Based on our analysis, our tentative guess is that this would result in an additional reduction of demand of allowances by 100 Mt CO_2 in 2030.

In total, the demand of the allowances in the balanced scenario can then be calculated by subtracting the factual demand in the ETS sectors for energy-related CO_2 emissions in the Reference Scenario with the impact of renewable energy, enabling policies and energy efficiency measures. Table 13 gives the results of this analysis.

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[17] In the GHG45EERES35 scenario, non-CO_2 emissions decrease also, but the non-energy related CO_2 emissions are supposed to increase (see also Table 1).

[18] This has been calculated assuming that 80% of the non-energy related CO_2 emissions fall under the EU ETS (EC, 2014, p56). As a result, one could calculate that PRIMES assumes that about two thirds of the industrial non-CO_2 emissions are regulated by the EU ETS as well in 2030. We furthermore assume that these percentages are fixed over the scenarios.

Table 13 **Potential for further reduction in the 'balanced scenario' for energy related CO_2 emissions**

Energy related CO_2 emissions ETS sectors (€ 35/tCO_2) excl. aviation	**1.242**
Minus enabling policies	-35
Minus renewable energy policies	-280
Minus energy efficiency policies	-100
Factual demand not stimulated by EE and RES policies	830
Demand under GHG45EERES35 € 15/tCO_2	913
Additional reductions feasible in the EU ETS excl. aviation	-83

The total reductions in the EU ETS would therefore be equivalent to 83 Mt CO_2 in the EU ETS for the industry and power sectors. This reduction is assumed to be similar to the reduction in the EU ETS if aviation is included. With aviation included, the total cap would fall from 1.076 Mt CO_2 in the GHG45RES35 scenario to 993 Mt CO_2 in the balanced scenario.[19]

We want to emphasize that this seems to be conservative estimate. If we compare the GHG40R with the GHG37R scenarios which are very similar from a policy perspective except for the higher price in the ETS (and non-ETS sectors) in the GHG40R scenario, one may conclude that the price impact on the ETS sectors could be larger than the calculated 83 Mt.[20]

4.3.2 Impacts in the non-ETS sectors

Apart from the impact of the EED policies, emissions in the non-ETS sectors may additionally decrease due to the implicit carbon price increase in the 'balanced scenario'. In the PRIMES calculations, all scenarios in the IA (except GHG35 and the Reference Scenario) assume price equalisation between the EU ETS sectors and non-EU ETS sectors.[21] From a comparison of the GHG37 scenario, in which an implicit carbon price of € 35/tCO_2 has been assumed in the non-ETS sectors, and the Reference Scenario (which assumes a price of € 0/tCO_2 in the non-ETS sectors after 2020), we estimate that an additional energy saving of 67 Mt CO_2 would result in the non-ETS sectors due to setting a carbon price of € 35/tCO_2. This is equivalent to 5% of CO_2 emissions in the non-ETS sectors.

In the GHG45 scenario, however, the carbon price in the non-ETS sectors is equivalent to € 15/tCO_2. Part of the 67 Mt CO_2 reductions in the non-ETS sectors would therefore already be factored into the GHG45 scenario. Since the abatement cost curve for the non-ETS sectors is convex (implying smaller reductions at higher EU ETS prices), we cannot exactly determine to which extent of the 67 Mt CO_2 reductions would already be covered by the GHG45 scenario. Our best guess here is that half of the 67 Mt CO_2 reductions in the non-ETS sectors would be the result from a price of € 15/tCO_2, leaving room for an additional 33 Mt CO_2 reduction from a price of € 35/tCO_2.

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[19] Hence, we did not take into account the potential impact of higher ETS prices on the demand of allowances from aviation.

[20] A price increase of € 35/tCO_2 in the GHG37R scenario to € 53/tCO_2 in the GHG40R scenario would reduce emissions by 100Mt (including aviation). Thus a price increase of € 18/tCO_2 would result in ETS emission to reduce by 100 Mt. Therefore we would expect that the price increase of € 20/tCO_2 in the balanced scenario compared to the values in the Reference Scenario could result in more than 100 Mt CO_2 emission reductions, especially since the marginal abatement cost curve would indicate that more reductions are possible at the lower end of the cost curve.

