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PART 2/3

COMMISSION STAFF WORKING DOCUMENT

IMPACT ASSESSMENT

Accompanying the document

Proposal for a Directive of the European Parliament and of the Council amending Directive 2012/27/EU on Energy Efficiency

{COM(2016) 761 final}
{SWD(2016) 406 final}

Table of Contents of the Annexes

1. Annex - Procedural issues

1.1 Lead DG and associated DGs

The preparation of the Impact Assessment started at the end of 2015. The inter-service group meetings on this document were held on 27 April 2016. The lead Directorate-General is DG Energy. The services invited to the ISG were Agriculture and Rural Development; Budget; Communications Networks, Content and Technology; Climate Action; Competition; Economic and Financial Affairs; Employment, Social Affairs and Inclusion; Enterprise and Industry; Environment; Eurostat; Justice; Joint Research Centre; Mobility and Transport; Regional and Urban Policy; RTD and Secretariat-General.

The Impact Assessment is supported by:

- Analysis of impacts on the energy system using the PRIMES partial equilibrium model, developed and used by the National Technical University of Athens (NTUA). A number of energy efficiency scenarios were modelled to analyse the impacts of different level of energy efficiency in 2030;
- Macroeconomic modelling using GEM-E3, a general equilibrium model, maintained and used by NTUA; and macroeconomic modelling using E3MG, a macro-econometric model run by Cambridge Econometrics – both building on PRIMES results;
- Analysis of air quality impacts by the GAINS model operated by IIASA – building on PRIMES results.
- Industrial Energy Efficiency Model (IEEM) operated by ICF.
- The POLES model operated by the JRC to quantify impacts on international fuel prices.

This energy efficiency package forms part of a full set of 2016 proposals for climate and energy policy under the Energy Union. It is assumed that all the other policies are to be implemented in line with the conclusions of the European Council of October 2014.

1.2 Consultation of the Regulatory Scrutiny Board

The Regulatory Scrutiny Board of the European Commission received the draft impact assessment report on 3 May 2016, and issued its positive opinion on 7 June 2016. The Regulatory Scrutiny Board made several recommendations. These are taken into account in this version of this impact assessment report as follows:

- The separate impact assessment reports on Articles 3 and 7 and 9-11 have been merged into a single document. The issue of metering and billing, in so far as electricity and gas is concerned, is referred to the upcoming impact assessment on market design and the present report only considers policy options in respect of thermal energy, regulated solely in the EED.
- It has been clarified (in Annex 3) how energy efficiency achievements contribute to the Effort Sharing Decision.
- The potential contribution of existing energy efficiency policies to the 2020 and 2030 target has been expanded and clarified in chapter 1.4.1 and chapter 5.6.
- More detail has been provided on the key policy areas for the achievement of the 2020 and 2030 targets in chapter1.4.1.
- The discussion of the relationship between the appropriate mix of policy measures and the energy efficiency target for 2030 has been expanded, in chapter 5.6.

- Chapter 4.1 describes in more detail how the policy mixes considered in this Impact Assessment represent a cost-effective approach.
- A discussion on the trade-offs between imposing targets and unified measures and the appropriate level of cost efficiency and flexibility for Member States has been developed in chapter 5.2.
- Energy poverty was further assessed in chapters **Error! Reference source not found.**
- The link between the EU target and the 1.5 % energy savings requirement of Article 7 of the EED has been explained further in chapter 5.4 and 5.6, and it has been made clear in chapter 5.2 that binding measures of this type would need to be looked at again if it was decided to adopt binding national energy efficiency targets.
- An analysis of the policy option of an energy intensity target for 2030, which was raised by stakeholders, has been added in chapter 5.3.
- Chapters 5.1.2, 5.1.5, 5.1.6 and Annex 8 have been adapted to better show the required levels of investments and to explain how the required investments for the different scenarios would need to be generated.
- Chapter 5.1.2 has been clarified to better describe possible crowding out effects.
- It has been clarified that the EED does not legally require the installation of smart meters.
- A discussion of sensitivities has been added in Annex 4.
- More explanation on monitoring and evaluation has been given in chapter 7.

The Board asked for the Reference scenario to be used as the baseline against which the impact of energy efficiency policy options would be assessed. The results of the Reference scenario 2016 are indeed consistenly reported in the impact assessment. A specific baseline assuming no additional energy efficiency efforts and policies while achieving the other 2030 targets for GHG and RES was not modelled. However, since all the policy scenarios need to include – in addition to energy efficiency policies – the 2030 greenhouse gas (GHG) and renewable energy policies as agreed by the European Council in October 2014, the EUCO27 scenario has been chosen as a baseline to assess the impacts of energy efficiency policies only. The reason for choosing EUCO27 baseline is explained in chapter 4.1.1 and in Annex 4 of the impact assessment accompanying the renewable energy initiative.

1.3 Public consultation[1]

A public consultation was launched on 4 November 2015 to collect views from stakeholders via on-line survey for the review of the Energy Efficiency Directive. It accepted responses for over 12 weeks and closed on 29 January 2016.. It focused on certain aspects of the EED, namely Articles 1, 3, 6, 7, 9-11, 20 and 24 , as outlined in the review's Evaluation and Inception Impact Assessment Roadmaps[2]. In line with the Better Regulation requirements and to assure transparency, submissions were published on the consultation website, unless confidentiality was requested[3].

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[1] Full report available on DG ENER website: http://ec.europa.eu/energy/en/consultations/consultation-review-directive-201227eu-energy-efficiency.

[2] http://ec.europa.eu/smart-regulation/roadmaps/docs/2015_ener_062_evaluation_energy_efficiency_eed_en.pdf.

[3] https://ec.europa.eu/energy/en/consultations/consultation-review-directive-201227eu-energy-efficiency.

The online survey was divided into two parts, the first covered more general questions, the second covered more technical ones (on Articles 6 and 7). Respondents were invited to answer all questions deemed relevant. A functional email address was created so as to assure additional guidance for participants, if required. The introduction of the consultation was translated into all 24 EU languages, which were published on the consultation website. To assure transparency both preliminary contributions as of 26 January 2016, and final contributions as of 29 January 2016 were made publicly available as Excel files[4]. The survey received 332 submissions, and an additional 69 documents were submitted to the functional email address, either complementary to or *in lieu* of survey-based submissions. The greatest number of contributions were submitted by industry associations (140), followed by private companies (47) and NGOs (33). A total of 18 central public authorities submitted contributions, including 17 from within the EEA. Of the 17 central public authorities from within the EU, 4 requested to remain anonymous. The remaining 13, all of which represented Member States, were from Austria, Belgium, Croatia, the Czech Republic, Denmark, Estonia, Finland, France, Hungary, Latvia, Lithuania, the Netherlands and Slovakia.

Main findings on the general questions related to the EED and the energy efficiency target 20303:

- Member States expressed the view that the EED, ETS and the ESD are instruments that work together to meet the EU's overall energy and climate objectives. It was seen by one Member State as positive that the EED had led to additional energy efficiency actions and to establishing a common framework for energy efficiency at EU level. Views highlighted the complexity of the existing legislation, and some Member States expressed a view that there were benefits to be gained from possible simplifications of the legislation. Several Member States underlined the centrality of articles 3, 7 and 24, and in combination, for the working of the Directive. The issue was raised in one case that the Member States have had little time to implement the EED and that it would have been an advantage to have more time and in consequence progress with respect to implementation was partial.
- One Member State raised the question of the benefits of the EED for driving energy savings compared to the Energy Services Directive. In another case a Member State expressed the view that to avoid situations where Member States curtail efforts to improve energy efficiency because they consume less energy than planned (for instance due to exogenous economic shocks or structural changes in the economy), it could be considered to make energy efficiency efforts mandatory regardless of the economic situation of a country.
- The view was expressed by one Member State that legislation should take into consideration both differences across Member States in terms of past experience with Energy Efficiency Obligation Schemes and the same yearly saving requirement may not be appropriate for all Member States.
- One Member States saw the EED's main contribution to be to the achievement of wider GHG reduction target. This Member State expressed the view that the importance that reductions in GHG emissions from non-energy activities due to changes in the production chain were not taken into proper consideration in this context.

[4] https://ec.europa.eu/energy/en/consultations/consultation-review-directive-201227eu-energy-efficiency.

- Most stakeholders agreed that the EED has successfully established a comprehensive energy efficiency framework for the EU. Several also expressed the view that the EED has been a key driver of initiatives in Member States, as evidenced, for example, by the extent to which Energy Efficiency Obligation Schemes (EEOSs) have been implemented across the Union. Respondents also underlined, however, that the present framework remains complex, and that Member States require additional guidance. Respondents requested the Commission to focus more on the transport sector, monitor Member States' progress, and, if necessary, sanction non-compliance.
- 31% of the respondents shared the view that the 2030 target should be expressed as both primary and final energy consumption, versus 23% who wanted it to be presented in terms of energy intensity. A large majority (73%) shared the view that energy consumption should be targeted irrespective of its source (i.e. that savings in renewable energy, for example, should continue to be taken into account).
- A variety of views were expressed on which factors should be taken into account for determining the target for 2030.
  - Several stakeholders expressed the view that when setting a new target for 2030 one should take into considerations that the current framework based on an indicative EU-level target and a mix of binding EU measures and national action had proved to be effective in reaching the 2020 EU objectives.
  - Many stakeholders expressed that the target should be ambitious.
    - Some saw an ambitious energy target as a cost-effective means to contribute to the achievement of the energy and climate goals of the EU.
    - Several stakeholders highlighted the agreement at the COP21. The EU needs to live up to the Paris agreement and increase its climate and energy targets for 2030 accordingly.
    - Representatives from industry that supported an ambitious goal for 2030 underlined the importance of a commitment at EU level to competitiveness.
    - It was also expressed that the current low ETS prices increased the need for a high energy efficiency target, to achieve all the goals the EU energy and climate policy.
  - A further argument was that many Member States will not of their own accord go beyond the minimum European legislation, and the EU should therefore set a sufficiently ambitious target to be confident of meeting its goals. In this regard some stakeholders highlighted the varying intensity of national implementation across Member States. In one instance the stakeholder referred to interviewed experts who claimed that the EED had been the sole driver for the introduction of energy efficiency measures in certain Member States.
  - Some stakeholders' experience with Member States' implementation of measures to reach the current EU 28 2020 target is that an overall non-binding European efficiency target will not be met unless the targets and associated measures set down in EU legislation are not sufficiently ambitious from the beginning.
  - A recurring theme from some stakeholders was that in their view energy efficiency is a policy that has general welfare benefits through contributing to value added, investment and jobs. As the energy efficiency gap is considerable there is an associated potential for substantial gains.
  - Interaction with other goals: Several stakeholders expressed the importance of policy coherence with the other energy and climate goals.
    - One factor that should be taken into account when setting an energy efficiency target is that barriers to energy efficiency in part cannot be effectively dealt with by market instruments. An energy efficiency target

complements the ETS. On the other hand, other stakeholders' view was there was room for reducing policy overlap between ETS and EE.
    - The EED should be seen as a tool to help achieving the goals of the effort sharing decision and there is a potential for positive synergy which could be further developed.
    - Interaction with RES target: one should take into consideration that it will be easier to achieve the RES target by reducing final energy consumption.
  - Stakeholders in general agreed that efficiency was an important criterion for setting the target.
  - The target is also seen as important to raise awareness among stakeholders across Europe.
  - Representatives from industry focused among other things on cost-effectiveness when designing the target, and in particular on the importance for industry's competitiveness of minimising the administrative burden.
  - A view expressed by several stakeholders was that the European Commission should propose a target that takes into consideration the EU principles of subsidiarity and proportionality. Furthermore, when defining a target allowances should be made for differences between Member States. The main rationale for energy efficiency can vary between Member States with a different emphasis on competitiveness, security of supply and reduced impact on the climate and the environment. Some others focused on the interactions between the target and the measures necessary to reach it, and that the design of the target would to some extent determine the mix of cost-effective measures.
  - Stakeholders highlighted also that the target set should serve to drive national energy efficiency policies and to provide a good mix between providing flexibility for Member States and the need to achieve the target.

Main findings on the stakeholder's views related to Article 7 (energy savings obligations) and Articles 9-11 (metering and billing) of the EED:

- *Article 7: Energy Efficiency Obligation Schemes (EEOSs)*

A large majority (68%) thought that Article 7 is an effective instrument for achieving final energy savings, versus 32% who opposed this view. Article 7 was seen as significantly stimulating the European energy efficiency service market, while simultaneously granting Member States valuable legislative flexibility. The three main barriers identified by participants to implementing Article 7 effectively were:

- A 'limited timeframe (2014-2020) that makes it hard to attract investment for long term measures' (115);
- A 'high administrative burden' associated with certain measures (113); and
- 'Ensuring sound and independent monitoring and verification of energy savings' (104).

Amongst those who favoured the extension of the policy, several argued that as savings could only be calculated up to 2020, the current scheme would discourage long-term measures towards the end of the legislative period. This contrasted with the assessment of 71% who thought that most measures introduced to-date under Article 7 have long lifetimes, and corresponded with the view of 63% who stated that the policy should continue beyond 2020.

More than half (57%) disagreed (39%) or even strongly disagreed (18%), however, that the current 1.5% energy savings target is adequate, versus 26% who either agreed (23%) or strongly agreed (3%). Some explained that savings could not increase linearly, and that logarithmic – that is, marginally decreasing gains – would be more realistic. Others made the case that energy suppliers are the wrong target group, as they neither primarily generate nor consume energy. Yet others pointed out that a 1.5% target is only marginally above the 1% natural rate of energy efficiency gains, and that the target would have to be more ambitious to comply with the new climate goals ratified during the 21st Conference of the Parties of the United Nations Framework Convention on Climate Change (COP21) to reduce global greenhouse gas emissions and stabilise global warming at 1.5-2 °C.

Participants were divided on whether EEOSs should have specific rules for vulnerable consumers, with 35% opposing such rules and 30% being in favour of them.

54% either strongly disagreed (36%) or disagreed (18%) that the option of establishing an EU-wide 'white certificate' scheme for energy efficiency gains should be considered for the post-2020 period; 25% had no view, while 21% were in favour of such a scheme.

- *Articles 9-11: Metering and billing*

43% shared the view that the EED's provisions on metering and billing are sufficient to guarantee consumers easily accessible, sufficiently frequent, detailed and understandable information on their energy consumption; 32% opposed this view and 25% had no specific view on this. Nearly half (47%) did not think that conditions such as technical feasibility or cost effectiveness should be harmonised across the EU, as such conditions would vary too greatly between Member States. The greatest obstacles identified to a large scale roll out of smart meters were cost effectiveness and consumer acceptance. Regarding the latter, many noted that smart meters would raise a number of data protection and cyber security issues. One Member State was cited several times as an example of how to address such concerns: citizens are entitled to 'opt out' of the smart meter scheme, but if they withdraw they may not track their energy consumption online. They would nevertheless be required to provide accurate data to their respective utility.

1.4 Overview of Member States' positions on Article 7 (to Public Consultation)

17 Member States (MS) including Norway (referred to as a MS for the case of simplification in the following) expressed a view on Article 7 in the Public Consultation relating to the review of the EED. Three of these MS asked not to be identified.

<u>General effectiveness of the provision</u>

Out of 17 MS that participated in the public consultation relating to article 7, eleven MS expressed an explicit opinion on the effectiveness of Article 7. Six MS considered the Article to be effective and five Member States considered that Article 7 is not an effective instrument to achieve final energy savings.

Six other MS considered Article 7 either to be of some limited effectiveness or refrained from answering the question. One MS, while not expressing a stance on the general effectiveness of Article 7, estimates that the current rules exclude certain effective measures, while allowing ineffective ones. Another MS considers specifically Energy Efficiency Obligation Systems (EEOS) to be an effective tools.

<u>Potential benefits of EEOS</u>

Respondents were asked to express agreement / disagreement on a list of defined potential benefits of EEOS.

Out of 12 Member States that expressed their opinion, most consider EEOS to have the following potential benefits:

- Better awareness of energy efficiency potential by consumers (10 MS agree, 2 MS disagree)
- Development of new financial models (8 MS agree, 2 MS disagree)
- Stimulation of energy efficient potential of buildings (7 MS agree, 3 MS disagree)
- Improved business and administrative environment for upcoming innovative services (7 MS agree, 2 MS disagree).

Furthermore, a relative majority of MS that responded considers EEOS to have the following potential benefits

- Increased competitiveness in energy markets (5 MS agree, 3 MS disagree)
- Better relationship between energy suppliers, distributors and customers (5 agree, 3 MS disagree).

In contrast, a relative majority the of Member States that responded do **not** share the view that EEOS have the following benefits:

- Lower energy bills for consumers (6 MS disagree, 5 MS agree)
- Aggregation of small – scale investments (5 MS disagree, 2 MS agree)
- Lower energy generation (and transmission) costs for utilities (4 MS disagree, 3 MS agree).

In the free text comments, one MS pointed to the favourable contribution of EEOS to GHG Emission Reductions.

One MS, while considering that EEOS generally lowered consumers' energy costs and tend to cost suppliers less than originally anticipated, noted the regressive effect of EEOs costs on consumers compared to taxes: The MS noted that low income households would contribute more financially to an EEOS obligation scheme than to tax-financed efficiency measures.

Similarly, another MS expressed views about negative impact of having an EEOS which would translate into higher energy prices, and sees the suppliers' claim that EEOSs would lead to increased bills to consumers as a challenge.

Nine MS consider that most measures triggered by EEOS have long lifetimes and will have an impact beyond 2020 and two MS think that *some* measures have such a long term-impact. The long – term impact of measures relating to buildings was highlighted by some MS in their free text answer.

Eight MS think it is inappropriate to design a system where EEOs include elements for increasing the share of renewables. However one MS is in favour and one expresses an intermediate view.

Major barriers to implementing Article 7[5]

Most participating MS identified as major challenges/barriers to implementing Article 7:

- High administrative burden[6]
- Developing the calculation methodology in line with the requirements of Article V[7]
- Ensuring sound and independent monitoring and verification of energy savings[8]

Potential for simplification

Eleven out of the 16 MS that responded to the public consultation considered the current rules related to Article 7 in their free text reply *generally* as too complex and/or posing a high administrative burden and mostly asked for the simplification of the rules and two further MS ask for simple, easily understandable rules for any future amendments to be adopted.

Six MS highlighted the administrative burden/complexity and costs specifically related to *Monitoring and Verification;* one MS pointed to the administrative burden for enterprises.

Three MS called in their free text contributions explicitly to reduce/streamline the reporting burden of M S and three MS consider that the calculation requirements applying to savings is too complex. MS should have more leeway to calculate savings (three MS). One MS regrets the absence of a *standardised calculation tool* and another MS suggested introducing a reporting and monitoring tool relating to Eurostat data. Three Ms consider Article 7 or pivotal provisions thereof to be unclear. However, with regard to the provisions of Annex V, three other MS see no need for clarification.

In contrast, clarification was asked on:

- Explaining better materiality (2 MS)
- Which price elasticities can be used (one MS)
- How to deal with confidential information from enterprises which needs to be reported to the Commission (one MS)
- More guidance on how to calculate savings (two MS), in particular scaled savings and savings from soft measures (one MS).
- Which renewables are eligible (one MS)

More flexibility vs harmonisation

Five MS considered in their free text comments the architecture of Article 7 overall as too restrictive, and ask for more flexibility for Member States to achieve their savings and one MS asks to be able to use the tools they have already in place. One MS considers the rules on eligibility of measures already now as too restrictive. One MS asks that the current degree of flexibility is maintained.

In their free text replies, two MS warn against limiting the number of eligible alternative measures in the future.

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[5] The public consultation ask to tick up to five options for identifying main challenges or barriers to implanting Article 7 in the respective countries.

[6] 8 out of 13 MS

[7] 10 out of 13 MS

[8] 10 out of 13 MS

Participants were asked to express their views on the harmonisation of a defined list of the requirements of Article 7 in order to allow more consistent implementation in Member States. The 13 MS expressed rather divergent views on harmonisation. Four MS are against any harmonisation of the requirements indicated above. In contrast three three MS asked for a harmonisation of all indicated requirements.

All in all Member States' Pro and Cons for more harmonisation are as indicated below:

- Calculation methods (6 MS yes, 7 MS no)
- Materiality definition (7 MS yes, 6 MS no)
- Additionality (7 MS yes, MS 6 no)
- Lifetimes (7 MS yes, 5 MS no)
- Price demand elasticities for taxation measures in real terms (6 MS yes, 5 MS no)
- Indicative list of eligible energy saving measures (5 MS yes, 5 MS no)
- Monitoring and verification procedures (5 MS yes, 8 MS no)
- Reporting (6 MS yes, 6 MS no)

Clarifying and expanding the scope of the eligible measures beyond end-user savings

Three out of 12 MS see no need to clarify the scope of the eligible measures, one MS fears that a clarification would curtail the flexibility of MS. However, nine out of 12 Member States ask for expanding the scope of admissible measures beyond end-user savings with regard to the following measures:

- Measures to switch fossil fuel heating and cooling fully or partially to renewable energy (e.g. through individual appliances, district heating and cooling, centralised distributed units supplying larger building complexes or groups of buildings) (8 MS)
- Savings from energy management systems (7 MS)
- Primary energy savings from the utilisation and recovery of waste heat (e.g. in district networks) (7 MS)
- Measures to increase efficiency of district network infrastructure and generation, including through thermal storage facilities (7 MS)
- Measures to make energy generation from small scale generation more efficient, below the ETS threshold (7 MS)
- Switch to self-consumption, auto-generation and energy positive buildings (7 MS)
- Participation in demand response, including from providing storage capacities (3 MS)

Furthermore, MS ask in the free text replies to expand the scope of eligible measures to:

- All measures (one MS),
- To more measures (one MS)
- Use of electric vehicles (one MS)
- All on-site generation of energy (one MS)
- Use of renewables (one MS)

Each of the expansion of eligible measures is asked for by one Member State.

Request to relax the rule on the 'additionality' requirement

Nine MS see in their free text comments the requirement of additionality critically, i.e. the requirement that allows measures only to be counted if they are not demanded by existing EU legislation.

Of these, three Member States ask explicitly to remove the additionality requirement completely); two other MS want to remove it with regard to buildings and products. Two MS are concerned with the additionality specifically relating to the EPBD and ask for a "Review on the interaction of EPBD and EED" (one MS) or suggest merging both directives (another MS). Three MS consider the rules on additionality generally to be unclear. In contrast, two MS see positive synergies between the EED and EPBD.

Review the concept of Materiality

In their respective free text comments, five MS ask to review or clarify the concept of materiality, one MS suggests to abandon the materiality criterion altogether.

Is the 1.5% savings rate in Article 7 adequate?

Seven MS suggest that the current level of energy savings of 1.5% defined in Article 7 is adequate. Of these, 3 MS ask not increase the ambition of the savings requirement.

Four MS consider the savings requirement to be too high. Among these, the following comments were made:

- National GDP and growth should be taken into account for target definition;
- Climatic conditions should be taken into account;
- The savings requirement of 1.5% used to be ok at a time when the Directive was agreed upon but has turned out to be too ambitious;

Four MS expressed the following intermediate views, such as:

- The savings requirement might be considered to be appropriate but is too high in the light of the Commission's interpretation of the rules.
- The savings requirement should be defined at national level
- One MS ticked the box for considering the savings requirement to be inappropriate, but considered in its free text response the target to be at the upper [acceptable] limit.
- Another MS expressed and ambiguous view

Lifting the Sunset Clause under Article 7

15 Member States expressed views on continuing the current framework of Article 7 beyond 2020 with a view of the new energy efficiency target of 2030 ("Lifting the sunset clause").

Four Member States express themselves in favour of lifting the sunset clause: The following views were put forward:

- The size of the reduction should depend on the overall indicative target and the contributions from other energy efficiency measures;
- Payback time should be taken into account when setting savings requirement;
- The possibility of excluding sales in transport from the baseline should be excluded;
- All exemptions under Article 7 (2) should be excluded;
- Possibility for banking and borrowing energy savings should be kept.
- The savings requirement should be decided in light of the Commission’s Impact Assessment
-

Seven MS are against lifting the sunset clause; and another MS is reluctant to support lifting the clause.