[21] It seems that this is primarily a modelling decision instead of a discussion of the desirability and feasibility of price equalisation among ETS and non-sectors.

4.3.3 Non-energy use equivalent to Reference Scenario

Non-energy use CO_2 emissions relate to the process emissions of the cement, metals and chemical industries that are not due to burning fossil fuels. Non-energy related CO_2 emissions are to a large extent (around 75%) covered by the EU ETS, in particular process emissions in the metal, cement and chemicals industries. These emissions decline in the Reference Scenario by 15% in 2030 compared to 2005, mainly driven by the continuation of the annual reduction factor in the ETS and the projected ETS price of € 35 that results from it. Since we assume in our calculations an ETS price of € 35/tCO_2 we have taken the development of non-energy use process emissions as in the Reference Scenario. This implies that the non-energy use CO_2 emissions decline from 281 Mt CO_2 in the GHG45RES35 scenario in 2030 to 240 Mt CO_2 in 2030 – equivalent to the decrease in the Reference Scenario.

4.3.4 Non-CO_2 emissions as in GHG40 scenario

Non-CO_2 GHG emissions in EU 28 are expected to decline from 903 to 728 Mt CO_2 eq. between 2005 and 2030 in the Reference Scenario and stabilize on that level throughout the remaining projection period. The agricultural sector is a major contributor to emissions, responsible for over 50% in 2005 and with only minimal decline expected in the future. Non-CO_2 emissions decrease in the Reference Scenario because of EU waste policy, national bans on landfill of biodegradable waste, EU and national regulations to reduce F-gas emissions, inclusion of mainly certain industrial emissions (mainly N_20) in the ETS, and national subsidies for anaerobic digesters enabling energy recovery. The IA notes that diet changes, which would have a considerable impact on agricultural non-CO_2 emissions (CH_4), have not been taken into account in the Reference Scenario.

The IA modelling efforts seems to have treated non-CO_2 emissions as a balancing item in which first all the other emission efforts have been calculated and then the need to reduce non-CO_2 emissions has been accessed. Non-CO_2 emission reductions are therefore highest in scenarios without EE and RES policies defined. Another influence is the influence from the ETS price which reduces non-CO_2 emissions in the non-agricultural sectors as a large share of these emissions fall under the EU ETS. In the GHG40 target with reference setting, the reductions are therefore the highest, resulting in a reduction of 43% in 2030 compared to 2005. We have taken this reduction effort as part in our 'balanced scenario'. This could, amongst others, be justified by pointing out at the long-term transition towards less meat-intensive diets as part of an existing development in several richer EU countries (Germany, Netherlands, France; see e.g. Kanerva, 2013). This would imply that the non-CO_2 emissions decrease to 539 Mt CO_2 in 2030.

4.4 Outcome of the analysis

Table 14 presents the outcome of the calculations for the balanced scenario where the total GHG emissions in 2030 according to the various sub-categories are compared to the GHG45EERES35 scenario and the Reference Scenario in the IA.

Table 14 **Outcome of the ‘balanced scenario’ in Mt GHG emissions in 2030 compared to the GHG45EERES35 and Reference Scenario from the Impact Assessment**

	Balanced	GHG45EERES35	Ref
Non-energy CO_2	240	281	240
Non-CO_2 GHG	539	590	728
CO_2 emissions ETS sectors (incl. aviation)	993	1,076	1,419
CO_2 emissions non-ETS sectors	1,136	1,173	1,457
Total GHG emissions	2,908	3,119	3,844
Reduction compared to 1990	48.8%	45.1%	32.4%

We see here that the balanced scenario would yield additional emission reductions leading in 2030 to a total of almost 49% reduction GHG emissions compared to 1990. This number must be interpreted with care as, we have not been able to determine exactly the potential reduction efforts from our comparison of the modelling results of the scenarios of PRIMES because the information in the IA is not exhaustive. But it shows that additional reduction efforts beyond 45% GHG reduction are feasible within the logic of the scenarios analysed in the IA.

The balanced scenario would combine a € 35/ton price signal in the EU ETS with ambitious EE policies and renewable energy policies. The scenario itself may be made more cost-effective, e.g. by lowering the ambition of renewable energy policies and increasing the price of carbon to higher values which would stimulate fuel switching, energy efficiency measures in sectors not targeted by the energy efficiency policies and the development of new technologies. As discussed in the IA (on p. 45), this would yield similar emission reductions albeit at lower costs (and lower co-benefits as well).

5 Conclusions

The EC has made a proposal for the 2030 framework for energy and climate policies. Central elements in this proposal are the choice for a domestic 40% GHG reduction target and a EU-wide renewable energy target of 27%. These choices have been based, amongst others, on the Impact Assessment (IA) that has accompanied the EC proposal.

The IA has analysed seven policy scenarios with GHG targets ranging between -35% to -45% domestic GHG reduction in 2030 compared to 1990 and compares these impacts with the new updated PRIMES Reference scenario (2013). The Reference Scenario itself already results in emission reductions of more than 32% in 2030 and will require significant efforts due to the continuous decline of the ETS cap. The calculations in the IA shows that the macro-economic impact both on jobs and growth of the climate and energy policy packages presented in the IA is very limited for all policy options. For most scenarios the effect is net positive compared to the Reference Scenario.

The policy scenarios consist of a policy mix of price signals (both in the ETS and non-ETS sectors) and different levels of renewable energy and energy efficiency policies. The outcomes in four of the seven policy scenarios seem to be less ambitious than the Reference Scenario for specific elements, i.e. the carbon price and non-energy related CO_2 emissions. In the most ambitious policy scenario resulting in -45% GHG reduction in 2030 compared to 1990, the price of emission allowances in the EU ETS would be only € 15/tCO_2 – much below the predicted € 35/tCO_2 in the Reference Scenario. Moreover, non-energy related CO_2 emissions and deployment of CCS would be lower in this scenario than in the Reference Scenario. Such outcomes cast some doubt on the level of ambition of the chosen policy scenarios in the IA.

Furthermore, when we compare the present policy scenarios with the policy scenarios constructed in the 2050 Low Carbon Roadmap, we conclude that the most ambitious scenario in the present IA leading to -45% reduction is, in terms of policy efforts, similar to the ‘optimal’ reduction scenario in the 2050 Low Carbon Roadmap. This is because the present IA assumed a much lower economic growth than the 2050 Low Carbon Roadmap.

The IA does not contain a standardized way of comparing the costs and benefits of each of the policy options. Using monetized values for environmental impacts we have compared the costs and benefits of each of the scenarios in a social-cost-benefit framework. This leads us to the conclusion that the -45% reduction scenario (the most ambitious scenario in the IA) leads to the highest benefit/cost ratio. Therefore, the additional investment costs from stepping up to higher reduction scenarios does pay off by improved air quality and lower CO_2 emissions given people’s preferences for clean air and absence of climate related weather events.

Given the fact that the highest end reduction scenario analysed in the IA leading to -45% reduction can be regarded as ‘the optimal’ scenario (both from the view of comparing costs/benefits and from the analysis of the 2050 Low Carbon Roadmap) we advocate the EC to investigate higher end reduction scenarios to fully reap the economic and technological potentials for climate and energy policies. Within the present research we have investigated what

GHG reductions would be feasible when we combine various elements of the constructed policy scenarios into a ‘balanced scenario’. This balanced scenario would have ambitious renewable energy and energy efficiency policies in place, comparable to the -45% reduction scenario, but would combine this with a decent price signal of € 35/tCO_2 in 2030 in the EU ETS and non-ETS sectors and reduce non-energy CO_2 emissions to the potential identified in the -40% reduction scenario.