Among these MS the following comments were made

- Indicative target for 2030 sufficient, as Article 7 is complex and burdensome.
  - However, if sunset clause if lifted, eligible measures should not be further restricted.
- The Council Conclusions of 2014 agreement stated that there will not be nationally binding targets: lifting the sunset clause would constitute such a target.
- Better to set targets at sector level, while taking macroeconomic indicators into account.
- Reluctant to lift the clause, due to restrictive current rules of energy savings calculations, lack of promotion of cost-effective measures and insufficient focus on GHG reductions

Three MS express intermediate views.

- Lifting of the sunset clause to be discussed, in particular in the view of the bureaucratic burden;
- Level of ambition to be reviewed in the light of lower energy prices and the positive impact of efficiency measures already in place;
- Another MS ticked the box of being not in favour of lifting the sunset clause. On the other hand this MS but expressed in its free text reply mostly a preference for a continuation of the status quo: MS should continue to have the [current] choice between EEOS and alternative measures, which allows MS to have the most efficient mix of energy efficiency measures.

White Certificates, Transfer of savings between MS

Two MS expressed a preference for considering the introduction of an EU-wide white Certificate Scheme, eight MS are against, three MS express intermediate or indifferent views.

Retail Price regulation

In its free text comment, one MS emphasizes the adverse effect of price regulation on energy efficiency.

1.5 General Issues Raised with Member States in the EU Pilots on Article 7

This chapter gives a brief overview of the issues clarified with Member States related to the implementation of Article 7 since 2014.

1. Eligibility/materiality:

- do measures have to be primarily aimed at energy efficiency?
- or is it sufficient that there is a (measurable) energy efficiency gain?
- do the measures have to result in a reduction of sales of energy to final customers?
- free riders – how do Member States work out what would have happened anyway?
- How are lifetimes proved?

2. Additionality:

- What should be considered the "EU Norm" under the EPBD?
- how does additionality work in relation to directly applicable ecodesign measures?
- How do MS show that a measure speeded up the up-take of a compulsory norm?

3. Monitoring and verification:

- What is a "statistically significant proportion and representative sample"?

- How is the independence of the checking system ensured?

4. Calculation of saving requirements

- Discrepancies with Eurostat data
- Use of exemptions leading to more than 25% reduction
- Own energy use
- Art 7(2)d) – how to show that "early actions" continue to have an effect after 2020?
- How to avoid double counting?
- Article 7(7)c) and "banking and borrowing"

5. Calculation of savings:

- Final/primary energy?
- Use of elasticities in taxation measures
- Use of climatic variations

6. Energy Efficiency Obligation Schemes

- Relationship with National Energy Efficiency Fund?
- Publication of savings of obligated parties
- Social aims?
- Are savings by 3rd parties allowed?

7. Alternative measures:

- How to prove energy savings from "behavioural" measures such as information campaigns?
- What if progress towards savings is not satisfactory?
- How to ensure that only one party claims the savings?
- How does the requirement to have penalties work in relation to alternative measures set in place by the State? Should it punish itself?

1.6 Other consultations

More targeted consultation with Member States took place through the EED Committee of 2 February 2016 and Concerted Action meeting of 17-18 March 2016.

Further stakeholder inputs were collected through the organisation of thematic workshops, notably on Monitoring and Verification (of 3 February) and on trading of energy savings under Article 7 (of 29 February).

Findings of the workshop on trading of energy savings under Article 7 (29 February):

12 Member States and 15 stakeholders attended the workshop. The discussion was preceded by presentations on the existing national White Certificate Schemes in France, Italy, Ireland, and on Energy Efficiency Obligations in some US States.

Overall, no support was expressed as regards establishing an EU trading system for energy savings or an EU White Certificates Scheme at this stage. The following arguments were mentioned by the participants as major impediments for cross-border trade:

  - Complexity of rules that a EU-wide trading system would imply;

- The divergent and incompatible national Monitoring and Verification systems to account properly the traded savings, which would hinder a cross- border clearing of trades;
- Incompatibility of specific national policy objectives and
- Political necessity to see national savings efforts translated in material efficiency gains at a national level (dilemma between - who pays and who benefits from the trading).

Conclusions of the stakeholder event on the EED Review (14 March 2016):

A dedicated stakeholder event on the policy options took place on 14 March 2016 and the discussion fed into the impact assessment process. Some 282 representatives from Member States and Stakeholders' European umbrella organisations gathered on 14 March 2016 in Brussels to react to the evaluations, problem definitions, and policy options raised in the framework of the review processes of the Energy Efficiency Directive (EED) and of the Energy Performance of Buildings Directive (EPBD). The event was organised as a consultation in the framework of the Better Regulation Initiative.

As regards the energy efficiency target for 2030, there was considerable interest from stakeholders in the target and many stakeholders expressed views on both design, in particular whether it should be a binding or non-binding target and the level of ambition for 2030.

Analysis of energy efficiency levels up to 40% in 2030 was supported by the majority of stakeholders who expressed their views, while views differed with regard to the binding character of the 2030 target and on the expression of the target in terms of final and/or primary energy consumption. Some of the participants asked for an explicit analysis of options in case indicative targets or national plans for 2030 would not deliver the required level of energy savings in 2030. In addition, it was highlighted that the EED framework needs to be coherent with the ETS, the Effort Sharing Decision and the RES Directive.

On Article 7 on energy efficiency obligation schemes stakeholders did not express the view that the clause should not be extended. Stakeholders expressed different views on whether the scope should be broadened to also take into account savings from additional use of renewables.

Concerning Articles 9 to 11 on metering and billing, there was considerable response from the stakeholders on these articles, with discussion also focusing on interaction with the internal energy market. Views from stakeholders varied on the need to re-open the articles.

2 Annex - Who is affected?

2.1 Article 1 and 3

The entire economy, including households, the public sector and various economic sectors are affected by the above mentioned problem:

- Member States authorities at national, regional and local levels, as they are responsible for planning and implementing necessary energy efficiency policy and legislation. Member States can benefit from lower energy bills, economic growth, employment impacts and improved energy security of supply.
- Households, in particular low income households, might be affected if remaining cost-efficient energy saving potentials are not exploited as high energy bills affect their well-being e.g. if those households cannot keep their houses warm or cool in the summer.
- European companies might improve their competitiveness by further developing energy efficiency, particularly as it better protects them against energy price differentials. This also holds for small and medium size industries which have high share of energy costs related to total production costs and would benefit from investing in energy efficiency to lower their energy purchasing costs.
- Producers of energy efficient equipment and appliances will benefit from increased demand for their products, while energy suppliers will be affected by reduced demand.
- European citizens should benefitfrom a better environment.

Stakeholders outside the EU are also affected as climate change is a global problem, which goes beyond the boundaries of the European Union. In this context, ambitious and successful EU energy policies can be replicated by third countries.

2.2 Article 7 and 9-11

- Member States' authorities at national, regional and local levels, as they are responsible for planning and implementing necessary energy efficiency policy and legislation.
- Consumers who could benefit from energy savings and reduced energy bills as a result of lower energy consumption and accurate, clearer additional billing and consumption information.
- Industry in general, which equally benefits from reduced energy costs.
- Non-SMEs as they are subject to energy audits every four years.
- SMEs as Member States are encouraged to offer voluntary energy audits or energy management systems to them.
- Obligated parties (energy distributors or retail energy sales companies), participating and entrusted parties (enterprises or public authorities involved in carrying out the energy efficiency measures) affected by Article 7 of the EED.
- Investors who may obtain greater investment security and stable investment return.
- Other financial actors, such as commercial banks, which may benefit from increased business opportunities.

Table 1: An overview of the stakeholder groups affected by this initiative

Stakeholder group	Article 1 and 3	Article 7	Articles 9-11
Member States authorities	Will be responsible for planning and implementing necessary energy efficiency policy to achieve the energy efficiency target 2030, they can benefit from lower energy bills, economic growth, employment impacts and improved energy security of supply etc.	Will be responsible for planning and implementing necessary energy efficiency policy in view of the next obligation period; Will benefit from the coherence and complementarity with the other legislation as Article 7, e.g. will contribute to the achievement of more ambitious GHG emission reduction targets under the Effort Sharing Decision for 2030;	Will be responsible for planning and implementing necessary energy efficiency policy.
Obligated parties (energy distributors or retail energy sales companies), and participating and entrusted parties (enterprises or public authorities)	X	Will be carrying out the energy efficiency measures and work with the consumers, including auditing the savings ensuring reporting to the implementing public authority; Will benefit from lower administrative burden as a result of simplification of what savings can be counted under Article 7, especially those targeting the energy efficiency renovations; Obligated parties will benefit from the improved reputation and better relationship with consumers thanks to consumer oriented business approach; Utilities will benefit from lower energy generation (and transmission) costs for the utilities	District heating/cooling companies as well as owners or managers of multi-apartment/purpose buildings or service providers will have to be involved in implementing the new billing and metering rules and adjust their processes.
Consumers	With an ambitious energy efficiency commitment of Member States, consumers benefit from an improved energy efficiency	Consumers will bear some costs of energy efficiency measures, and will benefit from reduced energy bills as a result of energy efficiency improvement measures and	Consumers of centrally provided thermal energy will benefit from more frequent, accurate, clearer additional billing and

	framework/measures which will help consumers to bear the costs of the energy efficiency measures, and they will benefit from the reduced energy bills, higher living standards, health benefits etc.	lower energy consumption; The energy poor will benefit from the continued policy as Art. 7 targets mostly energy efficiency renovations of existing buildings. Consumers will benefit from increased awareness of the benefits of energy efficiency, and possibly better – customer oriented service by the energy providers.	consumption information.
Businesses including SMEs	Will benefit from increased business opportunities and innovation with an ambitious 2030 energy efficiency target	Will benefit from increased business opportunities and innovation (energy performance contracting) and competitiveness related to the more developed energy services market; Demand for energy services would require more skills and jobs to perform the renovations and installation of the energy efficiency measures.	Will benefit from increased business opportunities and innovation.
Investors and financial actors	Play a crucial role to provide smart financing solutions for energy efficiency investments in order to exploit energy efficiency potentials to achieve the 2030 energy efficiency target	Investors will have greater investment security and stable investment return and may benefit from increased business opportunities; Financial actors such as commercial banks will benefit from increased business opportunities.	

3 Annex - Interactions with other elements of the 2030 energy climate framework

3.1 EED interaction with the EPBD, ecodesign and labelling

The 2012 Energy Efficiency Directive establishes a set of binding measures to help the EU reach its 20% energy efficiency target by 2020. The EED sets the overall energy efficiency framework which requires Member States to ensure that energy is used more efficiently at all stages of the energy chain from its production to its final consumption. New national measures have to ensure major energy savings for consumers and industry alike. These have to be achieved by taking into account the existing requirements set by the relevant legislation:

a) Minimum standards for new/renovated buildings (EPBD) and new products (ecodesign), so that when consumers do invest they take into account existing European and national standards and the set of investments available to them excludes those which have a weak case once the costs and benefits are looked at over the life cycle;

b) Information requirements for buildings (EPBD) and products (energy labelling) so that consumers which invest can reliably identify the energy performance of the building or product.

It also complements the implementation of other aspects of the EU's energy efficiency policy. For example the Energy Performance of Buildings Directive (EPBD) sets minimum energy requirements for new or renovated buildings but contains no requirements as to how many buildings must be renovated, or by when. By contrast Article 7 requires actual energy savings, and therefore encourages building renovations to take place in practice. Likewise, energy labelling requirements inform consumers of the efficiency of appliances, but a government information campaign will actively encourage consumers to buy those more efficient appliances. The EED, and in particular Article 7, can therefore be seen as a 'pull' factor in terms of increasing the take up of the linked policies.

Studies show that: (i) minimum standards and information requirements are having a good effect on the *quality* of investment; (ii) the *rate* of investment continues to be a problem, and this has been worsened by the recession.

3.2 Effort Sharing Decision / Regulation

Energy efficiency targets have a link with climate targets and in particular the Effort Sharing Decision (ESD) that defines GHG emission reduction targets for Member States for the years to 2020. This is because the level of the target for energy efficiency influences the amount of GHG reduction achieved in sectors covered by the ESD. Energy efficiency policies contribute significantly to the take-up of energy saving technologies in buildings, industry and transport and energy efficiency measures are a cost-effective way of helping Member States achieve the effort sharing targets. Assessing the level of energy efficiency for 2030 is therefore closely linked to the Commission's proposal for a new Effort Sharing Regulation (ESR)[9] on how to

[9] COM(2016)482.

achieve a 30% reduction in GHG emission in the non-ETS sectors (comprising effort sharing sectors and LULUCF) in 2030 compared to 2005.

The European Council has agreed on a non-ETS target (comprising ESD and LULUCF) for 2030 of -30% below 2005 levels, the latter to be implemented by national binding targets. The European Council also concluded that the national reduction targets for the non-ETS sectors should be set based on GDP per capita differentiation, keeping them in a range from 0% to -40% compared to 2005. However the targets for Member States with a GDP per capita above the EU average should be relatively adjusted to reflect cost-effectiveness in a fair and balanced manner. As the cost-effective energy efficiency potential differs significantly between Member States, the different energy efficiency levels for 2030 can affect emission reduction potentials and costs in Member States to a different extent. Therefore two different levels of the 2030 energy efficiency target are also taken into account in the analysis underpinning the Commission's proposal for the new Effort Sharing Decision (27% and 30%)[10], and the analytical underpinning of this impact assessment and the impact assessment for the ESR[11] are based on the same two scenarios.

The post 2020 non-ETS targets will no longer allow any Member State to have growing GHG emissions (as in the current period), hence the effort required from every Member State will be bigger. Setting national binding emission reduction targets for each Member State, however, does not contradict the overall energy efficiency target for 2030 or specific energy efficiency measures set under the EED, e.g. the saving target of 1.5% under Article 7. Energy efficiency measures help to reduce GHG emissions in transport, buildings and smaller industrial installations. Importantly, energy efficiency policies ensure that market barriers are tackled in a targeted manner and existing saving potentials are exploited (which would not necessarily happen under a GHG effort sharing-only system). They ensure that all Member States improve energy efficiency and thus facilitate achievement of the ESR targets. The reason for the complementarity between the two policy areas is that European energy efficiency measures are only adopted where action is more effective at European than at national level. Thus these measures do some of the work that Member States would otherwise have to do in fulfilling their obligations under the ESD/ESR – and do it more effectively.

In the EUCO27 scenario, Member States increase their energy efficiency level starting from national energy efficiency efforts as depicted in the EU Reference scenario 2016. This leads to a reduction of primary energy consumption in 2030 of between 1 and 7% for all Member State, with the reduction at the EU28 level of 4.7%. With higher energy efficiency levels (than 27% in 2030) some Member States are projected to overachieve and some to underachieve their ESR target. Member States can use their flexibility provided in the ESR, which would allow a transfer of annual emission allocations (AEAs) in case they achieve higher energy efficiency

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[10] Member States have significant differences in economic strength and investment capacity as well as in emission reduction potentials and costs. As the 2030 framework impact assessment (SWD(2014)15) has shown, applying cost-effectiveness as sole criterion for the distribution of efforts would lead to considerable variations in the necessary national economic effort and would imply (on average) relatively higher efforts and costs per unit of GDP for lower income Member States. The current ESD and the proposed ESR address the differences in economic capacity by differentiating national targets according to relative differences in GDP per capita. However, setting targets based solely on GDP per capita may result in large differences in the costs per ton reduced emissions between Member States if the reductions have to be achieved domestically, and might induce very costly efforts for those higher income Member States with more limited remaining mitigation potentials.

[11] SWD/2016/247.

improvements than required for their national ESR target. Overall, this reflects a cost efficient achievement of GHG reductions.

Energy efficiency measures play an important role for all sectors covered by the ESD/ESR. However, EU measures on energy efficiency do not restrict Member States' freedom to choose the measures they wish to implement to attain their national GHG reduction targets. The EED already offers substantial freedom to Member States as regards how to implement different obligations and how to achieve their indicative national targets. Member States can decide e.g. with regard to Articles 5 and 7 between default and alternative approaches. Other articles leave enough room for Member States to consider their national circumstances and on which sectors they want to focus. Constraining the freedom of Member States would risk increasing costs for them. All instruments under the ESD/ESR and energy efficiency policies complement each other.

Ambitious national and European energy efficiency policies leading to a level of 33% of energy efficiency in 2030 or higher would result in more emission reductions (34%-39% in 2030) in the non-ETS sectors than agreed in the European Council conclusions in October 2014.

The 2014 Report of the European Environmental Agency confirmed that progressing towards several climate and energy targets has created a number of positive synergies. Energy efficiency measures help meet the national 2020 ESD targets. The latter can be an additional incentive to implement more ambitious efficiency policies[12].

3.3 EU Emissions Trading System

The European Council agreed on an EU ETS target of -43% emission reductions compared to 2005. Energy efficiency targets and policies interact with the EU Emissions Trading System (ETS). ETS acts on the failure of prices to internalise external costs; energy efficiency policies address non-price barriers such as lack of information, bounded rationality and split incentives.

The current policies and targets linked to the 2030 climate and energy framework were designed in a way that climate and energy efficiency targets are consistent and enable the ETS and energy efficiency measures to be mutually reinforcing instruments. Energy efficiency policies benefit from the fact that carbon prices created by the ETS open up new markets and applications for energy efficient products and technologies (notably in industrial installations and transport modes covered by ETS and in all equipment consuming electricity).

Savings in electricity consumption or in other energy forms used in industrial sectors covered by the ETS have an impact on the demand for allowances in the ETS[13]. The ETS Market Stability Reserve (MSR) adopted in 2015 will respond to major changes in the demand of allowances, regardless of whether these are the result of economic factors or due to policy developments, for example in relation to improved energy efficiency. The architecture of the reserve is such that it automatically and in a gradual manner reduces the auction supply if there is a significant oversupply of allowances. For very ambitious levels of 2030 energy efficiency targets, this poses risks to the overall coherence in delivering the climate objective. Therefore, it might need

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12 Trends and projections in Europe 2014: Tracking progress towards Europe's climate and energy targets: http://www.eea.europa.eu/publications/trends-and-projections-in-europe-2014.

13 SWD(2014) 16 final.

to be considered as part of the first review of the Market Stability Reserve parameters foreseen by 2021 whether this justifies a change to the parameters (e.g. the MSR feeding rate) in case of ambitious energy efficiency targets to preserve the overall policy coherence in delivering the climate objective in a cost effective manner, as agreed by European leaders.

3.4 Renewable energies

Energy consumption reductions help to ensure progress towards higher shares of renewables, as lower energy consumption means a lower denominator in the ratio between consumption of renewables and gross final energy consumption. Non-thermal renewable energy typically has lower transformation losses than conventional energy sources, lowering the primary energy consumption for any given final energy consumption. Higher shares of renewable energy can therefore help to make progress towards the energy savings target, as the target relates to primary energy consumption.

All policy scenarios assessed in this Impact Assessment achieve RES shares of 27-28% in 2030 by assumption (more ambitious EUCO+ scenarios are overshooting 27% share). However to test the implications of ambitious energy efficiency policy with a renewable energy share of 30%, for example as a result of a high level of ambition on renewable energy across a range of Member States, and reflecting the call from the European Parliament, the impact of a scenario with 30% energy savings and 30% renewable energy on the energy system was assessed in addition.

As shown in Annex 4, GHG emissions decrease by 43.2% overall in this scenario; in the ETS sector by 48.1% and non-ETS by 30.7%. This is due to the fact that this scenario achieves mostly additional GHG reductions in the power generation sector, where additional renewable capacity would be installed. The increase in RES-E share is quite significant. Mostly driven by the shift to RES in the power sector, primary energy consumption decreases (compared to 2007 baseline) by an additional 0.8 percentage points (-30.8% instead of -30% in EUCO30), while final energy consumption remains constant, due to identical energy efficiency policies mix as in EUCO30. Due to the higher rate of RES deployment, import dependency is reduced compared with EUCO30. Average annual energy system costs in the period 2021-30 increase marginally compared to EUCO30, by 0.23% (€5 billion) driven by higher investment in grid as well as power generation. In a 2021-50 perspective, average annual energy systems costs are only slightly higher (€3 billion) than for EUCO30.

As regards the interaction of Article 7 with the RES Directive, allowing renewable actions to be counted under Article 7 will result in changing the energy mix through the integration of renewable energy targeting the residential sector.

3.5 Internal energy market

Europe's energy markets are in a period of transition to a low carbon economy. To deliver the needed investment, allow for the free flow of electricity across borders, deliver on the new deal for consumers, ensure security of electricity supply and allow for an increased share of (variable) renewables in the system, the Commission intends to make a proposal on how to reform Europe's energy markets organisation and regulation. All this means delivering a market with the consumers – households and businesses – at its core which is fit for renewables and which is mutually reinforcing with energy efficiency policies.

Energy markets providing effective price signals are a key condition for mobilising the required capital for the transition of the energy sector while maintaining a high level of security of supply. Meeting the 2030 energy and climate goals will require significant investment flows into the energy sector. Therefore, the Commission's Energy Market Design Initiative will take into account the impacts of the moderation of energy demand on the necessary investments in the energy sector (generation, networks, storage and the demand side). As the analysis in this Impact Assessment has shown, a lower demand of energy in 2030 could reduce the need for investments in additional power generation and grid capacities. Lower investments in power generation capacity contribute to lower electricity prices.

Energy efficiency policies, e.g. the requirement for individual meters for consumers or rules on demand response ensure that consumers benefit from the new framework by better integrating wholesale and retail markets and ensuring better information for consumers. These energy efficiency policies empower and encourage consumers to become active players in the future energy market as they can manage their energy consumption more easily. However, the current design of the electricity market and regulated energy prices in some Member States mean that many consumers have no incentive to change their consumption in response to changing prices on the market. Price signals in real time are currently not passed on to final consumers, resulting in inflexible demand patterns. Real time pricing would make electricity demand more flexible (smart white electronics, electric vehicles deployment as well as heat pumps in insulated buildings are examples of new flexible load shifting demand able to take advantage of such price differentials). Two aspects are relevant here: improving consumer access to fit-for-purpose smart systems as well as electricity supply contracts with dynamic prices linked to the spot market; and removing the primary market barriers for independent demand response service-providers (i.e. aggregators), creating a level playing field for them. As the current design of the retail market prevents consumers from being able to fully profit from these possibilities to participate in the energy market fully, this Impact Assessment tackled the barriers related to metering and billing for thermal energy and the new market design initiative will address these remaining barriers to exploit the full potentials of energy efficiency policies.

4 Annex - Analytical models and model-based scenarios used

4.1 Description of analytical models used

The model suite used for the key scenarios presented in this Impact Assessment has a successful record of use in the Commission's energy and climate policy impact assessments – it is the same model suite as used for the 2020 climate and energy package as well as for the 2030 climate and energy policy framework. The models and their linkages are briefly described in the following subsections. Detailed model descriptions can be found on the DG CLIMA website[14].

The model suite covers:

- **The entire energy system** (energy demand, supply, prices and investments to the future) and all GHG emissions and removals.
- **Time horizon:** 1990 to 2050 (5-year time steps)
- **Geography:** individually all EU Member States, EU candidate countries and, where relevant Norway, Switzerland and Bosnia and Herzegovina
- **Impacts:** on energy, transport and industry (PRIMES and its satellite models on biomass and transport), agriculture (CAPRI), forestry and land use (GLOBIOM-G4M), atmospheric dispersion, health and ecosystems (acidification, eutrophication) (GAINS); macro-economy with multiple sectors, employment and social welfare (E3ME and GEM-E3).

The models are linked with each other in formally-defined ways to ensure consistency in the building of scenarios, as shown graphically in Figure 1. These inter-linkages are necessary to provide the core of the analysis, which are energy, transport and GHG emissions trends.