We estimated that this ‘balanced scenario’ could result in an emission reduction of about 49%GHG compared to 1990 levels. Such outcomes seem to us more logical when the full potential to reduce GHG emissions is to be exploited. The economic impacts of this ‘balanced scenario’ could not be assessed without full access to the underlying models. However, since this scenario consists of components that have been included in other scenarios, this would not imply excessive costs or unreasonable technological (or economic) demands. Therefore we believe that it would be worthwhile for the EC to consider additional scenarios in their IA which will yield larger GHG reductions and at the same time still make sense economically.

Finally, there is an important caveat to the analysis of the impacts in the IA. The environmental, energy system and macro-economic impacts of the policy packages have been established running nine different models. However, we fear that these models have been poorly integrated with each other. This is especially important for feedback loops for the international energy market, costs of adaptation, innovation and international capital markets. Including such impacts may have increased both costs and benefits in each of the policy scenarios. However, it is beyond the scope of the present analysis to make an estimation of these impacts.

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Annex A Main assumptions underlying the calculations

A.1 Comparing scenarios and obtaining relationships between them

Our main information on the assumed relationships between the variables in the PRIMES model comes from a comparison of the outcome of individual scenarios.

Table 15 shows the starting point of our analysis, which is related to understanding the impact of the EED on the calculation of primary energy use (i.e. primary energy consumption minus non-energy use). Based on the information in the IA and information from PRIMES on non-energy use in the Reference Scenario, we can calculate the primary energy use in the scenarios that reflect the outcome of the EED baseline (based on 2007 PRIMES forecasts).

Table 15 Mtoe primary energy consumption and use in 2030 in the eight scenarios based on the IA and PRIMES Reference Scenario

	Ref	GHG40	GHG40EE	GHG40EE RES30	GHG45EE RES35	GHG35R	GHG37R	GHG40R
Primary Energy Consumption	1,611	1,534	1,448	1,433	1,364	1,542	1,576	1,548
Non-energy use	120.9	Na	Na	Na	Na	Na	Na	Na
Primary Energy Use	**1,490.0**	**1,412.6**	**1,333.4**	**1,318.3**	**1,250.4**	**1,425.8**	**1,454.1**	**1,425.8**
EED 2007 Baseline^	21.0%	25.1%	29.3%	30.1%	33.7%	24.4%	22.9%	24.4%
EU ETS price (€/tCO2)	35	40	22	11	15	27	35	53

^ Reduction in percentages compared to 2007 baseline of 1,886 Mtoe primary energy use.

From this table, we can investigate that the difference between GHG37R and the Reference Scenario suggests a reduction of 35.9 Mtoe in primary energy use. Both scenarios use a price of € 35/tCO_2 and are similar in terms of policy impacts. The only difference is that the GHG37R assumes price equalisation between ETS and non-ETS sectors, while the Reference Scenario does not assume a price in the non-ETS sectors. Therefore, we can conclude that a price of € 35/tCO_2 in the non-ETS sectors results in a decrease of 35.9 Mtoe primary energy use economy-wide.

The other relationship we can investigate is the relationship between renewable energy input and primary energy consumption. When more renewables are being deployed, primary energy consumption will fall.
By comparing the GHG40EE and GHG40EERES30 scenarios, one can observe that by raising the renewable energy target from 26.4% in the GHG40EE scenario to 30.0% in the GHG40EERES30 scenario, results in additional decrease in primary energy use equivalent to 15.1 Mtoe. Assuming full linearity in the deployment of renewables and impacts on primary energy use, this

would imply that there exists a factor of 4.2 Mtoe reductions in primary energy use for every percent more deployment of renewables.[22]

A third relationship one may observe is the impact from enabling scenarios. The GHG40 scenario is a scenario that assumes enabling settings, while the GHG40R scenario does not assume enabling settings. One may observe that primary energy use is 13.2 Mtoe lower due to the enabling settings. This has to be regarded as a lower end as the impact of the enabling settings is greater, since the EUA price is € 40/tCO_2 in the GHG40 scenario and € 53/tCO_2 in the GHG40R scenario, which would result in a higher impetus to reduce emissions.