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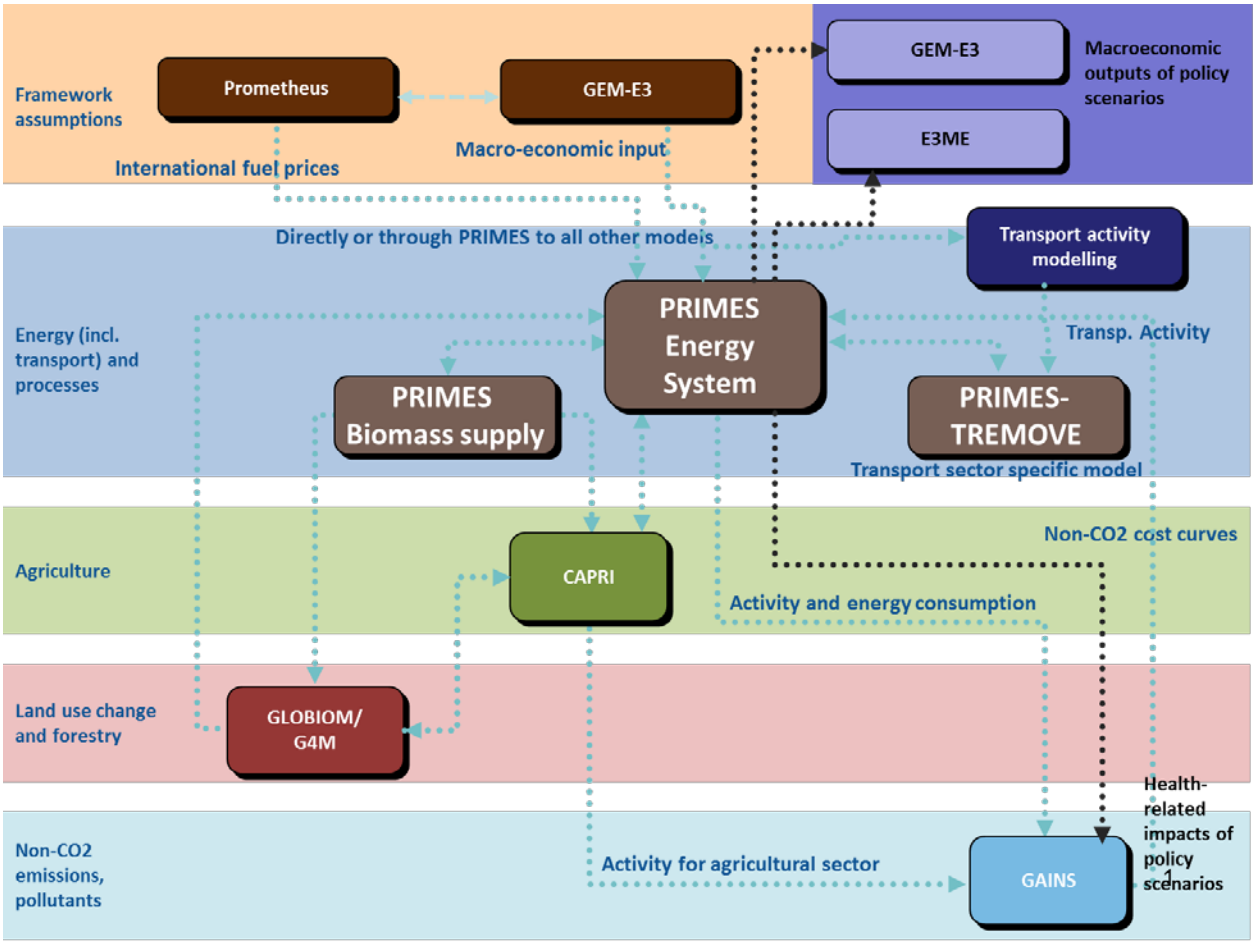
14 http://ec.europa.eu/clima/policies/strategies/analysis/models/index_en.htm.

Figure 1: Inter-linkages between models



Source: DG CLIMA based on E3MLab/ICCS[15]

The results of these energy-system scenarios can serve as input for the two macroeconomic models (GEM-E3 and E3ME) used to assess the macroeconomic implications of various energy efficiency targets. In addition, the energy-system scenarios also serve as input for assessing the health implications of the scenarios, via the model GAINS.

4.1.1 PRIMES

The PRIMES model is an EU energy system model which simulates energy consumption and the energy supply system. It is a partial equilibrium modelling system that simulates an energy market equilibrium in the European Union and each of its Member States. This includes consistent EU carbon price trajectories.

Decision making behaviour is forward looking and grounded in micro-economic theory. The model also represents in an explicit way energy demand, supply and emission abatement technologies, and includes technology vintages.

The core model is complemented by a set of sub-modules, of which the transport sector module and the biomass supply module are described below separately in more detail. Industrial non-

15 http://ec.europa.eu/clima/policies/strategies/analysis/models/index_en.htm

energy related CO2 emissions are covered by a sub-module so that total CO2 emissions can be projected. The model proceeds in five year steps and is for the years 2000 to 2010 calibrated to Eurostat data.

The PRIMES model is suitable for analysing the impacts of different sets of climate, energy and transport policies on the energy system as a whole, notably on the fuel mix, CO2 emissions, investment needs and energy purchases as well as overall system costs. It is also suitable for analysing the interaction of policies on combating climate change, promotion of energy efficiency and renewable energies. Through the formalised linkages with GAINS non-CO_2 emission results and cost curves, it also covers total GHG emissions and total ESD sector emissions. It provides details on the Member State level, showing differential impacts across Member States.

The PRIMES model represents energy efficiency by simulating different measures with different techniques. These modelling techniques will affect the context and conditions under which stylized agents per sector, make their decisions on energy consumption.

PRIMES has been used for the analysis underpinning the Commission's proposal on the EU 2020 targets (including energy efficiency), the Low Carbon Economy and Energy 2050 Roadmaps, the 2030 policy framework for climate and energy and the energy efficiency Impact Assessment in 2014.

PRIMES is a private model and has been developed and is maintained by E3MLab/ICCS of National Technical University of Athens[16] in the context of a series of research programmes co-financed by the European Commission.

The model has been successfully peer reviewed[17], most recently in 2011[18].

4.1.2. PRIMES -TAPEM & PRIMES-TREMOVE

PRIMES-TAPEM, operated by ICCS/E3MLab is an econometric model for transport activity projections. It takes GEM-E3 projections (GDP, activity by sector, demographics and bilateral trade by product, and by country) as drivers, to produce transport activity projections to be fed into PRIMES-TREMOVE. The econometric exercise also includes fuel prices coming from PROMETHEUS, as well as transport network infrastructure (length of motorways and rail-ways), as drivers. The PRIMES-TAPEM model provides the transport activity projections for the Reference scenario.

The PRIMES-TREMOVE Transport Model projects the evolution of demand for passengers and freight transport by transport mode and transport mean. It is essentially a dynamic system of multi-agent choices under several constraints, which are not necessarily binding simultaneously. The model consists of two main modules, the transport demand allocation module and the technology choice and equipment operation module. The two modules interact with each other and are solved simultaneously.

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16 http://www.e3mlab.National Technical University of Athens.gr/e3mlab/.

17 http://ec.europa.eu/clima/policies/strategies/analysis/models/docs/primes_model_2013-2014_en.pdf.

18 https://ec.europa.eu/energy/sites/ener/files/documents/sec_2011_1569_2.pdf'.

The projection includes details for a large number of transport means, technologies and fuels, including conventional and alternative types, and their penetration in various transport market segments. It also includes details about GHG and air pollution emissions, as well as impacts on external costs of congestion, noise and accidents.

PRIMES-TREMOVE has been used for the 2011 White Paper on Transport, Low Carbon Economy and Energy 2050 Roadmaps as well as the 2030 policy framework for climate and energy.[19]

The PRIMES-TREMOVE is a private model that has been developed and is maintained by E3MLab/ICCS of National Technical University of Athens [20], based on, but extending features of the open source TREMOVE model developed by the TREMOVE[21] modelling community. Part of the model (e.g. the utility nested tree) was built following the TREMOVE model.[22] Other parts, like the component on fuel consumption and emissions, follow the COPERT model.

In the transport field, PRIMES-TREMOVE is suitable for modelling *soft measures* (e.g. eco-driving, deployment of Intelligent Transport Systems, labelling), *economic measures* (e.g. subsidies and taxes on fuels, vehicles, emissions; ETS for transport when linked with PRIMES; pricing of congestion and other externalities such as air pollution, accidents and noise; measures supporting R&D), *regulatory measures* (e.g. CO_2 emission performance standards for new passenger cars and new light commercial vehicles; EURO standards on road transport vehicles; technology standards for non-road transport technologies), *infrastructure policies for alternative fuels* (e.g. deployment of refuelling/recharging infrastructure for electricity, hydrogen, LNG, CNG). Used as a module which contributes to a broader PRIMES scenario, it can show how policies and trends in the field of transport contribute to economy wide trends in energy use and emissions. Using data disaggregated per Member State, it can show differentiated trends across Member States.

4.1.3. PRIMES Biomass Supply

The biomass system model is linked with the PRIMES energy system model for Europe and can be either solved as a satellite model through a closed-loop process or as a stand-alone model.

It is an economic supply model that computes the optimal use of biomass/waste resources and investment in secondary and final transformation, so as to meet a given demand of final

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19 The model can be run either as a stand-alone tool (e.g. for the 2011 White Paper on Transport) or fully integrated in the rest of the PRIMES energy systems model (e.g. for the Low Carbon Economy and Energy 2050 Roadmaps, and for the 2030 policy framework for climate and energy). When coupled with PRIMES, interaction with the energy sector is taken into account in an iterative way.

20 http://www.e3mlab.National Technical University of Athens.gr/e3mlab/.

21 http://www.tmleuven.be/methode/tremove/home.htm.

22 Several model enhancements were made compared to the standard TREMOVE model, as for example: for the number of vintages (allowing representation of the choice of second-hand cars); for the technology categories which include vehicle types using electricity from the grid and fuel cells. The model also incorporates additional fuel types, such as biofuels (when they differ from standard fossil fuel technologies), LPG and methane fuels. In addition, representation of infrastructure for refuelling and recharging are among the model refinements, influencing fuel choices. A major model enhancement concerns the inclusion of heterogeneity in the distance of stylised trips; the model considers that the trip distances follow a distribution function with different distances and frequencies. The inclusion of heterogeneity was found to be of significant influence in the choice of vehicle-fuels especially for vehicles-fuels with range limitations.

biomass/waste energy products, projected to the future by the rest of the PRIMES model. The biomass supply model determines the consumer prices of the final biomass/waste products used for energy purposes and also the consumption of other energy products in the production, transportation and processing of the biomass/waste products. The model also reflects the sustainability criteria currently in place and can be used for reflecting policies facilitating the use of renewable energy sources. After cross check of input data and draft results, results of the biomass supply model are used to ensure consistency between PRIMES, CAPRI and GLOBIOM bioenergy modelling.

The PRIMES biomass supply model is private and has been developed and is maintained by E3MLab/ICCS of National Technical University of Athens[23].

4.1.2 GAINS

The GAINS (Greenhouse gas and Air Pollution Information and Simulation) model is an integrated assessment model of air pollutant and GHG gas emissions and their interactions. GAINS brings together data on economic development, the structure, control potential and costs of emission sources and the formation and dispersion of pollutants in the atmosphere.

In addition to the projection and mitigation of GHG emissions at detailed sub-sectorial level, GAINS assesses air pollution impacts on human health from fine particulate matter and ground-level ozone, vegetation damage caused by ground-level ozone, the acidification of terrestrial and aquatic ecosystems and excess nitrogen deposition of soils.

Model uses include the projection of non-CO2 GHG emissions and air pollutant emissions for EU Reference scenario and policy scenarios, calibrated to UNFCCC emission data as historical data source. This allows for an assessment, per Member State, of the (technical) options and emission potential for non-CO2emissions. Health and environmental co-benefits of climate and energy policies such as energy efficiency can also be assessed.

The GAINS model is accessible for expert users through a model interface[24] and has been developed and is maintained by the International Institute of Applied Systems Analysis[25]. The underlying algorithms are described in publicly available literature. The source code is not disclosed. GAINS and its predecessor RAINS have been peer reviewed multiple times, in 2004, 2009 and 2011.

4.1.5. GLOBIOM-G4M

The Global Biosphere Management Model (GLOBIOM) is a global recursive dynamic partial equilibrium model integrating the agricultural, bioenergy and forestry sectors with the aim to provide policy analysis on global issues concerning land use competition between the major land-based production sectors. Agricultural and forestry production as well as bioenergy production are modelled in a detailed way accounting for about 20 globally most important crops, a range of livestock production activities, forestry commodities as well as different energy transformation pathways.

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[23] http://www.e3mlab.National Technical University of Athens.gr/e3mlab/
[24] http://gains.iiasa.ac.at/models/.
[25] http://www.iiasa.ac.at/.

GLOBIOM covers 28 (or 50) world regions. The disaggregation of the EU into individual countries has been performed only recently.

Model uses include the projection of emissions from land use, land use change and forestry (LULUCF) for EU Reference scenario and policy scenarios. For the forestry sector, emissions and removals are projected by the Global Forestry Model (G4M), a geographically explicit agent-based model that assesses afforestation-deforestation-forest management decisions. GLOBIOM-G4M is also used in the Impact Assessment for agriculture and LULUCF to assess the options (afforestation, deforestation, forest management, cropland and grassland management) and costs of enhancing the LULUCF sink for each Member State.

The GLOBIOM-G4M is a private model and has been developed and is maintained by the International Institute of Applied Systems Analysis[26].

4.1.6. Prometheus

PROMETHEUS is a fully stochastic world energy model used for assessing uncertainties and risks associated with the main energy aggregates including uncertainties associated with economic growth and resource endowment as well as the impact of policy actions. The model projects endogenously the world energy prices, supply, demand and emissions for ten world regions.

World fossil fuel price trajectories are used as import price assumptions for EU Reference scenario and for policy scenario modelling.

The Prometheus model is private and has been developed and is maintained by E3MLab/ICCS of National Technical University of Athens[27]

4.1.7. CAPRI

CAPRI is an open source economic partial equilibrium model developed by European Commission research funds. Operational since more than a decade, it supports decision making related to the Common Agricultural Policy and Environmental policy related to agriculture based on sound scientific quantitative analysis.

CAPRI is only viable due to its pan-European network of researchers which based on an open source approach tender together for projects, develop and maintain the model, apply it for policy impact assessment, write scientific publications and consult clients based on its results. It has been the basis of numerous peer reviewed publications.

The model has been used to provide consistent agricultural activity projections for the EU Reference scenario 2016s. It is also used in the LULUCF impact assessment. The CAPRI model is an open source model which has been developed and is maintained by Eurocare GmbH[28], JRC, and other partners of the CAPRI network.

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26 http://www.iiasa.ac.at/
27 http://www.e3mlab.National Technical University of Athens.gr/e3mlab/
28 http://www.eurocare-bonn.de/

4.1.3 Macroeconomic models (E3ME and GEM-E3)

Macroeconomic models have played a role in two stages of the preparation of the modelling scenarios for this Impact Assessment. First, GEM-E3 is used to provide the EU Reference scenario macroeconomic assumptions, particularly in terms of sectoral value added projections. Second, the macroeconomic and sectoral economic impacts of various ambition levels in energy efficiency are assessed using two versatile macroeconomic models: E3ME and GEM-E3[29].

Similar to previous relevant Impact Assessments[30] the choice in this Impact Assessment has been to use two macroeconomic models that represent two main different schools of economic thought, which dominate the literature and have been frequently used in the macroeconomic assessment of energy and climate policies. This helps to effectively manage current model and theoretical uncertainties and reflect the best way of assessing the corresponding impacts. The application of two different macro-models enables not only to establish a range of possible impacts, but also to identify the conditions necessary for realising potential benefits.

There are important differences between the two models that arise from their underlying assumptions and respective structures. E3ME is a macro-econometric model, based on a post-Keynesian demand-driven non-optimisation non-equilibrium framework; GEM-E3 is a general equilibrium model that draws strongly on supply-driven neoclassical economic theory and optimising behaviour of rational economic agents who ensure that markets always clear[31]. GEM-E3 assumes that capital resources are optimally allocated in the economy (given existing tax "distortions"), and a policy intervention to increase investments in a particular sector (e.g. energy efficiency) is likely to take place at the expense of limiting capital availability, as a factor of production, for other profitable sectors ("crowding out" effect). In other words, in GEM-E3, the total effect on the economy depends on the net effect of core offsetting factors, particularly between positive improved energy efficiency and economic expansion effects (Keynesian multiplier), on one hand, and negative economic effects stemming from crowding out, pressures on primary factor markets and competitiveness losses, on the other hand. Nonetheless, the GEM-E3 version used in this Impact Assessment has significantly advanced and substantially departs from standard CGE models, in that it captures involuntary unemployment, myopic expectations, and avoids instantaneous crowding out effects (i.e. static savings-investments closure) through the inclusion of the banking sector, amongst others (explained in more detail below).

E3ME does not adhere to the ‘general’ equilibrium rule; instead demand and supply only partly adjust due to persistent market imperfections and resulting imbalances may remain a long-run feature of the economy. It also allows for the possibility of non-optimal allocation of capital,

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[29] The GEM-E3 version of the model used in this Impact Assessment is enhanced with an explicit representation of the banking system and financial flows (see for instance, Capros P., Karkatsoulis P., Paroussos L., "Modelling the financial sector in GEM-E3", E3M-Lab technical report, National Technical University of Athens, May 2016.

[30] The Impact Assessment on energy and climate policy up to 2030 and the Impact Assessment accompanying the 2014 Energy Efficiency Communication (SWD(214)255 final).

[31] Market clearance in GEM-E3 is achieved through the full adjustment of prices which allow supply to equal demand and thus a ‘general’ equilibrium is reached and maintained throughout the system.

accounting for the existing spare capacity in the economy[32]. Therefore, the level of output, which is a function of the level of demand, may continue to be less than potential supply or a scenario in which demand increases can also see an increase in output.

Having said this, the two macroeconomic models have many similarities, such as the inclusion of substantial sectorial detail, the assessment of complex interactions between the different sectors of an economy, markets and agents, as well as the simulation of inter-linkages between world economic and energy systems and the environment. Furthermore, in both models, additional effects are associated with a reduction in energy demand due to energy efficiency investments, including reduced import demand for energy inputs and a reduced need for energy generation within the EU28. A change in energy prices and of energy efficiency expenditures due to energy efficiency measures could result in the substitution of imported fuels with domestically produced goods and services. Both models also allow for the existence of unemployment.

Most importantly, in this Impact Assessment, the approaches have converged to some extent compared to previous analytical work. Notably, GEM-E3 has improved its modelling approach by incorporating an explicit representation of the financial sector at the global level and across countries. This changes the dynamics of crowding out effects as opposed to standard CGE models without a banking sector (more described below). E3ME, on the other hand, has explored the issue of "crowding out" and the possibility of capacity constraints limiting investment-driven output expansion particularly relevant in scenarios involving ambitious energy efficiency investment requirements.

4.1.3.1 E3ME

E3ME is a computer-based model of Europe’s economies, linked to their energy systems and the environment. The model was originally developed through the European Commission’s research framework programmes in the 1990s and is now widely used in collaboration with a range of European institutions for policy assessment, for forecasting and for research purposes. Only the main E3ME model features and mechanisms relevant for this Impact Assessment are presented, as a detailed description of the model is available in the E3ME manual[33].

The figure below shows the main modules in E3ME. The economy and energy demand are closely linked; economic activity creates the demand for energy, but energy consumption also affects the economy through output in the energy production and distribution sectors (e.g. electricity sector, oil and gas sector). Most environmental emissions are caused by fuel combustion (modelled as a fixed coefficient) but there are also direct economy-emission linkages through process emissions.

Technology, which is endogenous in E3ME, can affect many of these relationships. For example, the use of energy-efficient vehicles allows an increase in economic production without

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[32] The degree of adjustment between supply and demand and the resulting imbalances are derived from econometric evidence of historical non-optimal behaviour based on the extensive databases and time-series underpinning the E3ME macro-econometric model.

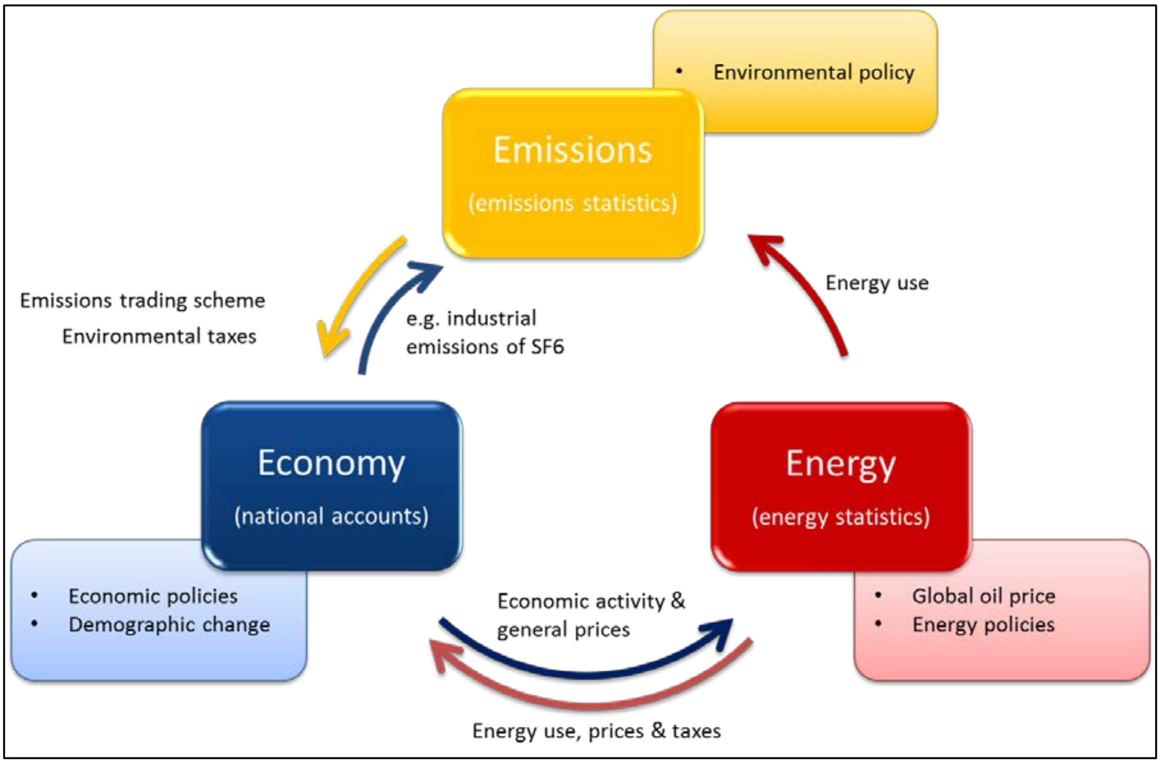
[33] Detailed information on model mechanisms are available in the E3ME manual at: http://www.camecon.com/EnergyEnvironment/EnergyEnvironmentEurope/ModellingCapability/E3ME/E3MEManual.aspx.

an increase in energy consumption and emissions. Some particular technologies like CCS or renewables allow energy consumption to increase without increasing emissions

The main dimensions of the model are:

- 33 countries (limited in scope to the EU28 Member States for this study)
- 69 economic sectors, defined at the NACE (rev2) 2-digit level, linked by input-output relationships;
- 43 categories of household expenditure;
- 13 types of household, including income quintiles and socio-economic groups such as the unemployed, inactive and retired, plus an urban/rural split;
- 22 different users of 12 different fuel types;
- the 6 Kyoto GHGs; other emissions where available.

Figure 2: E3ME modules

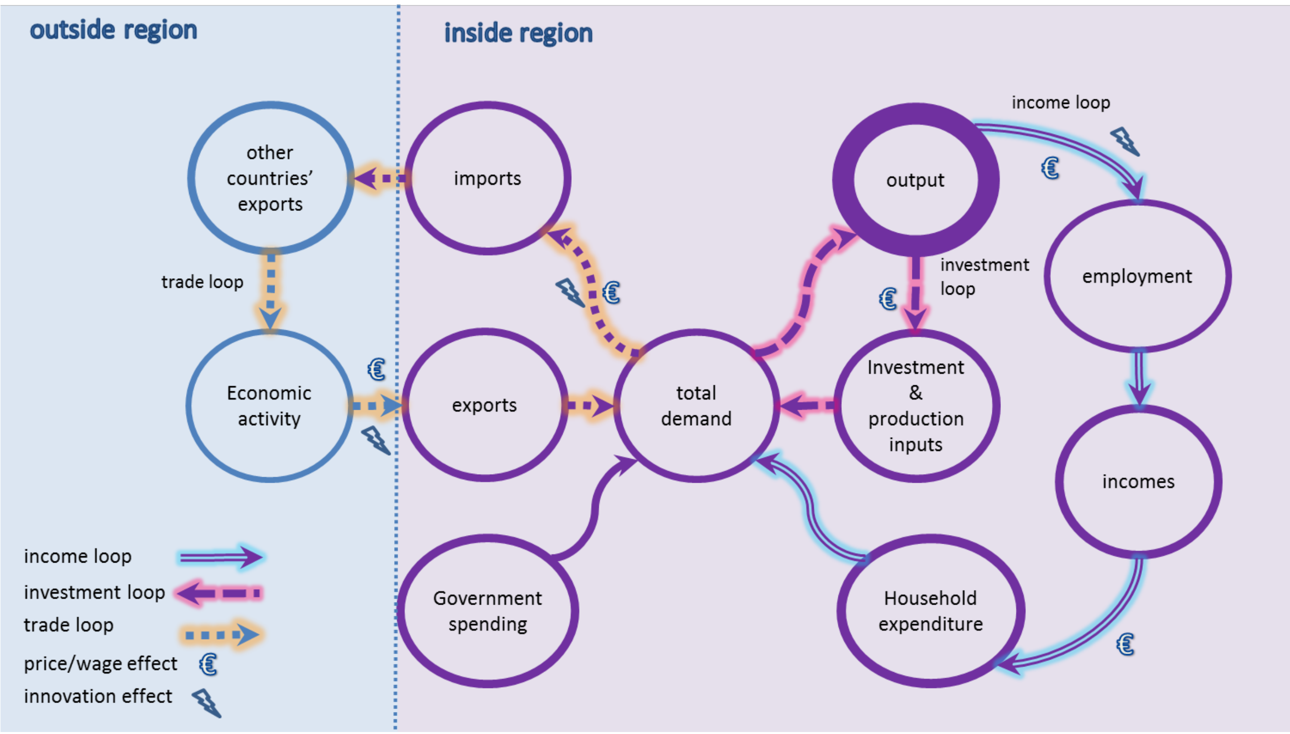


Source: E3ME, Cambridge Econometrics

The economic structure of E3ME is based on the system of national accounts, as defined by ESA95 (European Commission, 1996). The labour market is also covered in detail, with estimated sets of equations for labour demand, supply, wages and working hours. In total there are 33 sets of econometrically estimated equations, also including the components of GDP (consumption, investment and international trade), prices, energy demand and materials demand. Each equation set is disaggregated by country and by sector.

Figure 3 provides a summarised graphical representation of the main economic flows for a single European country. It displays the income loops, investment lops, trade loops, price/wage effects and innovation effects as captured in E3ME. Short-term multiplier effects occur through the various interdependencies and feedback loops that are present in the model structure.

Figure 3: E3ME's basic economic structure



Source: E3ME, Cambridge Econometrics

4.1.3.2 GEM-E3

The GEM-E3 model has been developed and is maintained by E3MLab/ICCS of National Technical University of Athens[34], JRC-IPTS[35] and others. It is documented in detail but the specific versions are private. The version of the GEM-E3 model used for this Impact Assessment is the one of E3MLab/ICCS.

The GEM-E3 model is a multi-regional, multi-sectoral, recursive dynamic computable general equilibrium (CGE) model which provides details on the macro-economy and its interaction with the environment and the energy system. It is an empirical, large scale model, written entirely in structural form. GEM-E3 allows for a consistent comparative analysis of policy scenarios since it ensures that in all scenarios, the economic system remains in general equilibrium. In addition it incorporates micro-economic mechanisms and institutional features within a consistent macro-economic framework and avoids the representation of behaviour in reduced form. The model is built on rigorous microeconomic foundations and is able to provide in a transparent way insights on the distributional aspects of long-term structural adjustments. The GEM-E3 model is extensively used as a tool of policy analysis and impact assessment.

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[34] http://147.102.23.135/index.php?option=com_content&view=category&id=36%3Agem-e3&Itemid=71&layout=default&lang=en.

[35] https://ec.europa.eu/jrc/en/gem-e3/model

It is updated regularly using the latest revisions of the GTAP database and Eurostat statistics for the EU Member States. This version of the GEM-E3 model used for this Impact Assessment simultaneously represents 38 regions and 29 sectors linked through endogenous bilateral trade flows. Most importantly new databases have been added compared to previous versions of the model: i) the GEM-E3 model has been calibrated to GTAP 9, year 2011 (this is the most recent available complete dataset for global IO tables) ii) The EU28 GTAP 9 IO tables have been replaced with EUROSTAT IO tables where possible[36] iii) A new split of EUROSTAT IO energy transactions has been made so as to be consistent with energy volumes as reported in EUROSTAT energy balances iv) To support the explicit representation of the financial sector in the new version of the GEM-E3 model a complete database regarding agents financial transactions has been developed. The financial database includes the following key financial instruments: i) bonds (corporate and public), ii) time deposits and iii) deposits.

Its scope is general in two terms: it includes all simultaneously interrelated markets and represents the system at the appropriate level with respect to geography, the sub-system (energy, environment, economy) and the dynamic mechanisms of agent's behaviour.

The GEM-E3 model includes projections of full Input-Output tables by country/region, national accounts, employment by economic activity, unemployment rate, balance of payments, public finance and revenues, household consumption, energy use and supply, GHG emissions and atmospheric pollutants.

GEM-E3 formulates separately the supply or demand behaviour of the economic agents who are considered to optimise individually their objective while market derived prices guarantee global equilibrium, allowing the consistent evaluation of distributional effects of policies. It also considers explicitly the market clearing mechanism and the related price formation in the energy, environment and economy markets: prices are computed by the model as a result of supply and demand interactions in the markets and different market clearing mechanisms, in addition to perfect competition, are allowed.

Total demand (final and intermediate) in each country is optimally allocated between domestic and imported goods, under the hypothesis that these are considered as imperfect substitutes (the "Armington" assumption). Institutional regimes, that affect agent behaviour and market clearing, are explicitly represented, including public finance, taxation and social policy. Figure 4 illustrates the overall structure of the GEM-E3 model.

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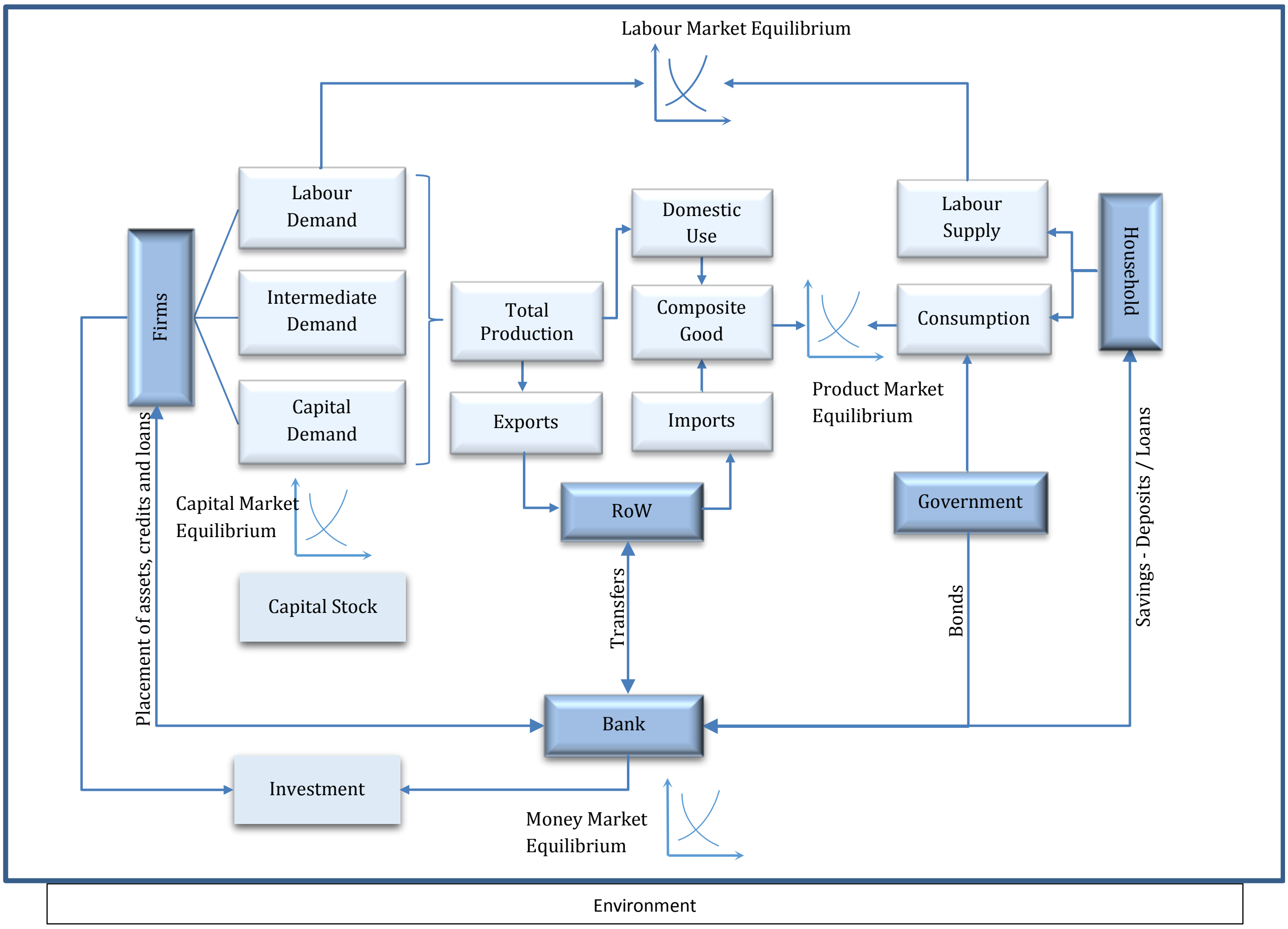
[36] Austria, Belgium, Bulgaria, Czech Republic, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Lithuania, Netherlands, Slovakia, Slovenia, Sweden, Romania, UK. For the rest of EU28 countries the GTAP IO tables have been used as there were no symmetric IO tables available from EUROSTAT.

Figure 4: GEM-E3 model structure



Source: GEM-E3, E3M-Lab, National Technical University of Athens

The model formulates production technologies in an endogenous manner allowing for price-driven derivation of all intermediate consumption and the services from capital and labour. In the electricity sector, a bottom up approach is adopted for the representation of the different power producing technologies. For the demand-side, the model formulates consumer behaviour and distinguishes between durable (equipment) and consumable goods and services.

GEM-E3 is dynamic, recursive over time, driven by accumulation of capital and equipment. In other words, the properties of the model are mainly manifested through stock/flow relationships, technical progress, capital accumulation and agents' (myopic) expectations. Technology progress is explicitly represented in the production function, either exogenous or endogenous, depending on R&D expenditure by private and public sector and taking into account spill-over effects. Moreover, it is based on the myopic expectations of the participant agents. In other words, the uptake of advanced technologies accelerates learning making them cheaper and more efficient. As higher volumes of advanced technologies are chosen by consumers, their production moves further on the learning curve hence efficiency improvements occur faster. At the same time the investment cost in advanced technologies increases with increasing efficiency performance. GEM-E3 includes learning curves that reduce capital costs depending on accumulated capacity (learning by doing).

New model features: explicitly capturing finance

Compared to the version of the GEM-E3 model used in previous similar analyses[37], and in addition to the data updates mentioned above, a series of methodological advancements have been introduced in the model. These relate in particular to the modelling of interactions between financial flows and the real economy. In other words, this version of GEM-E3 is a financial CGE model that explicitly represents the full-scale detailed financial sector for each country and at the global level.

The modelling of the interactions between finance and the real economy draws from Capros and Karadeloglou (1991 and 1996)[38], Bourgignon et al (1989)[39] and Dixon et al. (2015)[40]. It deviates from the standard CGE framework, mainly by introducing a dynamic inter-temporal financial closure in contrast with the static savings-investment closure that standard CGE models use. The CGE models with financial modelling are relatively sparse in empirical policy analysis applied to energy-climate issues. The version of GEM-E3 used in this Impact Assessment includes a detailed financial sector country-by-country, where institutional sectors (government, private and foreign) raise and repay debts financed by commercial banks, which take leverage from a central bank. The commercial banks collect the savings of economic agents and issue loans at interest rates. Governments and firms issue bonds to cover their financing needs. Agents' decision to lend or borrow depends on the interest rates. Two leading interest rates, one for the market of public debt, the other for the market of private debt, are determined from market clearing conditions.

Money supply can either be fixed with endogenously determined interest rates (money multiplier theory) or be adjustable (endogenous money theory) at given interest rate (i.e. bank reserves adjust as needed to accommodate loan demand at prevailing interest rates). In the version used in this study, the money multiplier approach has been used. In the model the base year net lending/borrowing position of the agents is calculated[41] in detail according to the institutional transactions[42] that have been collected from EUROSTAT. Dynamically the net credit position of each agent depends on a number of endogenously determined variables like the households' disposable income, firms' sales, consumption, saving and investment. The financial assets considered in the model are: public bonds, corporate bonds, household loans, deposits and time deposits.

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37 For instance, in the Cambridge Econometrics (2015) study on social and employment impacts of energy efficiency or the 2014 energy efficiency Impact Assessment SWD(2014)255 final.

38 Capros Pantelis, Pavlos Karadeloglou & Gregory Mentzas (1991), 'Market imperfections in a general equilibrium framework: An empirical analysis', Economic Modelling, Volume 8, Issue 1, January 1991, Pages 116–128; Capros Pantelis and Pavlos Karadeloglou (1996) "Structural Adjustment and Public Deficit: A Computable General Equilibrium Modelling Analysis for Greece", in P. Capros and D. Meulders (editors) "Budgetary Policy Modelling: Public Expenditure", Routledge Publ. Co., Chapman and Hall, London.

39 Bourguignon François, William H. Branson, J. de Melo (1989), 'Macroeconomic Adjustment and Income Distribution: A Macro-Micro Simulation Model', Technical report, ECD Development Centre Working Papers 1.

40 Dixon Peter, Maureen Rimmer, L. R. (2014), 'Adding financial flows to a CGE model of PNG'(No. G-242, ISBN 978-1-921654-50-3), Technical report, Centre of Policy Studies.

41 The net lending position of each economic agent has been built from bottom up data (all sources of income including dividend payments, interest rates, debt payments, bond interest rates etc.). Data regarding the structure of the bilateral debt by agent (domestic-foreign) and country (who owns to whom) have been constructed according to current account and cumulative bilateral trade transactions.

42 Full sequence of National Accounts that include all secondary transactions (property income, income from deposits, interest rates, etc.) of all economic agents.

The model is based on a matrix of flows of funds, involving, all economic agents, namely the household, government, firms, banks and foreign, as displayed in

Table 2.

Table 2: Simplified Flow of Funds matrix in GEM-E3

	Private	Banks	Government	Foreign
Assets	Placement of assets	Supply of loans and credit		Transfers and financing of foreign debt
Liabilities	Credits and Loans	Deposits	Bonds	

Source: GEM-E3, E3M-Lab National Technical University of Athens

The financial behaviour of households is based on a portfolio model which is derived by maximising expected utility. Households allocate their disposable income to consumption and financial assets on the basis of expected yields. The behaviour of firms and the public sector in the financial model is represented only with respect to the financing of their deficit. Total public and private debts are updated dynamically by accumulating deficits or surpluses. The level of the debts in relation to the leverage of commercial banks as defined by central banks influence the interest rates. Cross-country financing is also modelled. Options in the model allow defining possible financial closures at multi-country regional level, versus financial closing at global level. Risk premium factors influencing cross border financing are also introduced. The global economy financial closure is inter-temporal (in essence it is an extension of the Walras law) and leads to a world interest rate of equilibrium, or alternatively to regional interest rates of equilibrium depending on modelling options.

The banking[43] and private sectors are represented following an "assets-liabilities balance" approach. On the assets side of the private sector, total wealth is evaluated, dynamically, by private net savings, a variable coming from the real part of the model. In the banking sector the assets-liabilities balance serves to evaluate the capacity of banks to lend the private sector, which depends also on lending from central bank.

Interest rates are derived from the equilibrium of financial supply and demand flows. The model determines endogenously two equilibrium prices: i) Demand/supply equilibrium in financing public deficits serves to determine the rate of interest of government lending, i.e. interest rates of bonds ii) Demand/supply equilibrium of the capital flows addressed to the private sector serves to determine the private lending interest rate.

The inclusion of the financial sector in the model improves its simulation capabilities in the following respects:

- Creates loan repayment schedules that span over several periods and can also combine with cross-border lending thus mitigating considerably the crowding out effect.
- Book keeping of stock/flow relationships of debt accounting (domestic and external Private and Public debt) which influences the dynamic properties of the real economies.
- Endogenous computation of interest rates depending on alternative uses of financial resources by the agents (deposits, bonds, household and business financing, etc.).

[43] The banking system, as defined in this model comprises commercial banks and the central bank.

- Income availability by sector is adjustable depending on borrowing behaviour.
- Lending capabilities depend on accumulated debt and on leverage assumptions. Thus demand and supply of money/deposits, bonds and securities determine interest rates.
- Option for financing can be: i) From own resources – self finance (savings, reduced consumption) or ii) Borrowing from other agents (domestic or/and from abroad), iii) combination of i) and ii).

4.2 The EU Reference scenario 2016[44]

4.2.1 Scenario design, consultation process and quality assurance

Building an EU Reference scenario is a regular exercise by the Commission. It is coordinated by DGs: ENER, CLIMA and MOVE in association with the JRC, and the involvement of other services via a specific inter-service group.

The Reference Scenario 2016 (REF2016) has been developed building on a modelling framework including as core models PRIMES (PRIMES-TREMOVE for transport), GAINS and GLOBIOM-G4M and as supporting models GEM-E3, PROMETHEUS, PRIMES Biomass supply and CAPRI (see prior section for details).

For the REF2016, the model was calibrated on energy data up to year 2013 from Eurostat and other sources, and for agriculture and non-CO_2 emission data up to the year 2015.

Member States were consulted throughout the development process through a specific Reference scenario expert group, which met three times during the development of REF2016. Member States provided information about adopted national policies via a specific questionnaire, key assumptions have been discussed and in each modelling step, draft Member State specific results were sent for consultation. Comments of Member States were addressed to the extent possible, keeping in mind the need for overall comparability and consistency of the results.

Quality of modelling results was assured by using state of the art modelling tools, detailed checks of assumptions and results by the coordinating Commission services as well as by the country specific comments by Member States.

REF2016 projects EU and Member States energy, transport and GHG emission-related developments up to 2050, given current global and EU market trends and adopted EU and Member States' energy, transport, climate and related relevant policies.

"Adopted policies" refer to those that have been cast in legislation in the EU or in MS (with a cut-off date end of 2014[45]). Therefore, the binding 2020 targets are assumed to be reached in the projection. This concerns GHG emission reduction targets (both for the EU ETS as well as ESD sectors) as well as RES targets, including RES in transport.

However, policies which are not yet legally implemented, e.g. those necessary to implement the 2030 energy and climate framework, are not part of REF2016[46]. On this basis, REF2016 can help identify areas where the current policy framework falls short of reaching the EU's climate and energy objectives[47]. Notably, REF2016 shows that current policy and market conditions

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[44] Please see complete publication at: https://ec.europa.eu/energy/en/news/reference-scenario-energy.

[45] In addition, amendments to two Directives only adopted in the beginning of 2015 were also considered. This concerns notably the ILUC amendment to the RES directive and the Market Stability Reserve Decision amending the ETS Directive.

[46] For the period after 2020, policies are included that are part of the EU *acquis*, as well as important investments that are part of Member States' national energy plans. For instance, ETS with the Market Stability Reserve is included in REF16, but not the Commission's proposal for a change in the linear reduction factor post-2020. New near-zero energy buildings after 2020 - as defined in the Energy Performance of Buildings Directive - continue to be built, as well as energy labelling continues. Member States also gave input on planned energy investments, particularly in nuclear energy.

[47] Each new update of the Reference scenario models the projected impact of policy adopted up to the relevant cut-off date. Therefore, differences between two consecutive Reference scenarios, e.g. between the one

will deliver neither the 2030 targets nor the long-term 2050 80-95% GHG emission reduction objective.

REF2016 provides projections, not forecasts. Unlike forecasts, projections do not make predictions about what the future will be. They rather indicate what would happen if the assumptions which underpin the projection actually occur. Still, the scenario allows for a consistent approach in the assessment of energy and climate trends across the EU and its Member States.

The report "EU Energy, Transport and GHG Emissions Trends to 2050 - Reference Scenario 2016" (available at https://ec.europa.eu/energy/en/news/reference-scenario-energy) describes the inputs and results in detail. This section summarises the main messages derived from it, especially those relevant for the Energy Union framework.

4.2.2 Main assumptions

The projections are based on a set of assumptions, including on population growth, macroeconomic and oil price developments, technology improvements, and policies.

4.2.2.1 Macroeconomic assumptions

In REF2016, the population projections draw on the European Population Projections (EUROPOP 2013) by Eurostat. The key drivers for demographic change are: higher life expectancy, convergence in the fertility rates across Member States in the long term, and inward migration. The EU28 population is expected to grow by 0.2% per year during 2010-2030 (0.1% for 2010-2050), to 516 million in 2030 (522 million by 2050). Elderly people, aged 65 or more, would account for 24% of the total population by 2030 (28% by 2050) as opposed to 18% today.

GDP projections mirror the joint work of DG ECFIN and the Economic Policy Committee, presented in the 2015 Ageing Report. The average EU GDP growth rate is projected to remain relatively low at 1.2% per year for 2010-2020, down from 1.9% per year during 1995-2010. In the medium to long term, higher expected growth rates (1.4% per year for 2020-2030 and 1.5% per year for 2030-2050) are taking account of the catching up potential of countries with relatively low GDP per capita, assuming convergence to a total factor productivity growth rate of 1% in the long run.

Sectoral activity projections are derived in a consistent way from these macroeconomic assumptions, using the macro-economic modelling tool GEM-E3 as well as econometric estimates for global demand for energy intensive industries.

4.2.2.2 Fossil fuel price assumptions

Oil prices have fallen by more than 60% since mid-2014, to an average of around 40 $/barrel for Brent crude oil in the first four months of 2016. The collapse of oil prices has been driven by low demand and sustained oversupply, due in particular to tight oil from North America and to the decision of Organization of Petroleum Exporting Countries (OPEC) countries not to cut their output to rebalance the market. REF2016 considers a gradual adjustment process with reduced investments in upstream productive capacities by non-OPEC countries. Quota discipline is assumed to gradually improve among OPEC members. Thus, oil price is projected to reach 87

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from 2013 and REF2016, can be explained by the implications of policies adopted in the meantime as well as by changed economic and technological trends.

$/barrel in 2020 (in year 2013-prices). Beyond 2020, as a result of persistent demand growth in non-OECD countries driven by economic growth and the increasing number of passenger cars, oil price would rise to 113 $/barrel by 2030 and 130 $/barrel by 2050. This price trend resulting from PROMETHEUS modelling is in line with other reference sources such as the 2015 IEA World Energy Outlook.

No specific sensitivities were prepared with respect to oil and gas price developments. Still, it can be recalled that lower fossil fuel price assumptions tend to increase energy consumption and CO_2 emissions not covered by the ETS. The magnitude of the change would depend on the price elasticities and on the share of taxation, like excise duties, in consumer prices. For instance, for transport, the changes would be limited (depending on the magnitude of the change in the oil price) due to the high share of excise duties in the consumer prices but they are still expected to lead to some higher energy consumption and CO2 emissions. They also tend to lead to lower overall energy system costs, as the increase in consumption is more than compensated by lower prices. Conversely, costs for emission mitigation could slightly increase.

4.2.2.3 Technoeconomic assumptions

In terms of technological developments, input assumptions are based on a wide range of sources, with estimates on technological costs across main types of energy equipment, from power generation to heating systems and appliances. In addition, it should be recalled that the PRIMES model (and other models where relevant) take into account technological progress.

In terms of technological developments relevant to the transport sector, battery costs for electric vehicles and plug-in hybrids are assumed to go down to 320-360 $/kWh by 2030 and 270-295 $/kWh by 2050; further improvements in the efficiency of both spark ignition gasoline and compression ignition diesel are assumed to take place. In addition, the market share of internal combustion engine (ICE) electric hybrids is expected to increase due to their lower fuel consumption compared to conventional ICE vehicles.