In order to obtain a relationship between the price of CO_2 (both in the ETS and non-ETS sectors) we compare the GHG40R scenario with the GHG37R scenario. These scenarios are completely similar with respect to energy efficiency policies, but in the GHG40R scenario the ETS price rises to € 53/tCO_2 which results in an additional reduction of 28 Mtoe primary energy use. This would imply that an EU ETS price € 1 higher may reduce energy demand by 1.6 Mtoe. Of course, this relationship is in itself not linear (abatement cost curves are not linear) but we don't know this so we have to assume here for the moment that in the space of ETS prices, the relationship between energy saving measures and CO_2 prices is linear.

Using this figure of a reduction of primary energy use of 1.6 Mt per euro increase in the price of carbon, we conclude that the enabling scenarios themselves would result in a reduction of primary energy use of 34 Mtoe.

The enabling settings will reduce energy use in both the ETS and non-ETS sectors. Without further information we cannot assess which part would accrue to the ETS and which part to the non-ETS sectors. Therefore we assume that the enabling settings reduce energy use evenly between ETS and non-ETS sectors. In general this would imply that enabling settings reduce energy use by about half in the ETS sectors.

In order to translate energy savings to CO_2 emissions we have to assume an emission factor. Emission factors will widely vary among sectors – however, using that information we would have to know exactly for which sectors enabling scenarios would result in energy savings (and by which fuel). Since we don't know this, we have to assume here a general emission factor from the Reference Scenario. This emission factor has been determined by calculating the CO_2 emissions of energy related uses (e.g. excluding feedstocks) excluding aviation and compare them with the energy use (excluding feedstocks and aviation). This would yield an emission factor of 1.89 tCO_2/toe in the Reference Scenario.

A.2 Renewable energy impacts

The renewable energy targets in the 'high cost efficiency scenario' are similar to GHG45, the most ambitious (and most beneficial) scenario in the IA. In the GHG45 scenario, renewable energy targets are set at 35% of gross inland consumption of energy – substantially higher than the estimated 24.4% renewable energy in the Reference Scenario. The 35% goal is supposed to be reached through a mechanism of policy instruments, such as feed-in tariffs/premiums or green certificate schemes. A higher share of renewable

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[22] This factor may also be influenced by the price differential of CO_2 in both scenarios.

energy stimulated with policy instruments outside the EU ETS has three impacts on the reduction effort of EU ETS sectors:

1. Since renewable energy has no CO_2 emissions except for biomass input, the carbon intensity of power production will drop.
2. Since renewable energy is assumed to increase power and heat prices in the IA, total demand for electricity and heat will be lower which implies lower reduction efforts within the EU ETS sectors.
3. Since renewable energy has no transformation losses except for biomass input, primary energy consumption will be lower which impacts on EED policies formulated as a percentage of primary energy use.

In total, the GHG45 scenario has an additional reduction of slightly more than 280 Mt CO_2 in the power and district heating sectors compared to the Reference Scenario with electricity prices rising by 11%. Nearly all of these emissions fall under the EU ETS in its present scope. Therefore we assume that demand in the EU ETS will be reduced by 280 Mt CO_2 from the renewable energy targets in the GHG45 scenario compared to the Reference Scenario.[23]

It should be noted that the true value may be higher than this 280 Mt CO_2 if the EU ETS price is to rise to € 35/tCO_2, since the increase in carbon costs will be passed on to the power prices. However, based on our analysis of the impact of power and ETS prices from the PRIMES scenarios we assume that this impact has been quite limited and that the electricity price increase seems to have been dominated by the increase in renewable energy input.

Based on our calculations we estimate that for every percent higher renewable energy input compared to the Reference Scenario, primary energy use will drop by 4.2 Mtoe. This will be a relevant impact when calculating the impacts for the energy efficiency targets.