For the techno-economic assumptions in the projection of non-CO_2 GHG emissions, see the detailed technical documentation. In general, technological progress in this domain is strongly linked to regulation; hence EU Reference scenario assumptions are conservative.

Technology assumptions are based on extensive literature review and have been peer-reviewed by the Joint Research Centre of the European Commission.

4.2.2.4 Specific policy assumptions

Following the above described policy modelling approach, the key policies included in the REF2016 are:

- The EU Emissions Trading System (Directive 2003/87/EC and its amendments) is fully reflected in the modelling, including the linear reduction factor of 1.74% for stationary installations and the recently adopted Market Stability Reserve.
- The Effort Sharing Decision (406/2009/EC) is assumed to be implemented, i.e. ESD GHG emission reductions at EU level in 2020 need to reach at least -10% compared to 2005 levels. It turned out that no specific policy incentives in addition to adopted EU and national policies were needed to achieve the EU level target. National ESD targets need not be achieved domestically given the existing flexibilities (e.g. transfers between Member States).

- The Energy Efficiency Directive (EED) and the Energy Performance of Buildings Directive (EPBD) are reflected, including Member States' specific obligations as regards energy savings obligation and buildings codes.
- Eco-design and Energy Labelling Directives and Regulations are also reflected.
- CO_2 standards for cars and vans regulations (Regulation (EC) No 443/2009, amended by Regulation EU No 333/2014 and Regulation (EU) No 510/2011, amended by Regulation EU 253/2014); CO2 standards for cars are assumed to be 95gCO2/km as of 2021 and for vans 147gCO2/km in line with current legislation. Standards are assumed constant after 2020/2021.
- The Renewable Energy Directive (Directive 2009/28/EC) and Fuel Quality Directive (Directive 2009/30/EC) including ILUC amendment (Directive (EU) 2015/1513): achievement of the legally binding RES target for 2020 (including 10% RES in transport target) for each MS, taking into account the use of flexibility mechanisms when relevant as well as of the cap on the amount of food or feed based biofuels (7%). Member States' specific renewable energy policies for the heating and cooling sector are also reflected where relevant.
- Directive on the deployment of alternative fuels infrastructure (Directive 2009/30/EC).
- The Waste Management Framework Directive (Directive 2008/98/EC) and in particular the Landfill Directive (Directive 1999/31/EC) which contribute to a significant reduction of emissions from waste.
- The revised F-gas Regulation (Regulation 517/2014) strengthens existing measures and introduces a number of far-reaching changes, notably limiting the total amount of the most important F-gases that can be sold in the EU from 2015 onwards and phasing them down in steps to one-fifth of 2014 sales in 2030, and banning the use of F-gases in many new types of equipment where less harmful alternatives are widely available.
- The impacts of the Reforms of the Common Agricultural Policy are taken into account, e.g. the milk quota abolition.
- Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP) for maritime transport.
- Relevant national policies, for instance on the promotion of renewable energy, on fuel and vehicle taxation or national building codes, are taken into account.

4.2.3 The modelling of energy efficiency policies in the EU Reference scenario

The EU Reference Scenario reflects policies that were adopted by the end of 2014 regarding energy efficiency in the EU and in Member States, including the Energy Efficiency Directive (EED) and the Energy Performance of Buildings Directive (EPBD). In the following, modelling instruments that reflect these policies in the PRIMES model are described.

The PRIMES model can simulate different energy efficiency policies with different modelling instruments. These instruments affect the context and conditions under which individuals - in the modelling represented by stylized agents per sector - make their decisions on energy consumption and the related equipment. The following are the main instruments:

- Modification of model parameters in order to mirror technology performance or building codes that are determined in the process of calibrating the interdependent model output to the observations from the relevant statistical year (in this exercise: 2015).
- Modification of assumptions about technical and economic performance of future technologies that are available for future choices by consumers.
- Modification of perception of costs of technologies by economic agents.
- Modelling instruments for capturing the effects of measures that promote or impose efficiency performance standards (BAT, ecodesign, CO2 standards for cars and vans). Such modelling instruments relate to individual technologies or groups of technologies and modify the perception of associated costs by the modelled agents or influence the portfolio of technologies that will be available for consumer choice.
- Another type of policy measures are those which improve consumer information through education, labelling, correct metering and billing, energy audits and technology support schemes aiming at inciting consumers to select more efficient technologies. Such measures are represented by the modelling instruments that modify the perception of costs of technologies by economic agents or are directly reflected in the modelling mechanisms, where economic agents are per-se informed correctly about the prevailing and to some extent future prices. This depends on the sector as there is less foresight in final demand sectors with shorter equipment lifetimes than in power generation sector.
- The penetration of ESCOs as explicitly incited by the EED leads to an environment with reduced risks for the consumers engaging in energy efficiency renovations, which can include both changes in the building structure and changes in the energy equipment. This is represented in the modelling by reduced discount rates for certain sectors, mirroring the changes in the decision making conditions and constraints of e.g. households and services. In addition, these measures also induce lower technical and financial risk, hence reducing the perceived costs of new technologies and saving investments (see also point above on perception of costs).
- Another key modelling tool are energy efficiency values (EEVs) – which are modelled as shadow values of virtual energy saving constraints optionally applying by energy demand sector. In the model, the EEVs influence the behaviour of consumers acting as a marginal cost to penalise energy consumption and stimulate energy savings. For houses and office buildings the EEVs mainly promote improvement of thermal integrity of building cells by inciting renovation, in industrial sector they incentivise broad range of energy efficiency. Essentially using the EEVs in the model is a way of representing non-identified policy measures, which aim at achieving energy savings in order to achieve a pre-defined target level of primary energy consumption in 2030. Instead of modelling one-by-one the broad range of energy efficiency policy measures, a practical way is to assume a non-zero value of EEVs and increase it until the non-identified measures induce an assumed amount of energy savings.

  In the context of the REF2016, one of the key elements which PRIMES depicts with EEVs are the energy efficiency obligation schemes required under Art 7 of EED (which by themselves according to current legislation can be implemented through a range of alternative policy instruments with a similar effect), but EEVs can also reflect some additional Member States' policies. Because of the diversity of approaches, implementation and intensity of polices, EEVs are differentiated between Member States.

The EEVs are measured in EUR/toe saved. A non-zero EEV is added to the unit cost of energy and therefore an additional amount of energy saving investments become cost-efficient. The use of a non-zero EEV has no financial implications for the consumers except the incurrence of additional investment expenditures which allow in the future lowering the expenditures for purchasing of fuels and electricity. The investment undertaken by the consumer is counted for e.g. in the energy system costs. In other words, an EEV is not a subsidy and is not a tax, as it has no direct implications on the consumer's budget.

The EU energy efficiency 2020 and 2030 targets are mainly measured in terms of primary energy consumption, which depends on several factors, including energy demand but also fuel mix in power generation, the efficiency of thermal conversion and loss rates in all supply sectors. The EEVs act only by inciting lower use of final energy in demand sectors and does not influence directly the fuel mix in these sectors. To achieve a certain energy efficiency objective in terms of primary energy, the model iterates with varying EEVs to influence demand for energy. At the same time, other model parameters also vary to represent other policies and targets. The model calculates in each iteration a projection of energy balances, investments, prices and emissions, forming a scenario.

The EEV have a national component that represents national policies as defined in the REF2016 and an EU-wide component, which also applies nationally. This EU-wide component is harmonised across the EU to ensure harmonisation of additional incentives across the MS and to ensure overall achievement of the target as defined by the specific policy scenarios.

- A multiplier effect is used to reflect the public procurement provisions, as the public sector assumes an exemplary role, i.e. private consumers are imitating the public sector energy efficiency actions.
- Other measures that foster energy efficiency relate to taxation, in particular excise type taxes (including those reflecting emissions); they are directly modelled in PRIMES by Member State and type of fuel, allowing for the full reflection of the effects of energy taxation and other financial instruments on end user prices and energy consumption.
- Also on supply side, energy efficiency policies can be modelled (promotion of CHP, district heating, limiting grid losses) – such policies were not, however, modelled in the scenarios presented in this Impact Assessment in comparison to the Impact Assessment SWD(2014)255.
- Improvements in the network tariff system and the regulations regarding the design and operation of gas and electricity infrastructure are also required in the context of the EED; moreover, the EED requires MS and regulators to encourage and promote participation of demand side response in wholesale and retail markets. In this context, the REF2016 assumes that intelligent metering is gradually introduced in the electricity system. This enables consumers to more actively manage their energy use. It allows for demand responses so as to decrease peak and over-charging situations, which generally imply higher losses in the power grids. Thus, efficiency is also improved as a result of the intelligent operation of systems.

- Finally, some policies and measures that do not target energy efficiency directly lead to significant additional energy efficiency benefits. Among these policies are the ETS Directive, the Effort Sharing Decision (ESD) – they are reflected by consideration of carbon market and the national ESD targets.

- Policies on promoting RES also indirectly lead to energy efficiency gains; in statistical terms many RES, such as hydro, wind and solar PV, have an efficiency factor of 1; thus, the penetration of RES in all sectors, in particular in power generation, induces energy savings. These policies are reflected by RES targets (modelling constraints) and RES shadow values (see explanations below).

The PRIMES model is based on individual decision making of agents demanding or supplying energy and on price-driven interactions in markets. The modelling framework includes two distinct stages: a) a first stage models decision-making behaviour of agents, hence investment and technology choices; b) a second stage calculates total costs for the entire energy system in order to support comparisons across scenarios.

In the first stage, agents take decisions considering the time dimension of money flows. Private discount factors can be defined as reflecting opportunity costs of raising funds by the actor on a private basis. The opportunity costs of an investment decision also vary with the degree of market distortions and non-market barriers as well as with the degree of risk associated with the decision options. The opportunity costs differ hence by sector and by type of agent.

The aim is to assess policy impacts as close as possible to reality and to avoid under- or over-estimation of the costs, and thus the difficulties, of transformation required to meet targets and transition objectives (i.e. transition towards a low carbon economy). Therefore, in line with the impact assessment guidelines the modelling is based on private discount rates[48].

For determining the values of discount rates to be applied, the model follows different approaches by sector. Decisions by firms are based on the weighted average cost of capital (WACC) to determine the discount rates. The EU Reference scenario applies different WACC rates by business sector, by type of technology (mature versus emerging), by scale level (e.g. industrial or decentralised versus utility scale) and for companies subject to regulation by the state. WACC rates vary between 7.5% and 11% as shown in the two tables below.

Table 3: Decision making discount rates in energy supply sectors (2020-2050)[49]

Assumptions for REF2016	Discount rates
Regulated monopolies and grids	7.5%
Companies in competitive energy supply markets	8.5%
RES investment under feed-in-tariff	7.5%
Investment under contract for differences	7.5%
RES investment under feed-in premium, RES obligation, Quota systems with certificates	8.5%
RES investment in competitive markets	8.5%
Risk premium specific to immature or less accepted technologies	1-3 %
Risk premium specific to investment surrounded by high regulatory or political uncertainty	No
Country-specific risk premiums	No

Source: PRIMES

[48] This is different from the perspective of a social planner who optimises the whole system from a societal perspective. In such a perspective social discount rates could play a role for determining normative inter-temporal choices.

[49] The assumptions shown in the table are similar to those of the Reference 2013 exercise.

Table 4: Decision making discount rates of firms in energy demand sectors (2020-2050)[50]

Assumptions for REF2016	Discount rates
Energy intensive industries	7.5%
Non energy intensive industries	9%
Services sectors	11%
Public transport (road and conventional rail)	7.5%
Public transport (advanced technologies, e.g. high speed rail)	8.5%
Business transport sectors (aviation, trucks, maritime)	9.5%
Country risks	No

Source: PRIMES

Decisions by individuals are modelled based on a subjective discount rate, annualizing investment costs following the equivalent annuity cost method. Literature surveys[51] find high implicit discount rates for households, because of various factors, such as lack of information, uncertainties, different income levels, lack of sufficient funding, agency costs, transaction and hidden costs. By varying the discount rates applied in the model, it is therefore possible to reflect, for instance, the effects of energy efficiency policy instruments, mainly ESCOs, campaigns and labelling programs, by lowering the discount rates when these policies are implemented. Therefore, the EU Reference scenario uses discount rates for individuals reflecting both existing barriers for investment decisions (which have an upward effect on discount rates) and the impact of existing energy efficiency policies, such as energy-labelling, energy performance certificates for buildings, or the promotion of energy service companies (ESCOs), which are reflected by lower discount rates compared to default values. As such, discount rates for investment decisions used in the Reference scenario are comprised between 9.5% and 12% depending on the consumer good subject that is purchased.

Table 5: Decision making discount rates of individuals in energy demand sectors (2020-2050)

	EU Reference scenario 2016	
	Default discount rates	Modified discount rates due to EE policies
Private cars	11%	11%
Households for renovation of houses and for heating equipment	14.75%	12%
Households for choice of appliances	13.5%	9.5%

50 The assumptions shown in the table are significantly lower than those used for the Reference 2013 exercise.

51 For instance: Mundaca Luis, Lena Neiz, Ernst Worell and Michael McNeil (2010) "*Evaluating energy efficiency policies with energy-economy models*", Ernest Orlando Lawrence Berkeley National Laboratory. For a full list of references, please refer to the Reference scenario publication (https://ec.europa.eu/energy/sites/ener/files/documents/REF2016_report_FINAL-web.pdf).

Note: the discount rate assumptions are significantly lower in Reference 2015 compared to Reference 2013

As described above, in a second stage the model analyses the resulting energy system costs. Here, the crucial element is the amount of money that energy consuming agents (households and firms, grouped into the sectors services and industry, transport and agriculture) are required to pay in order to get the energy services they need. Energy services are provided by using energy commodities purchased by end-consumers, which depend on energy efficiency at the consumption level. The PRIMES report aggregates capital or investment expenditures (CAPEX) and purchasing costs for fuels and other energy commodities or operational expenditures (OPEX) of end-consumers to show a single total cost figure. OPEX for end-users already incorporates through pricing of energy commodities the CAPEX and OPEX costs incurred by the energy supply and trading sectors (calculated using the above mentioned WACC rates for those sectors). For making costs comparable, the CAPEX figures related to investments by final energy demand consumers also need to be annualised, and a flat discount rate of 10% is used for this purpose[52].

As in previous modelling exercises, comparability across the scenarios is of key importance and implies that the discount rates used in the cost accounting must not vary between scenarios. Consequently, the flat discount rate of 10% used for annualising CAPEX of end-consumers in the cost reporting of PRIMES and the reporting discount rates used for the Reference scenario is kept unchanged in all scenarios.

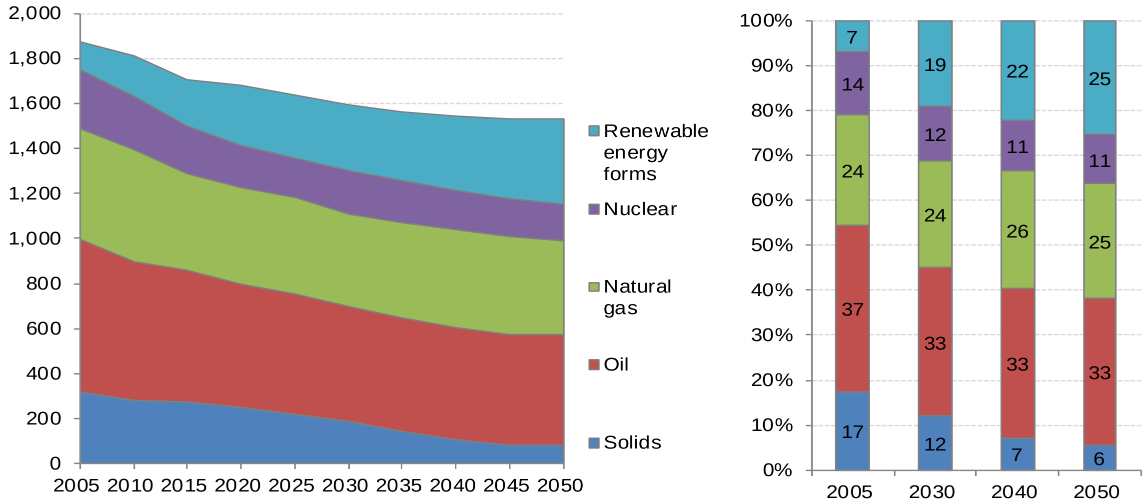
[52] The approach adopted in the 2016 Reference scenario and the present Impact Assessment accounts for the costs associated with CAPEX for final energy demand consumers using a flat rate (10%) across all end consumers, a lower rate than in the past that is more in line with the WACC used for the supply sector. This means that high perceived discount rates, which may be the result of market failures not related to financing (such as lack of information, split incentives), are no longer used for cost accounting.

4.3 Summary of EU Reference scenario 2016 main results

4.3.1 Gross inland consumption

The graphs below present the projected evolution of EU Gross Inland Energy Consumption. After the 2005 peak, energy consumption is projected to steadily decline until 2040, where it stabilises. Oil still represents the largest share in the energy mix, mostly because of transport demand. Solid fuels see a significant reduction in their share of the energy mix, while the biggest increase is for renewable energy. Natural gas and nuclear energy keep relatively stable shares in the energy mix.

Figure 5: EU28 Gross Inland Consumption (Mtoe, left; shares (%), right)

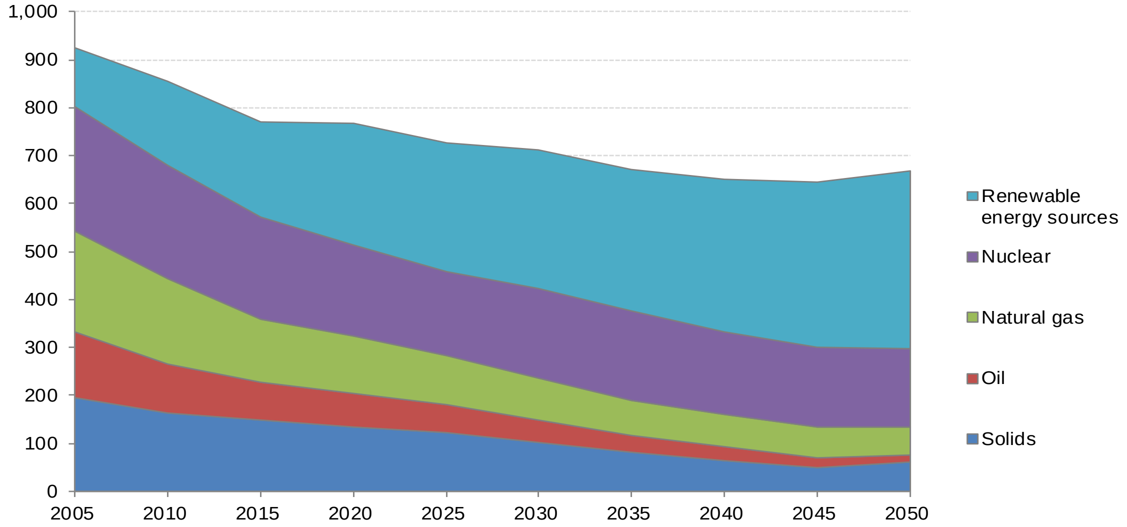


Source: PRIMES

4.3.2 Energy security

EU energy production is projected to continue to decrease from around 760 Mtoe in 2015 to around 660 Mtoe in 2050. The projected strong decline in EU domestic production for all fossil fuels (coal, oil and gas) coupled with a limited decline in nuclear energy production is partly compensated by an increase in domestic production of renewables. Biomass and biowaste will continue to dominate the fuel mix of EU domestic renewable production, although the share of solar and wind in the renewable mix will gradually increase from around 17% in 2015 to 36% in 2050.

Figure 6: EU28 energy production (Mtoe)



Source: PRIMES

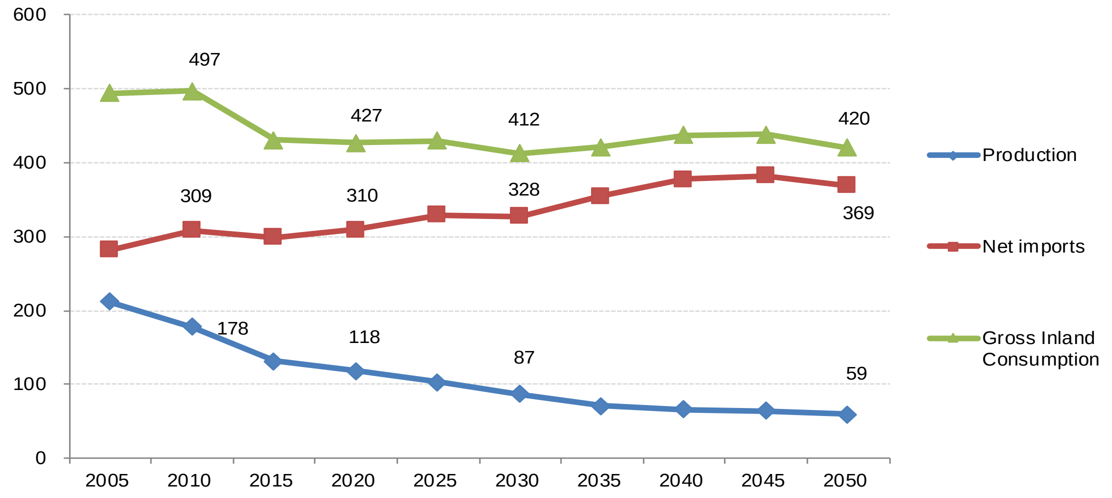
EU's import dependency shows a slowly increasing trend over the projected period, from 53% in 2010 to 58% in 2050. RES deployment, energy efficiency improvements and nuclear production (which remains stable) counteracts the strong projected decrease in EU's fossil-fuel production.

Solid imports as well as crude oil and (refinery) feedstock decline throughout the projection period, while oil products imports slightly increase. Natural gas imports increase slightly in the long term reaching approximately 370 bcm[53] net imports in 2050. Biomass remains mostly supplied domestically, although the combination of increased bioenergy demand and limited potential for additional EU domestic supply leads to some increases in biomass imports post-2020 (from 11% of biomass demand in 2020 to about 15% in 2030 and beyond).

Up to 2020, the consumption of gas is expected to remain stable at around 430bcm in gross inland terms. Post 2020, a slight decrease in gross inland consumption of gas (412 bcm in 2030) is projected, as well as further reductions in indigenous production of gas. Net import dependency of natural gas registers an increase as domestic gas production continues its downward trend. The imported volumes of gas are projected to increase between 2015 and 2040 and then to stabilise in the long term, 15% above the 2010 net import level (from 309 bcm in 2010 to 369 bcm in 2050).

[53] The conversion rate of 1 Mtoe = 1.11 bcm was used for natural gas, based on the BP conversion calculator.

Figure 7: Gas - production, net imports and demand (volumes expressed in bcm)



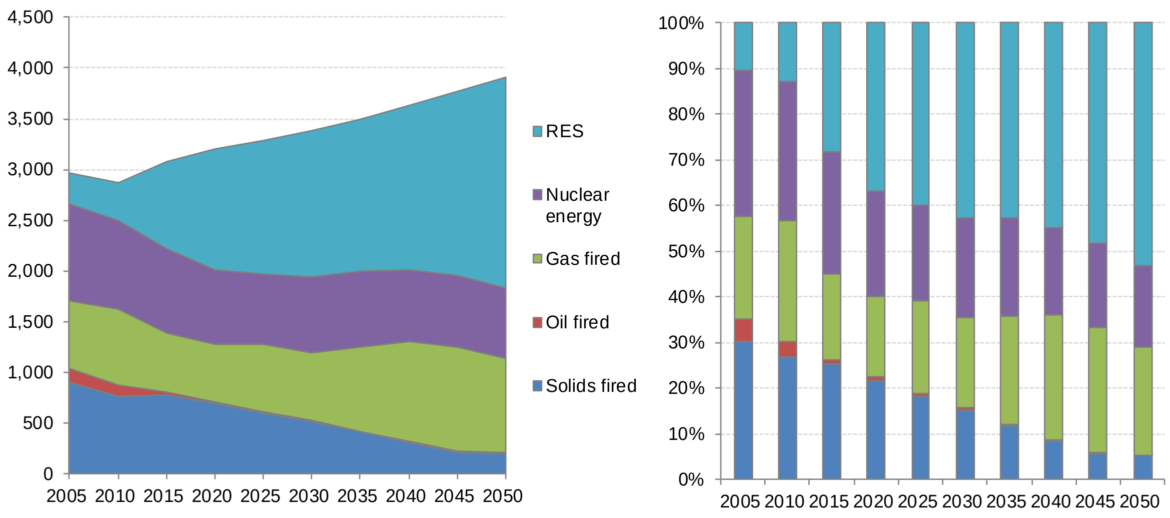
Source: PRIMES

4.3.3 Internal energy market and investments

The EU power generation mix changes considerably over the projected period in favour of renewables. Before 2020, this occurs to the detriment of gas, as strong RES policy to meet 2020 targets, very low coal prices compared to gas prices, and low CO_2 prices do not help gas to replace coal. After 2020, the change is characterised by further RES deployment, but also a larger coal to gas shift, driven mainly in anticipation of increasing CO_2 prices.

Gas therefore maintains its presence in the power generation mix in 2030 (at slightly higher levels in the long term compared to 2015). The share of solids/coal in power generation significantly declines, but not before 2020, to 15% in 2030.

Figure 8: EU power generation (net) by fuel (Mtoe – left, shares – right)



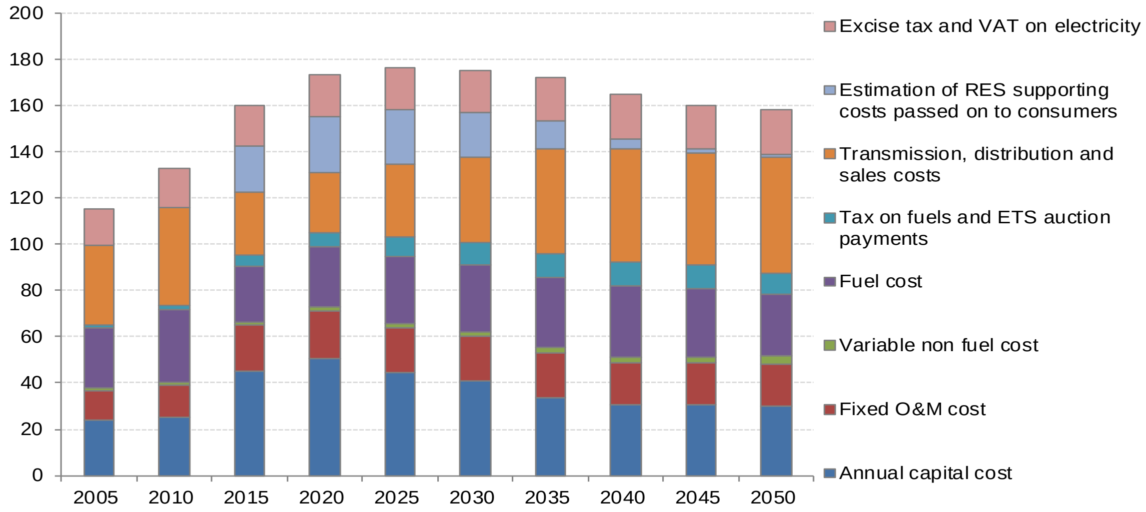
Source: PRIMES

Variable RES (solar and wind) reach around 19% of total net electricity generation in 2020, 25% in 2030 and 36% in 2050, demonstrating the growing need for flexibility in the power system. Wind onshore is expected to provide the largest contribution. Solar PV and biomass also increase over time. Hydro and geothermal remain roughly constant. The share of nuclear decreases gradually over the projected period despite some life time extensions and new built, from 27% in 2015 to 22% in 2030.

REF2016 shows increasing volumes of electricity trade over time. The flow between regions increases from 17% in 2015 to 26% in 2020, 29% in 2030 and then stays almost stable for the remainder of the projection period reaching 30% in 2050. Main drivers are intermittent RES power generation and the resulting balancing requirements. Trade is facilitated by the assumed successful development of the ENTSO-E Ten-Year Network Development Plan 2014[54] as well as pan-European market coupling and sharing of reserves and flexibility across Member States.

Average retail electricity prices[55] steadily increase up to 2030 by about 18% relative to 2010 levels, stabilising around 20% during 2030-2040, after which they start to gradually decrease. The structure of electricity costs changes over time, with the capital cost component (generation and grid costs) increasing significantly in the short term up to 2020, but decreasing afterwards in the longer term. From 2030, the fuel cost component remains stable despite the increase in fuel prices, due to a decreasing share of fossil-fuel combustion. Transmission and distribution costs increase significantly in the longer term, post-2030, partly linked to the need to cater for the increased presence of RES in the power generation mix.

Figure 9: Decomposition of electricity generation costs and prices (€'2013 MWh)



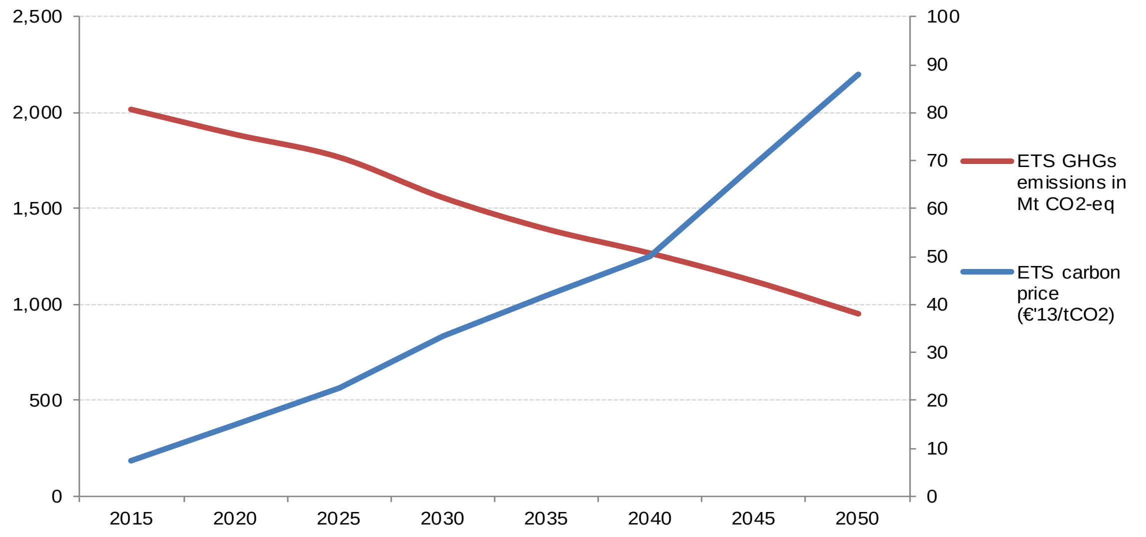
Source: PRIMES

As a result of the modelling, the carbon price is projected to increase, reflecting both the steadily decreasing ETS cap and the stabilising effect of the Market Stability Reserve. However, the increase in electricity prices due to ETS remains limited despite the significant increase in CO_2 price, as the share of carbon-intensive power generation decreases.

54 Source: https://www.entsoe.eu/major-projects/ten-year-network-development-plan/ten%20year%20network%20development%20plan%202016/Pages/default.aspx

55 In the PRIMES model, prices differ per type of end-user.

Figure 10: ETS emissions and carbon prices over time

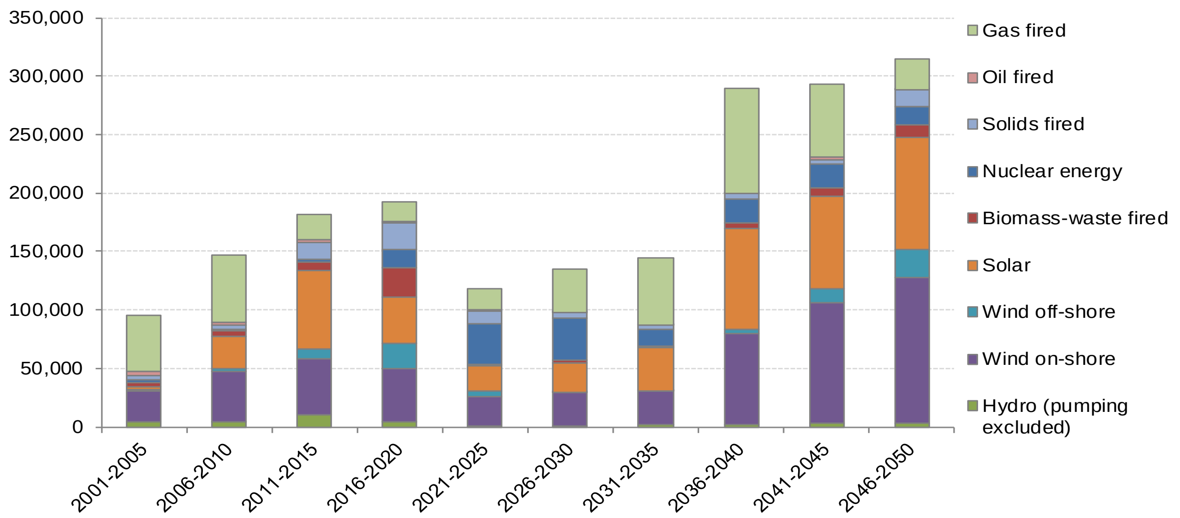


Source: PRIMES, GAINS

Electricity prices for households and services are projected to increase moderately in the medium term and to decrease slightly in the long term. Prices for industry on the contrary are stable or decrease over time as energy intensive industry maintains an electricity demand profile compatible with base-load power generation and bears a small fraction of grid costs and taxes. Taxes apply mainly on prices for households and services.

Investment expenditures for power supply increase substantially until 2020 driven by RES targets and developments, but slow down thereafter, until 2030, before increasing again from 2030 onwards notably due to increasing ETS carbon prices reflecting a continuously decreasing ETS cap based on the current linear factor. New power plant investment is dominated by RES, notably solar PV and wind onshore. Nuclear investment mostly takes place via lifetime extensions until 2030 and in the longer term via new built, such as projected in, for instance, the UK, Finland, Sweden, France, Poland, and other Central European Member States. New thermal plant investment is mainly taking place in gas-fired plants.

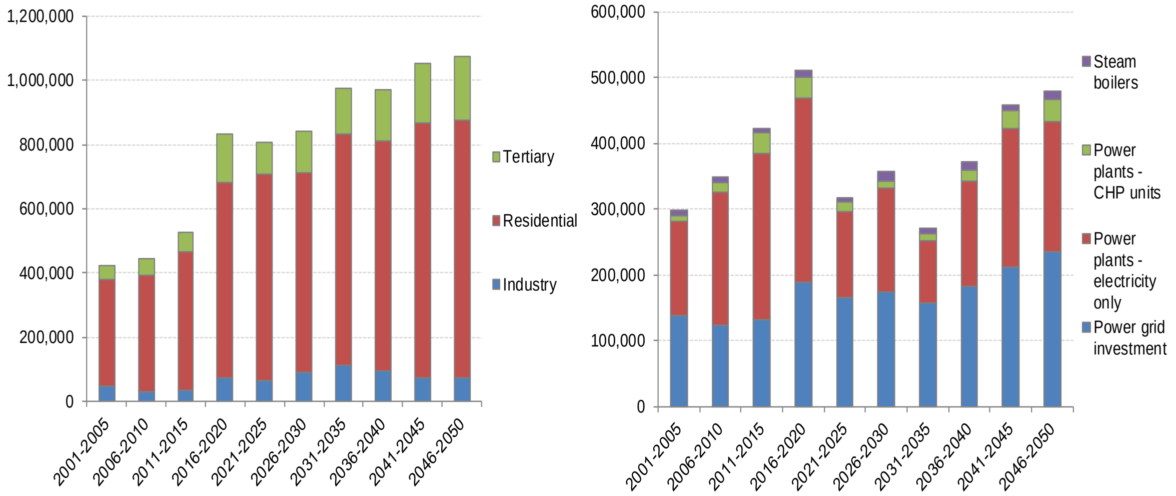
Figure 11: Net power capacity investments by plant type (MWh – for five year period)



Source: PRIMES

Investment expenditures in demand sectors (figure below – left hand side) over the projected period will be higher than in the past. They notably peak in the short term up to 2020, particularly in the residential and tertiary sectors, as a result of energy efficiency polices. Post-2020 they slightly decline until 2030, before increasing again to 2050. On the supply side (figure below – right hand side), investments peak towards 2020, followed by a decrease, notably explained by a decline in power generation investments.

Figure 12: Investment expenditures (5-year period) - demand side, million €'2013 (left, excluding transport) and supply side, million €'2013 (right)



Source: PRIMES

Transport investments (expenditures related to transport equipment) steadily increase over time but maintain a relatively stable share of GDP (i.e. between 4% and 4.5% of GDP over the projection period).

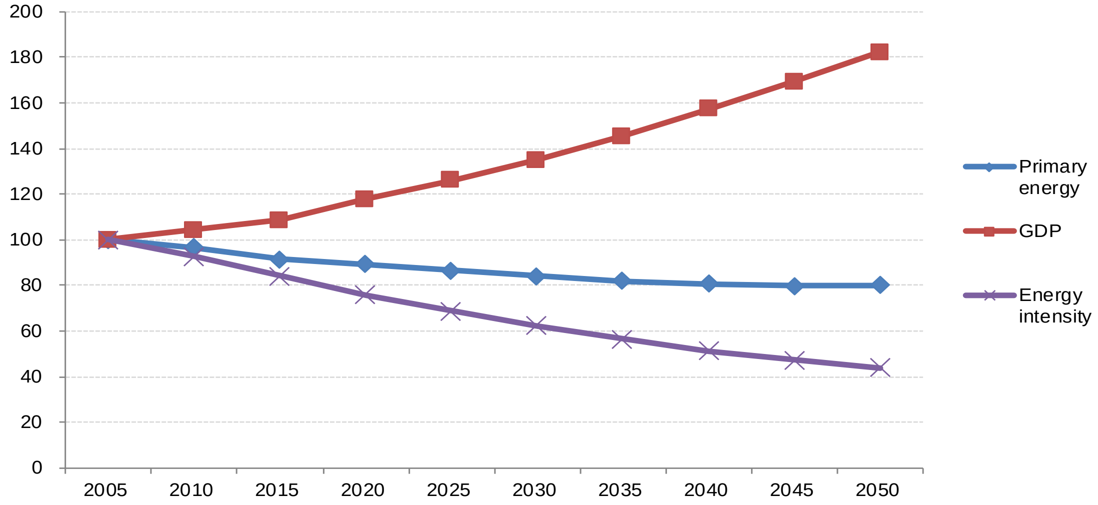
The relative weight of energy-related spending in households' expenditure[56] increases in 2020 compared to 2015 (7.5% compared to 6.8%), stabilising until 2030 before decreasing again until 2050 (6.1%).

4.3.4 Moderation of energy demand

In 2020, primary energy consumption decreases by 18.4% (relative to the 2007 baseline, i.e. how the energy efficiency target is defined), more than the sum of national Member States' indicative energy efficiency targets but still falling slightly short of the 2020 indicative EU energy efficiency target of 20%. In 2030, energy consumption is projected to decrease (again relative to 2007 baseline projections) by 23.9%. Primary energy demand and GDP continue to decouple which is consistent with the trends observed since 2005. Energy efficiency improvements are mainly driven by policy up to 2020 and by market/technology trends after 2020.

[56] Share of energy system costs for the residential sector (fuel costs and annualised capital costs of energy related investment expenditures) in total households' consumption

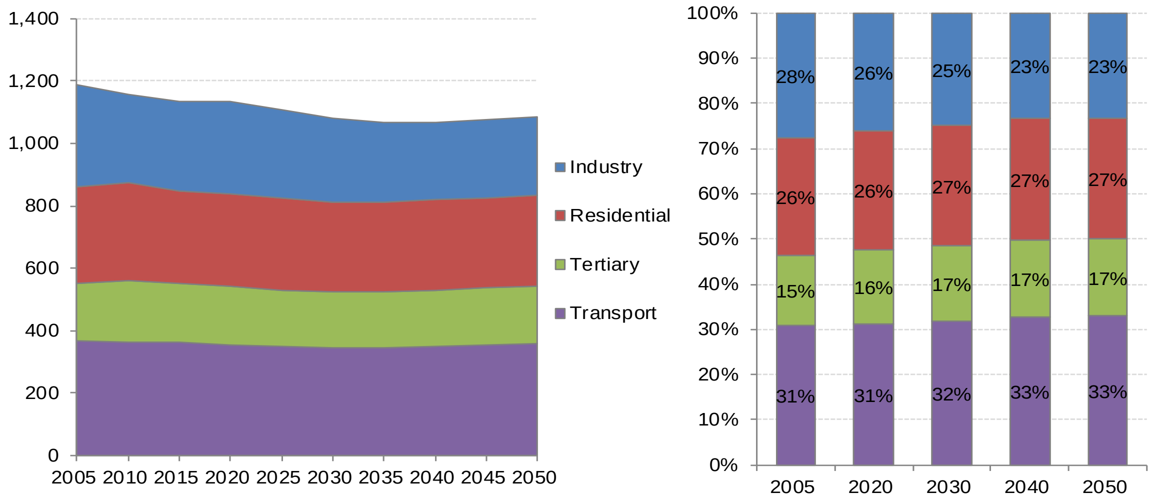
Figure 13: Decoupling of EU energy use and intensity from GDP (2005=100)



Source: Commission calculations based on PRIMES and GEM E3

The distribution of final energy consumption across sectors remains broadly similar to the current picture, all the way to 2050, with transport and the residential sector comprising the lion's share of final energy consumption (32% and 27% of final consumption, respectively, in 2030). Industry sees its share in final energy demand slightly decreasing, from 28% in 2005 to 23% in 2050, mostly due to improved energy efficiency in non-energy intensive industries. The tertiary (services and agriculture) sector keeps a stable share of about 17%.

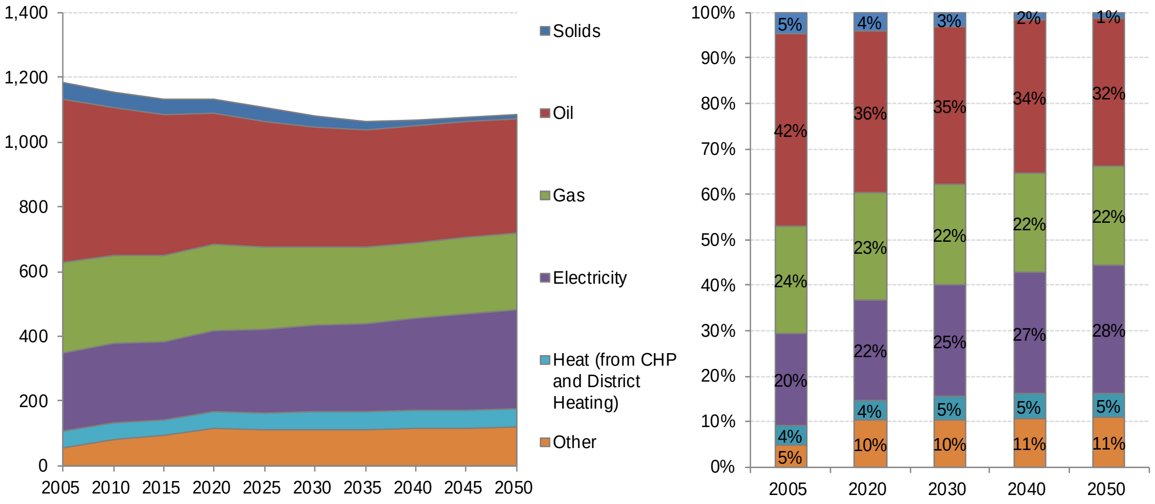
Figure 14: Evolution of final energy demand by sector (Mtoe – left, shares – right)



Source: PRIMES

With regard to the fuel mix in final energy demand, there is a gradual penetration of electricity (from 20% in total final energy use in 2005 to 28% in 2050). This is because of growing electricity demand as compared to other final energy use and to some electrification of heating (heat pumps) and to a limited extent of the transport sector.

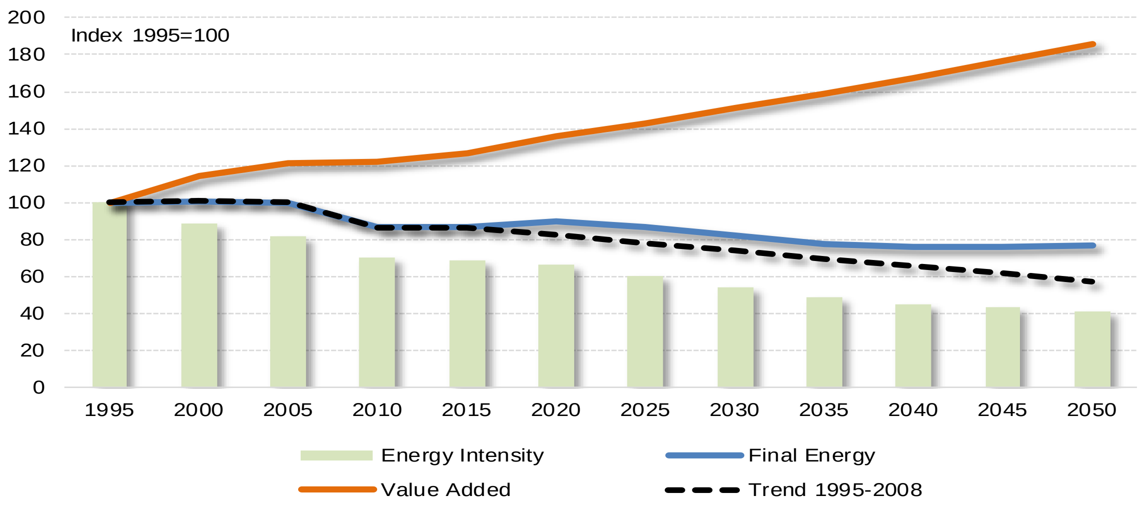
Figure 15: Evolution of final energy demand by fuel (Mtoe – left, shares – right)



Source: PRIMES

Energy intensity of the industrial sectors remains approximately constant in the medium term, as additional energy demand is due to the increase in production activity. In the long term however energy demand decreases, even though activity in terms of value added progresses. This is due to the energy efficiency embedded in the new capital vintages which replace old equipment and structural changes towards higher value added and less energy-intensive production processes, such as in iron and steel or non-ferrous metals.