A.3 Energy efficiency impacts

Energy efficiency policies are very ambitious in the GHG45 scenario. There are basically two elements in the energy efficiency policies, as formulated in the IA. The first element is the impact from the enabling conditions. Enabling conditions guarantee that the right market incentives and social attitudes are being developed that enable a long-term transition towards a low-carbon economy. In the IA it is stated that the energy-efficiency impacts from the enabling conditions contain:

- Up to 2020, a vigorous implementation of the current policy framework including EED (Energy Efficiency Directive), EPBD (Energy Performance of Buildings) and the extension and tightening of the Ecodesign and Labelling requirements.
- After 2020, a continuation of energy efficiency policies at the national level resulting in, e.g., higher investment in insulation of buildings, an accelerated uptake of efficient technologies, and enabling transport electrification through infrastructure measures and exogenous progress in battery technology.

As stated in Annex A.1 we calculated that the impact of enabling policies would result in a decrease of primary energy use of 34 Mtoe in 2030.

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[23] Also fuel switches may impact on this number. However, the amount of fuel switches seems to be limited between the various fossil fuel energy carriers so this impact has been ignored.

The second element is the policy package that has been formulated in the GHG45 scenario. These are being described in detail in Paragraph 7.3 of the IA. The main elements include:

- Measures speeding up the buildings renovation rate, which attains on average (2020 to 2050) 1.78%.
- Energy management systems introduced gradually over time and present in all new constructions as of 2015.
- Extended and more ambitious energy efficiency obligations. The average annual energy savings in 2020-2030 amount to a 2.3% savings per year.
- The efficiency standards for products driven by Eco-design regulations are continuously tightened, broadened, and extended to not yet regulated products to cover all energy product categories represented in the model.
- Additional support for smart grids and efficiency standards for power networks.
- Wide deployment of CHP and district heating/cooling.
- Stringent CO_2 standards for passenger cars: 70 g CO_2/km in 2030 and 17 g CO_2/km in 2050.
- Other additional transport related measures as reflected in the White Paper on Transport.

While ideally we would like to investigate the impact of these measures bottom-up, by investigating the impact on CO_2 emission reduction from every measure, this is not possible due to the absence of quantitative information. Therefore we have tried to estimate the impact of these policies top-down, by comparing the impacts from the GHG45 scenario with the other scenarios. In total, the GHG45 scenario would reduce primary energy use (e.g. primary energy consumption minus non-energy use) by 33.7% in 2030 compared to 16.8% in the Reference Scenario, which is equivalent to a reduction of 240 Mtoe of energy use. However, this measure in itself is a poor measure to estimate the impacts from the energy efficiency policies, because the lower carbon price in the GHG45 scenario, the enabling scenarios, and the deployment of renewable energy would also affect the primary energy use. Moreover, we need to investigate which part of this reduction comes at the expense of the ETS sectors and which part would accrue to the non-ETS sectors.

In order to calculate which part of these 240 Mtoe reductions would stem from the energy efficiency plans, we first subtract the impact of renewable energy on primary energy use. The higher RES deployment itself would result in a reduction in primary energy use of about 44 Mtoe in 2030.

Second, based on the analysis in Annex A.1, we observed that a higher EU ETS price of € 1 may reduce energy demand by 1.6 Mtoe. This would imply that in the high cost efficiency scenario, where the price of carbon rises from € 15tCO_2 to € 35/tCO_2, energy efficiency would be stimulated by an additional 32 Mtoe compared to the GHG45/EE/RES35 scenario.

The enabling scenarios themselves would reduce primary energy use by 34Mtoe (see Annex A.1).

Therefore, the true ‘additional’ value of the energy efficiency plans would therefore be around 134 Mtoe.[24]

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[24] E.g. 240 Mtoe energy efficiency reductions minus 44 Mtoe from the higher RES deployment minus 34 Mtoe of the enabling scenarios minus 32 Mtoe from the higher carbon price.

The energy efficiency plans would affect both ETS and non-ETS emissions. It is difficult to estimate in advance their impact on each of these categories. Based on the results of the PRIMES calculations we assume that they would for about 40% finally accrue to the ETS sectors through energy savings in industry and energy production and a reduction of electricity consumption.