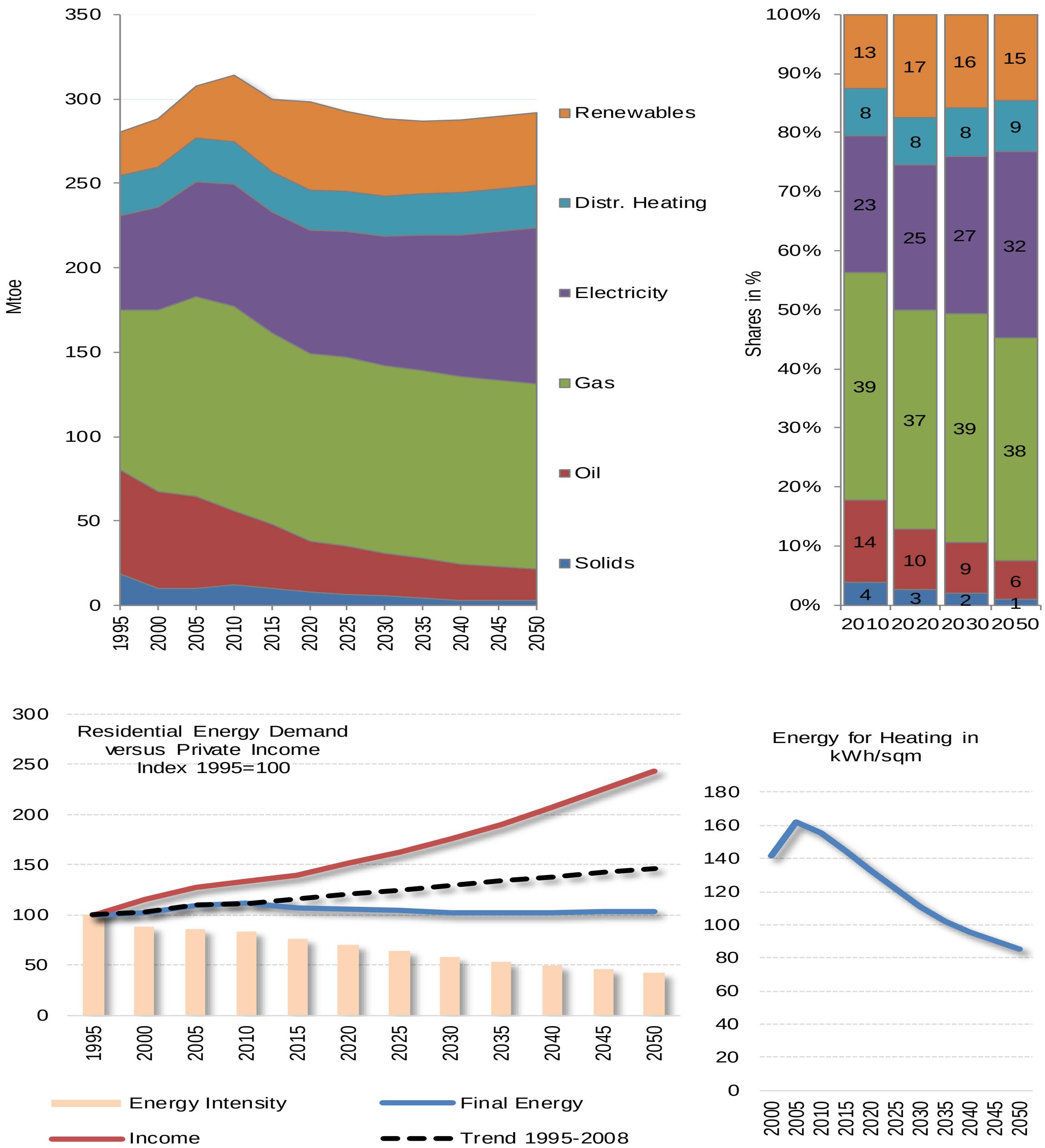
Figure 16: Industrial energy demand versus activity (value added)



Source: PRIMES

In the residential sector, energy demand remains below 2015 levels throughout the projection period. Energy demand decouples from income growth more than would be suggested by a simple extrapolation of past trends as the efficiency policies drive energy intensity improvements faster in the medium term; in the long term however the rate of improvements decreases due to the absence of additional policies.

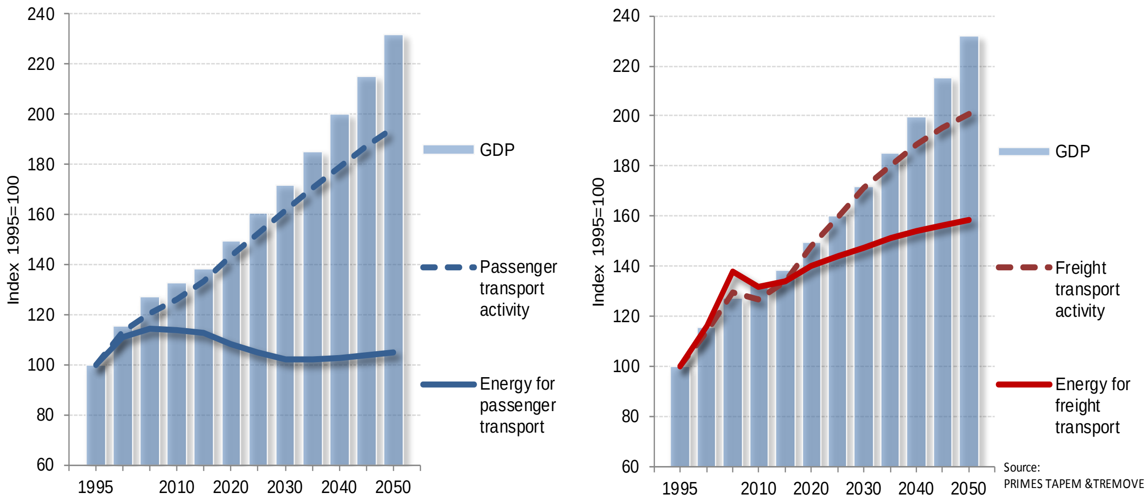
Figure 17: Final energy demand in the residential sector



Source: PRIMES

The activity of the transport sector shows a significant growth (**Error! Reference source not found.**4), with the highest increase in 2010 to 2030, driven by developments in economic activity. Historically, the growth of final energy demand in the transport sector has shown strong correlation with the evolution of transport activity. However, a decoupling between energy consumption and transport activity has been recorded in the past years. The decoupling between energy consumption and activity is projected to continue and even to intensify in the future.

Figure 18: Trends in transport activity and energy consumption



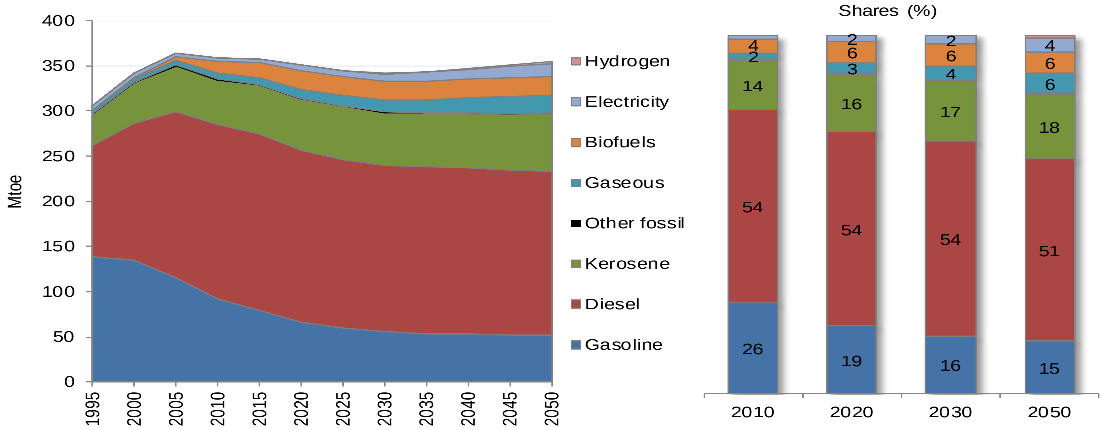
Source: PRIMES and GEM-E3; For aviation, passenger transport activity includes domestic, international intra-EU and international extra-EU aviation.

Electricity use in transport is expected to increase steadily as a result of further electrification of rail and the uptake of alternative powertrains in road transport. However, its share is projected to remain limited in the Reference scenario, increasing from 1% currently to 2% in 2030 and 4% in 2050. The uptake of hydrogen would be facilitated by the increased availability of refuelling infrastructure, but its use would remain low in lack of policies adopted beyond the end of 2014.

Liquefied natural gas becomes a candidate energy carrier for road freight and waterborne transport, especially in the medium to long term, driven by the implementation of the Directive on the deployment of alternative fuels infrastructure and the revised Trans-European Transport Network (TEN-T) guidelines which represent important drivers for the higher penetration of alternative fuels in the transport mix. However, the potential of gas demand developments in the transport sector do not fully materialise in the Reference scenario, suggesting that additional policy incentives would be needed to trigger further fuel switching.

Diesel is projected to maintain its share in total final energy demand in transport by 2030, slowly decreasing its share only during 2030-2050. Consumption of gasoline declines considerably until 2030, continuing the declining trend from 1995 and stabilizes from thereon to 2050. Consumption of jet fuels in aviation increases steadily by 2050 due to the strong growth in transport activity and despite improvements in energy efficiency.

Figure 19: Final energy demand in transport by fuel type



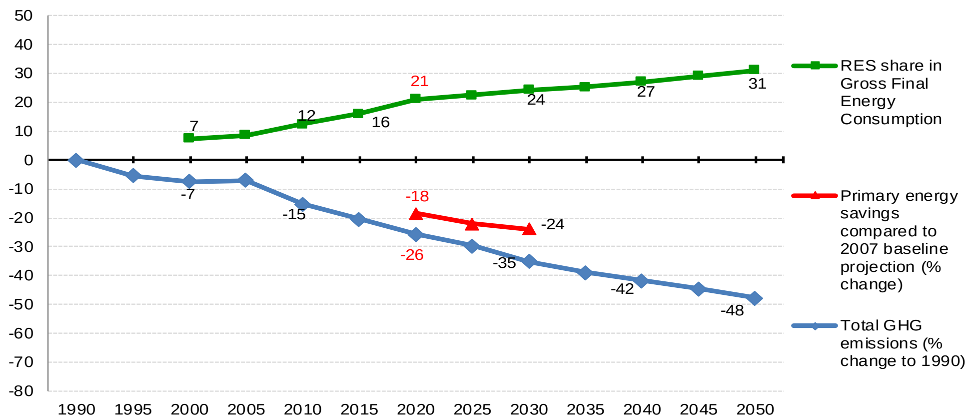
Source: PRIMES-TREMOVE; Biofuels include biomethane used in transport.

Oil products would still represent about 90% of the EU transport sector needs (including maritime bunker fuels) in 2030 and 86% in 2050, despite the renewables policies and the deployment of alternative fuels infrastructure which support some substitution effects towards liquid and gaseous biofuels, electricity, hydrogen and natural gas.

4.3.5 Decarbonisation

The EU Reference scenario 2016 is set up to meet the binding energy and climate targets for 2020, the latter being achieved as a result of existing policies. However, it shows that current policies and market conditions will deliver neither the agreed 2030 targets nor our long-term 2050 objective of 80 to 95% GHG emission reductions. In addition, as mentioned above, based on current market trends and adopted policies, the energy efficiency 2020 non-binding target is not met in REF2016, the scenario projecting a reduction in primary energy savings (relative to the 2007 baseline) of 18% in 2020, and, respectively, 24% in 2030. GHG emissions from sectors covered by the Effort Sharing Decision are projected to decrease by 16% in 2020 and by 24% in 2030 below 2005 levels, less than emissions in sectors covered by the EU Emission Trading System. The latter continue to decrease significantly after 2030.

Figure 20: Projection of key policy indicators: GHG, RES, (EE)



Source: PRIMES, GAINS

4.3.6 Renewable Energy

In 2020, the RES share in gross final energy consumption reaches 21% in 2020, while in 2030, it increases slightly further, reaching 24%.

Renewable electricity is projected to increase (as a share of net power generation) from around 28% in 2015 to 36% in 2020, which implies an acceleration compared to observed trends today, in particular in a number of countries that are currently facing difficulties to meet their target. Further RES share increases are more limited until 2030, reaching 43%, as RES policies are phased out in REF2016 after 2020 and only the most competitive RES technologies are projected to emerge.

The RES share in heating and cooling (RES-H&C) increases from 17% in 2015 to 22% in 2020, reaching 25% in 2030. The use of RES in final demand for heating and cooling is the main driver of RES-H&C increase in the short term, but its contribution stagnates in the long term. In the long-term, RES in CHP and heat plants (e.g. district heating), as well as some deployment of heat pumps, drive further increase of the RES-H&C share. Energy efficiency, implying lower demand for heat in all sectors, is also an important driver in the medium and long term.

The RES share in transport (RES-T) reaches 11% in 2020. The development of biofuels is the main driver in the short term, but their contribution stagnate in the long term. The biofuel penetration is mainly driven by the legally binding target of 10% renewable energy in the transport sector. Projections also take into consideration specific Member State mandatory blending obligations and tax incentives, as well as the Indirect Land Use Change (ILUC) amendment of the Renewables and Fuel Quality Directives, and corresponding changes in RES-T target accounting rules. Higher share of RES in electricity, combined with the relative increase of electricity use in transport (albeit modest in share terms), is the main contributor to RES-T in the long term.

4.3.7 CO_2 emission reduction

In REF2016, the binding energy and climate targets for 2020 will be met by assumption. However, current policy and market conditions will not deliver achievement of either the EU 2030 targets or the EU long-term 2050 decarbonisation goal.

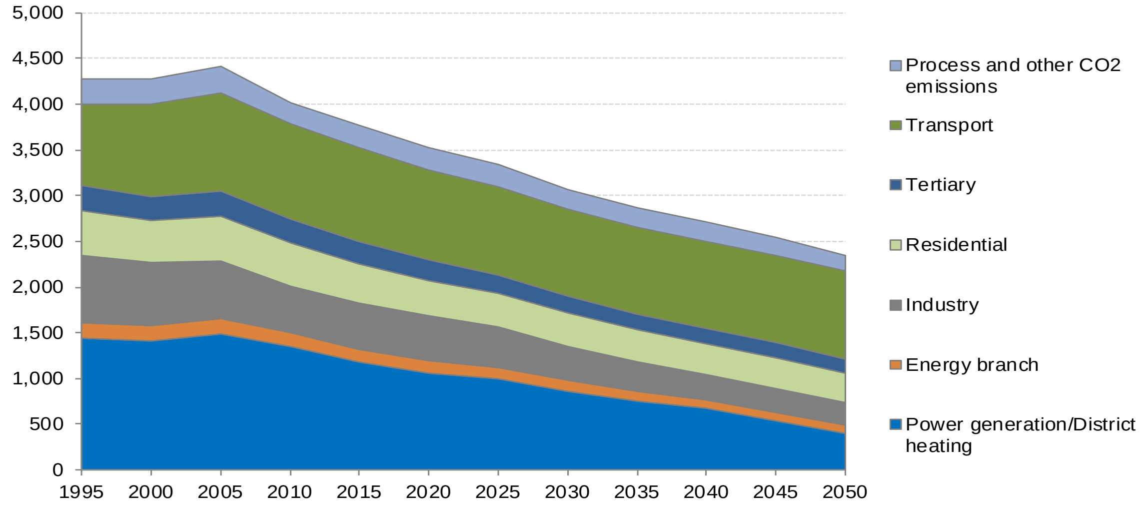
Total CO_2 emissions are projected to be 22% below 1990 levels by 2020. In 2030, CO_2 emissions reduce (relative to 1990 levels) by 32%. Most of these emissions are energy related, and this part also determines the overall trends. Non-energy related CO_2 emissions mainly relate to industrial processes, and remain rather stable. Land-use related CO_2 emissions are discussed below in the LULUCF section.

Emission reductions in the ETS sectors are larger than those in sectors covered by the Effort Sharing Decision (ESD) as current legislation implies a continuation of the reduction of the ETS cap with 1.74% per year over the projected period leading to a carbon price driving long term emission reduction. In the ESD sectors there are no further drivers beyond market forces (e.g. rising fossil future fuel prices) and the continued impact of adopted policies such as CO_2 standards for vehicles or energy performance standards for new building to further reduce energy and consequently emissions. Around two thirds of ESD sector emissions are CO_2 emissions, the rest are non-CO_2 emissions.

CO_2 emissions can be decomposed in the following components GDP, Energy Intensity of GDP and Carbon Intensity of Energy. The Energy Intensity of GDP component declines due to structural changes in the economy and increasing energy efficiency in all sectors. The decrease of carbon intensity of energy supply becomes an increasingly significant component over the period. This is mainly due to Renewable Energy policies in the short term and the ETS in the medium to long term.

On a sectoral level, CO_2 emissions decrease in all sectors between 2010 and 2050. The figure below shows a steep decrease in power generation, whereas emissions in the field of transport decrease at much slower pace, and the transport sector becomes the largest source of CO_2 emissions after 2030. Non-energy and non-land use related CO_2 emissions (e.g. industrial processes) reduce only slowly throughout the projection period; however they only represent a small share of total CO2 emissions.

Figure 21: Evolution of CO_2 emissions (Mt) by sector



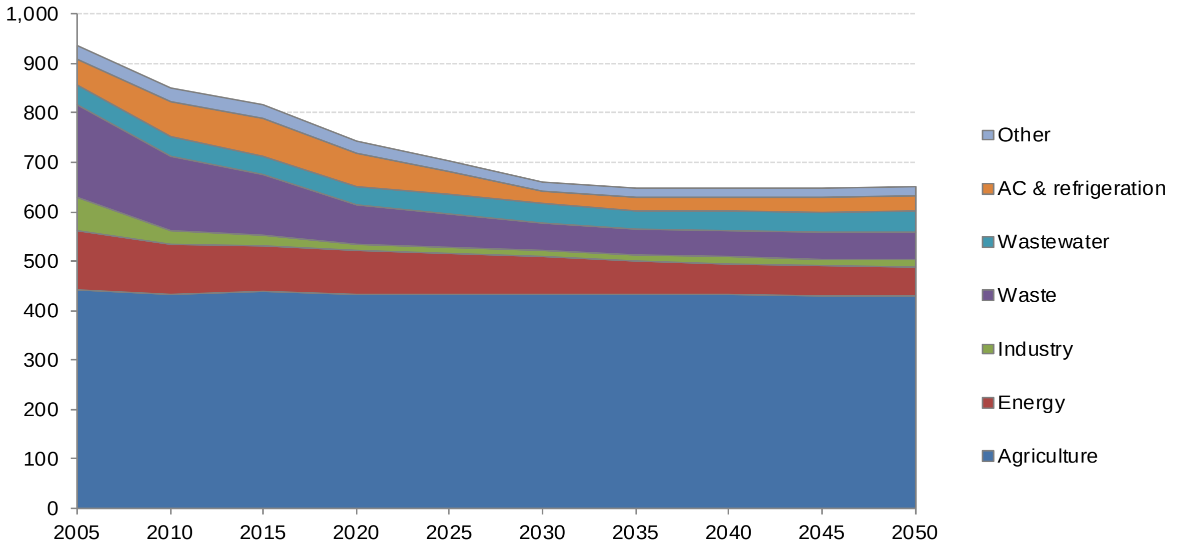
Source: PRIMES

4.3.8 Non-CO_2 GHG emission reductions

Non-CO_2 emissions (CH_4, N_2O and F-gases), accounted in 2013 for 18% of total EU GHG emissions (excluding LULUCF). They have decreased significantly (32%) between 1990 and 2013. They are expected to further decrease by 29% below 2005 levels in 2030 (-46% compared to 1990 levels), and to stagnate later on. CH_4 emissions – which have the largest share in this aggregate - are projected to decrease above average (33% due to declining trends in fossil fuel production, improvements in gas distribution and waste management) and N_2O emissions fall less than average (17%) until 2030, both remaining flat thereafter. F-gases would reduce by half between 2005 and 2030, largely driven by EU and Member State's policies (i.e. the 2014 F-gas regulation and Mobile Air Conditioning systems directive); F-gases would increase somewhat between 2030 and 2050 in line with economic developments. Except for a very minor fraction from some specific industries, non-CO_2 emissions fall under the ESD.

The non-CO_2 emission trends and their drivers vary by sector. **Agriculture** is responsible for about half of all non-CO2 emissions and is expected to increase its share in total non-CO_2 until 2030. While the agricultural non-CO_2 emissions have reduced by 22% between 1990 and 2013, they are projected to roughly stabilize at current levels as a result of different trends which compensate each other, such as decreasing herd sizes (both of dairy cows and of non-dairy cattle) but increasing milk yields. Slightly reduced use of mineral fertilizer through improved efficiency (2% less in 2030 than in 2005) leads to corresponding reductions in N_2O emissions from soils. Improved manure management (e.g. through anaerobic digestion) also delivers minor emission reductions. The Common Agricultural Policy influences, inter alia, livestock numbers/intensities and the Nitrogen Directive and the Water Framework Directive impact on the use of fertilizer.

Figure 22: Non CO2 GHG emissions



Source: GAINS

Waste is currently the second most important sector emitting non-CO2. There, a substantial reduction between 2005 and 2030 is expected (70%), strongly driven by environmental legislation, such as the Landfill directive and improvements in waste management as well as an update in inventory methodology of historic landfills that results in increased historic emissions and subsequent increased reductions of these emissions in the near to mid-term future. Also an increasing amount of CH_4 is recovered and utilised, thereby impacting on these trends towards lower emissions. After 2030, however, a moderate increase is projected, reflecting trends in economic development.

CH_4 and N_2O emissions from the **energy** sector (including transport) are expected to decrease by 36% from 2005 to 2030, and by 26% between 2030 and 2050. The main reductions come from less coal-mining and crude oil production in the EU, together with reduced emissions from power generation using fossil fuels. On the other hand, transport is expected to generate an increasing share of energy sector non-CO_2 emissions (N_2O from road transport being the most important contributor), growing from 12% in 2005 to 15% in 2030 and 20% in 2050 within the energy aggregate.

Emissions from **air conditioning and refrigeration** decrease by half from 2005 until 2030, also thanks to existing legislation (i.e. the new 2014 F-gas Regulation and the Mobile Air Conditioning systems Directive).

Most of the non-CO_2 emissions from **industry** – overall a minor non-CO_2 sector - are covered by the EU ETS (production of adipic and nitric acid, and of aluminium). The resulting incentives in combination with relatively cheap abatement options and existing national legislation cut emissions quite rapidly, to only a fifth in 2030 of those in 2005. For the period after 2030 slight increases are projected in line with economic trends.

Emissions from the **wastewater** sector and remaining **other sectors** are projected to increase moderately in line with economic development over the whole period covered.

4.3.9 LULUCF emissions and removals

The EU28 Land Use Land Use Change and Forestry (LULUCF) sector is at present a net carbon sink which has been sequestering annually on average more than 300 Mt CO_2 over the past decade according to the UNFCCC inventory data[57]. In REF2016, the LULUCF sink is expected to decline in the future to -288 Mt CO_2 eq in 2030 from -299 Mt CO_2 eq. in 2005 and decreases further after 2030. This decline is the result of changes in different land use activities of which changes in the forest sector are the most important. These changes are driven partly by the increase in timber demand (itself partially a result of the increase in bioenergy demand that is expected in order to reach the RES targets in 2020). The figure blow shows the projection of the total EU28 LULUCF sink in REF2016 and the contribution from different land use categories.

At present, the carbon sink in managed forest land (-373 Mt CO_2 eq. in 2010 without applying any accounting rules[58]) is the main component of the LULUCF sink. The managed forest land sink is driven by the balance of forest harvest and forest increment rates (accumulation of carbon in forest biomass as a result of tree growth). Forest harvest is projected to increase over time from 516 million m^3 in 2005 to 565 million m^3 in 2030 due to growing demand for wood for material uses and energy production. Along with the aging of EU forest – which reduces the capacity of forest to sequester carbon – the forest increments are projected to decrease from 751 million m^3 in 2005 to 725 million m^3 in 2030. As a consequence, the rate of accumulation of carbon (i.e. the sink) in managed forest land declines by 32% until 2030. This is partially compensated by a continuation of increasing trend in carbon sink from afforestation and decreasing trend of emissions from deforestation which decline from 63 Mt CO_2 in 2005 to 20 Mt CO_2 eq. in 2030. Carbon sequestration from afforested land increases steadily to 99 Mt CO_2eq. by 2030, as new forests continue, albeit at slower rate, to be established. In addition, young forests that were established over the last 20 years get into a phase of high biomass production.

Activity in the agricultural sector (on cropland and grassland) has a smaller impact on the total LULUCF sink than the forest sector. Still, net carbon emissions from cropland are projected to decline by some 18% by 2030 compared to 2005 as soils converge towards soil carbon equilibrium over time. In addition, perennial crops (miscanthus, switchgrass and short rotation coppice) that typically sequester additional carbon in soil and biomass contribute to decreasing cropland emissions. By 2030, 0.9 Mha of perennial crops are expected to be cultivated. The grassland sink increases to around -19 Mt CO_2 eq. in 2030 as land continues to be converted to grassland e.g. through cropland abandonment while at the same time the total grassland area slightly declines over time due to afforestation and the expansion of settlements.

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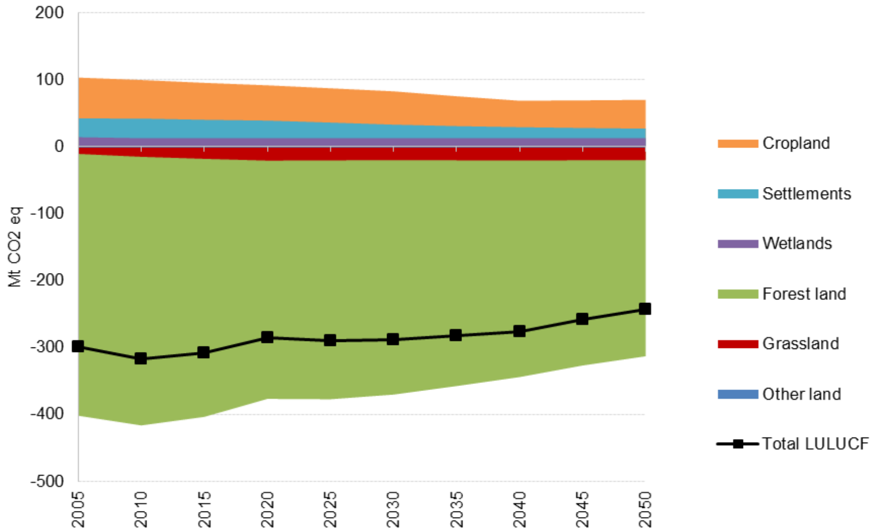
[57] See: http://unfccc.int.

[58] The GHG accounting approach for LULUCF differs from other emission sectors. Notably, forest management is not accounted compared to historic emissions, but against a so called Forest Management Reference Level. This means that the accounted removals from the LULUCF sector are much smaller than the reported removals seen by the atmosphere.

Figure 23: EU28 emissions/removals in the LULUCF sector in Mt CO2 eq. until 2050[59]



Source: GLOBIOM-G4M

4.3.10 Research, innovation and competitiveness

Although REF2016 does not deal explicitly with research and innovation, it does tackle directly the penetration of new technologies. The approach is in two steps. First, assumptions are made on techno-economic characteristics and technological learning curves based on latest scientific evidence[60]. Figure 20 presents an illustration of the RES power technologies assumptions used in REF2016. Second, the model endogenously selects the most economically viable technologies at each point in time, leading to further technological cost reduction as technologies are deployed at increasingly larger scales.

The development of solar photovoltaics (PVs) starts from lower costs than in the previous Reference Scenario and has a positive learning curve throughout the projection period. This translates into significant deployment of solar PVs in REF2016, especially in Southern Europe.

Although wind onshore costs are already competitive with many conventional technologies, the remaining potential for learning is estimated to be small, but costs can decrease due to the size of turbines and their height; very small scale wind is the only exception and still has high learning potential.

There remains large uncertainty about the costs for offshore wind and there have been cost increases due to previously unforeseen difficulties and logistics. Surveys have identified significant potential of cost decrease due to economies of scale and possibilities of improvement in logistics, but these cost decreases are likely to occur only towards 2030. As such, offshore wind developments in REF2016 are more conservative than in past exercises.

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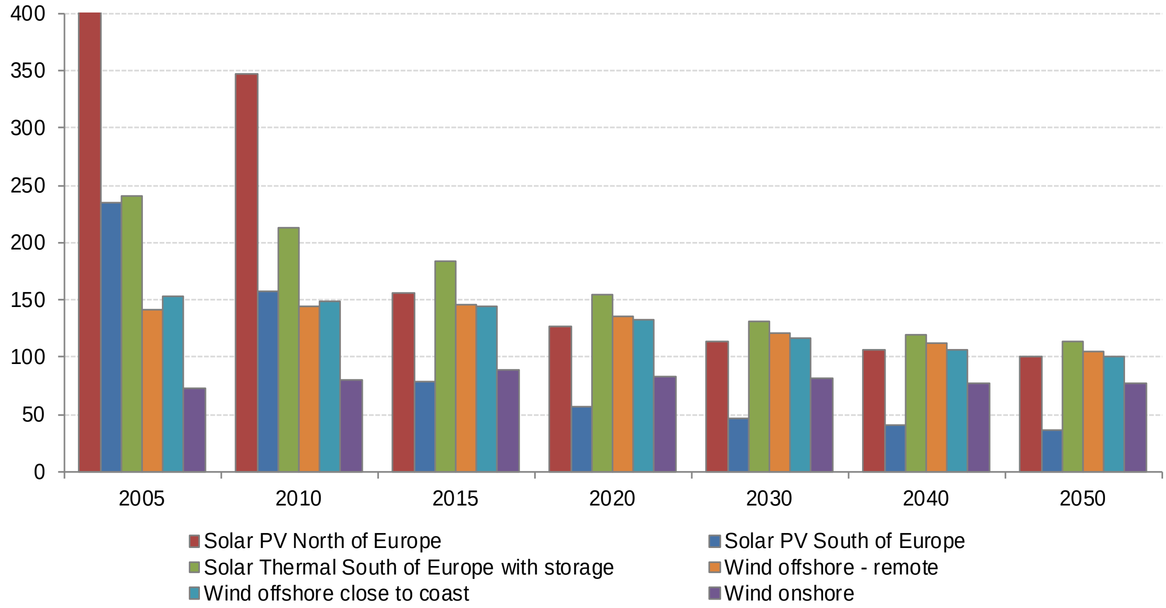
59 Emissions from deforestation and harvested wood products are included in "Forest land" in contrast to UNFCCC inventories.

60 See notably the European Commission's Joint Research Centre ETRI 2014 report, available at: https://setis.ec.europa.eu/publications/jrc-setis-reports/etri-2014

Figure 20: Illustrative levelized cost of electricity for selected RES technologies (expressed in €'2013/MWh-net)



Source: NTUA based on PRIMES

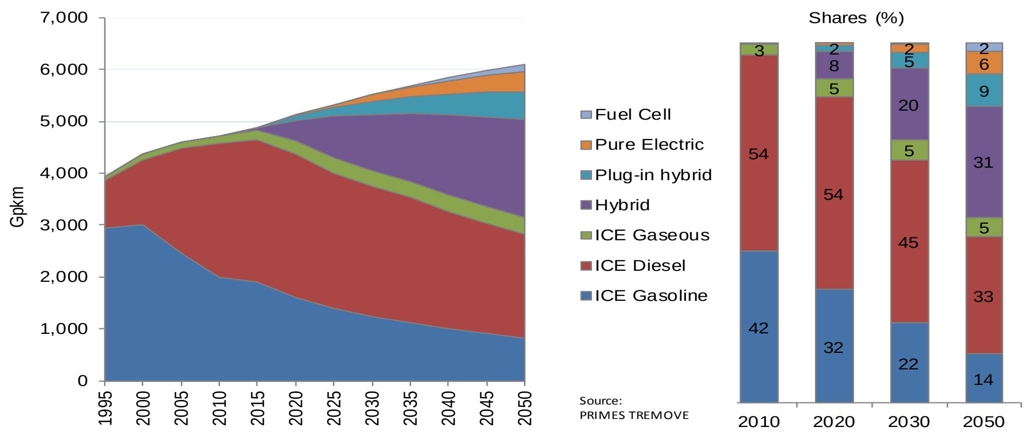
Compared to the previous Reference scenario, the costs of nuclear investment have increased and also the costs for nuclear refurbishments have been revised upwards. Although lifetime extensions of nuclear power plants remain economically viable in most cases, investments in new built plants are lower compared to previous projections.

The construction of power plants equipped with carbon capture and storage (CCS) technologies is developing at a very slow pace, and is dependent on public support (e.g. EEPR and NER300). Geological restrictions as well as current political restrictions on storage are also reflected. For these reasons, CCS costs are assumed higher than in previous Reference scenarios. Uptake of carbon capture and storage (CCS) in power and industry beyond supported demonstration plants remains very slow and occurs only towards the end of the projection period, driven by increasing ETS carbon prices.

On the demand side, demand for electric appliances continues to increase. However, there is an uncoupling between appliance stock and energy consumption due to the technological progress facilitated by ecodesign regulations.

Car manufacturers are expected to comply with the CO_2 standards by marketing vehicles equipped with hybrid system, which are becoming more appealing to the consumers thanks to lower costs. Electrically chargeable vehicles emerge around 2020 and are kick-started by existing EU and national policies as well as by incentive schemes aiming to boost their penetration. The share of activity of total electric vehicles in the total activity of light duty vehicles reaches 15% in 2050. Fuel cells would add an additional 2% by 2050. Other energy forms such as liquefied petroleum gas (LPG) and natural gas maintain a rather limited share.

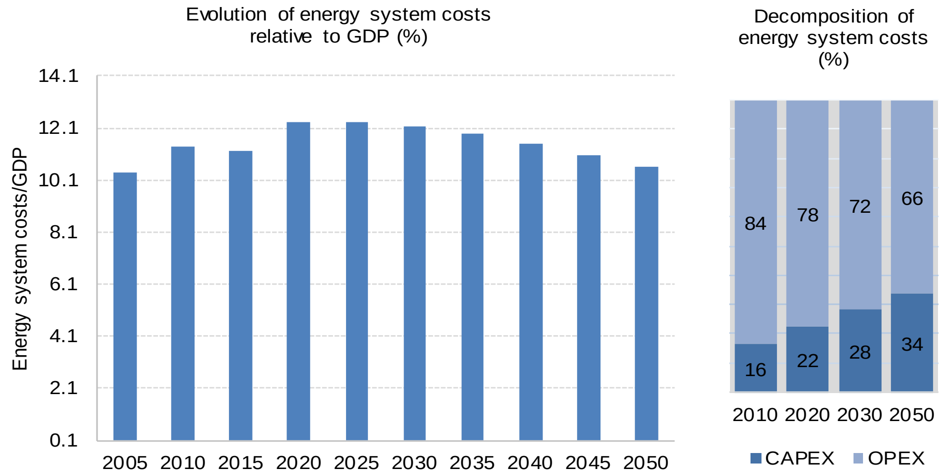
Figure 24: Evolution of activity of light duty vehicles by type and fuel[61]



Source: PRIMES-TREMOVE

Energy system costs increase up to 2020. Large investments are undertaken driven by current policies and measures. Overall, in 2020 energy system costs constitute 12.3% of the GDP, rising from 11.4% in 2010 and 11.2% in 2015, also driven by projected rising fossil fuel prices[62]. Despite further fossil fuel price increases, between 2020 and 2030 the share remains stable and decreases thereafter, as the system reaps benefits from the investments undertaken in the previous decade (notably via fuel savings). In this period, the share of energy system costs in GDP is gradually decreasing, reaching levels close to 2005 by 2050.

Figure 25: Projected evolution of energy system costs



Source: PRIMES, Energy system costs exclude ETS auction payments, given that they result in corresponding auction revenues.

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61 Light duty vehicles include passenger cars and light commercial vehicles.

62 Total system costs include total energy system costs, costs related to process-CO_2 abatement and non-CO_2 GHG abatement.

4.4 Overview of model-based policy scenarios

Two central policy scenarios reflecting the 2030 targets and main elements of the 2030 climate and energy framework agreed by the European Council in 2014[63] have been developed: EUCO27 and EUCO30. This recognises that for the energy efficiency target a review will still be undertaken to set the level of ambition. These scenarios also aim to provide consistency across a number of impact assessments underpinning 2016 Energy Union policy proposals. Using two central scenarios increases the robustness of policy conclusions.

All policy scenarios build on the REF2016, as described in the section above, and add the targets and policies described in detail in section below.

In addition, coordination policies are assumed which enable long term decarbonisation of the economy. Coordination policies replace the "enabling conditions" which have been modelled in 2030 framework IA and the 2014 Impact Assessment on 2030 energy efficiency targets.

4.4.1 EUCO27 policy scenario

In October 2014, the European Council decided on the energy and climate 2030 framework[64]. The following was agreed among the heads of states and governments:

- Substantial progress has been made towards the attainment of the EU targets for GHG emission reduction, renewable energy and energy efficiency, which need to be fully met by 2020.
- Binding EU target is set of an at least 40% domestic reduction in GHG emissions by 2030 compared to 1990.
- This overall target will be delivered collectively by the EU in the most cost-effective manner possible, with the reductions in the ETS and non-ETS sectors amounting to 43% and 30% by 2030 compared to 2005, respectively.
- A well-functioning, reformed Emissions Trading System (ETS) with an instrument to stabilise the market in line with the Commission proposal will be the main European instrument to achieve this target; the annual factor to reduce the cap on the maximum permitted emissions will be changed from 1.74% to 2.2% from 2021 onwards.
- An EU target of at least 27% is set for the share of renewable energy consumed in the EU in 2030. This target will be binding at EU level.
- An indicative target at the EU level of at least 27% is set for improving energy efficiency in 2030 compared to projections of future energy consumption based on the current criteria. It will be delivered in a cost-effective manner and it will fully respect the effectiveness of the ETS-system in contributing to the overall climate goals. This target will be reviewed by 2020, having in mind an EU level of 30%.
- Reliable and transparent governance system is to be established to help ensure that the EU meets its energy policy goals, with the necessary flexibility for Member States and fully respecting their freedom to determine their energy mix.

63 http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/145397.pdf.

64 http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/145397.pdf.

These requirements are reflected in the scenario called the European Council (EUCO) scenario with a minimum 27% energy efficiency target for 2030: EUCO27.

The table below summarises the assumptions on climate, renewable energy and specific energy efficiency policies in the EUCO27 baseline scenario that have been modelled.

Table 6: Policy assumptions in EUCO27 scenario

EUCO27	This scenario is designed to meet **all 2030 targets set by the European Council:** • At least 40% GHG reduction (wrt. 1990). • 43% GHG emissions reduction in ETS sectors (wrt. 2005). • 30% GHG emissions reduction in Effort Sharing Decision sectors (wrt. 2005). • At least 27% share of RES in final energy consumption. • **27% primary energy consumption reduction** (i.e. achieving 1369 Mtoe in 2030) compared to PRIMES 2007 baseline (1887 Mtoe in 2030). This equals a reduction of primary energy consumption of 20% compared to 2005 primary energy consumption (1713 Mtoe in 2005). **Main policies and incentives additional to REF2016:** **Revised EU ETS** • Increase of ETS linear factor to 2.2% for 2021-30. • After 2030 cap trajectory to achieve -90% emission reduction in 2050 in line with Low Carbon Economy Roadmap. **Renewables policies** • Renewables policies necessary to achieve 27% target, reflected by RES values applied in electricity, heating&cooling and transport sectors. **Energy efficiency policies:** **Residential and services sector** • Increasing energy efficiency of buildings via increasing the rate of renovation and depth of renovation. In this model, better implementation of EPBD and EED, continuation of Art 7 of EED and dedicated national policies are depicted by the application of energy efficiency values (EEVs). • Financial instruments and other financing measures on the European level facilitating access to capital for investment in thermal renovation of buildings. This, together with further labelling policies for heating equipment, is depicted by a **reduction of behavioural discount rates for**

	households from 12% to 11.5%. • More stringent (than in REF2016[65]) ecodesign standards banning the least efficient technologies. **Industry** • More stringent (than in REF2016) ecodesign standards for motors. **Transport** • CO_2 standard for cars: 85g/km in 2025; 75g/km in 2030 and 25 gCO_2/km in 2050[66]. • CO_2 standards for vans: 135g/km in 2025; 120g/km in 2030; 60g/km in 2050[67]. • 1.5% average annual energy efficiency improvements for new conventional and hybrid heavy goods vehicles between 2010-2030 and 0.7% between 2030-2050. • Measures on management of transport demand: - recently adopted measures for road freight, railways and inland navigation[68]; - gradual internalisation of transport local externalities[69] as of 2025 and full internalisation by 2050 on the inter-urban network. **Non-CO2 policies** • In 2030, carbon values of €0.05 applied to non-CO2 GHG emissions in order to trigger cost-effective emissions reductions in these sectors including in agriculture. • After 2030, carbon values set at EU ETS carbon price level.

In the EUCO27 scenario, energy efficiency delivers a large part of GHG emissions reduction in the ESD sectors. This reduction is complemented by cost-effective reductions in non-CO_2 emissions – mostly in agriculture. This approach reflects the Commission's 2013 analysis of 2030 targets (SWD(2014) 15 final), where a certain amount of non-CO_2 emissions reduction was necessary to achieve 40% GHG reduction.

Reductions of non-CO_2 emissions in the 2030 perspective can be (up to a certain extent) cost-effective. To achieve those cost-effective reductions in the agricultural sector would require a political commitment for corresponding EU or national measures. This option is, however, only explored in the baseline EUCO27 scenario, as in the additional policy scenarios more ambitious energy efficiency policies deliver all necessary reductions in ESD sectors.

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[65] The Reference scenario 2016 does not include the revisions of existing eco-design measures that are required by their implementing regulations or any future measures under this directive which are currently under discussion.

[66] On NEDC test-cycle.

[67] On NEDC test-cycle.

[68] Directive on Weights & Dimensions, Fourth railway package, NAIADES II package, Ports Package.

[69] Costs of infrastructure wear & tear, congestion, air pollution and noise.

4.4.2 EUCO30 policy scenario

The EUCO30 scenario is constructed similarly to the EUCO27 scenario, but raises the ambition level of the specific energy efficiency policies in a cost effective way. It implements the European Council guidance of having in mind 30% for the review of the Energy Efficiency Target. A relevant implication is that more ambitious energy efficiency policies deliver all necessary reductions in ESD sectors, and no reductions in non-CO2 sectors such as agriculture beyond REF2016 take place.

<table>
<tr><td>EUCO30</td><td>This scenario is designed to meet all 2030 targets set by the European Council:

At least 40% GHG reduction (wrt. 1990).
43% GHG emissions reduction in ETS sectors (wrt 2005).
30% GHG emissions in Effort Sharing Decision sectors (wrt 2005).
At least 27% share of RES in final energy consumption.
30% primary energy consumption reduction (i.e. achieving 1321 Mtoe in 2030) compared to PRIMES 2007 baseline (1887 Mtoe in 2030). This equals a reduction of primary energy consumption of 23% compared to 2005 primary energy consumption (1713 Mtoe in 2005).

Main policies and incentives additional to REF2016:

Revised EU ETS

Increase of ETS linear factor to 2.2% for 2021-30.
After 2030 cap trajectory to achieve -90% emission reduction in 2050 in line with Low Carbon Economy Roadmap.

Renewables policies

Renewables policies necessary to achieve 27% target, reflected by RES values applied in electricity, heating&cooling and transport sectors.

<u>Energy efficiency policies:</u>

Residential and services sector

Further increasing energy efficiency of buildings via increasing the rate of renovation and depth of renovation as well as behavioural change. In this model, better implementation of EPBD and EED, continuation of Art 7 of EED and dedicated national policies are depicted by the application of energy efficiency values (EEVs). EEVs are increased compared to EUCO27.
Financial instruments and other financing measures on the European level facilitating access to capital for investment in thermal renovation of buildings. This, together with further labelling policies for heating equipment, is depicted by a reduction of behavioural discount rates for households from 12% to 11.5%.
More stringent (compared to EUCO27) ec-design standards banning the least efficient technologies.
Policies facilitating uptake of heat pumps .
</td></tr>
</table>

	Industry • Application of Energy efficiency values in industry (fraction of those applied in residential and services sector) leading to deeper energy efficiency effort and heat recovery. • More stringent (compared to EUCO27) ecodesign standards for motors. **Transport** • CO_2 standard for cars: 80g/km in 2025; 70g/km in 2030 and 25 gCO_2/km in 2050. • CO_2 standards for vans: 130g/km in 2025; 110g/km in 2030; 60g/km in 2050. • 1.5% average annual energy efficiency improvements for new conventional and hybrid heavy goods vehicles (HGVs) between 2010-2030 and 0.7% between 2030-2050. • Measures on management of transport demand: - recently adopted measures for road freight, railways and inland navigation[70]; - gradual internalisation of transport local externalities[71] as of 2025 and full internalisation by 2050 on the inter-urban network; - modulation of infrastructure charges for HGVs according to CO2 emissions leading to faster fleet renewal; - eco-driving; - deployment of Collaborative Intelligent Transport Systems. **Non-CO2 policies** • No policy incentive until 2030 • After 2030, carbon values set at EU ETS carbon price level

4.4.3 EUCO+ scenarios with more ambitious 33, 35 and 40% energy efficiency targets

The table below summarises the assumptions on specific energy efficiency policies in EUCO+33, EUCO+35 and EUCO+40 scenarios that have been modelled. As these scenarios built on EUCO30 policy scenario they are progressively scaled up in terms of ambition of energy efficiency policies, only the differences that illustrate the increases level of ambition are listed.

Table 7: Assumptions in EUCO+33, EUCO+35, EUCO+40 scenarios

EUCO+33	**As EUCO30 except:** • **33% primary energy consumption reduction target is set** (i.e. achieving 1260 Mtoe in 2030) compared to PRIMES 2007 baseline (1887 Mtoe in 2030). This equals a reduction of primary energy consumption of 26% compared to 2005

70 Directive on Weights & Dimensions, Fourth railway package, NAIADES II package, Ports Package.
71 Costs of infrastructure wear & tear, congestion, air pollution and noise.

	primary energy consumption (1713 Mtoe in 2005). • As a result some 2030 GHG targets set by the European Council are slightly overshot: - 43% GHG reduction (wrt. 1990); - 44% GHG reduction in ETS sectors (wrt 2005) - 34% GHG emissions reduction in Effort Sharing Decision sectors (wrt 2005). • Also, as a result of energy efficiency policies reducing demand, 28% RES share in final energy consumption is achieved. **Main policies and incentives additional to Reference:** **Energy efficiency policies:** **Residential and services sector** • Further increasing of energy efficiency values compared to EUCO30. • Financial instrument and other financing measures are made more widely available on the European level further facilitating access to capital for investment in thermal renovation of buildings and further labelling policies for heating equipment are pursued – depicted by **reduction of the discount rates for households from 11.5% (in EUCO30) to 11%.** • More ambitious policies (than in EUCO30) facilitating uptake of heat pumps. **Industry** • Increasing energy efficiency values in industry (fraction of those applied in residential and services sector) leading to deeper energy efficiency effort and heat recovery (compared to EUCO30). • Application of Best Available Techniques. **Transport** • Promotion of public procurement that provides effective incentives for purchasing cleaner vehicles (i.e. Revision of Clean Vehicles Directive). • Additional measures on management of transport demand: - full internalisation of transport local externalities as of 2025 on the inter-urban network; - more ambitious deployment of Collaborative Intelligent Transport Systems and support for multimodal travel information; - promoting efficiency improvements and multimodality (e.g. review of Combined Transport Directive, review of Rail Freight Corridors Regulation, review of market access rules for road transport); - promotion of urban policies curbing pollutant emissions.

<table>
<tr><td>EUCO+35</td><td>As EUCO+33 except:
35% primary energy consumption reduction target is set (i.e. achieving 1220 Mtoe in 2030) compared to PRIMES 2007 baseline (1887 Mtoe in 2030). This equals a reduction of primary energy consumption of 29% compared to 2005 primary energy consumption (1713 Mtoe in 2005).
As a result all 2030 GHG targets set by the European Council are slightly overshot:
- 44% GHG emissions reduction (wrt. 1990),
- 44% GHG emissions reduction in ETS sectors (wrt 2005)
- 36% GHG emissions reduction in Effort Sharing Decision sectors (wrt 2005)
- Also, as a result of energy efficiency policies reducing demand, 28% RES share in final energy consumption is achieved.
Main policies and incentives additional to Reference:

<u>Energy efficiency policies:</u>

Residential and services sector
Further increasing of energy efficiency values compared to EUCO+33.
More ambitious (than in EUCO+33) policies facilitating uptake of heat pumps.
Industry
Increasing EEVs in industry (fraction of those applied in residential and services sector) leading to deeper energy efficiency effort and heat recovery (compared to EUCO+33).
Application of more advanced (compared to EUCO+33) Best Available Techniques
Transport
CO_2 standard for cars: 77g/km in 2025; 67g/km in 2030 and 25 gCO_2/km in 2050.
CO_2 standards for vans: 118g/km in 2025; 106g/km in 2030; 60g/km in 2050.
Energy taxation aligning the minimum tax rates of petrol and gas oil used as motor fuel.</td></tr>
<tr><td>EUCO+40</td><td>As EUCO+35 except:
40% primary energy consumption reduction target is set (i.e. achieving 1129 Mtoe in 2030) compared to PRIMES 2007 baseline (1887 Mtoe in 2030). This equals a reduction of primary energy consumption of 34% compared to 2005 primary energy consumption (1713 Mtoe in 2005).
As a result all 2030 GHG targets set by the European Counci significantly overshot:
- 47% GHG emissions reduction (wrt. 1990) is achieved.</td></tr>
</table>

	- 48% GHG emissions reduction in ETS sectors (wrt 2005) is achieved - 39% GHG emission reduction in Effort Sharing Decision sectors (wrt 2005) is achieved. • Also, as a result of energy efficiency policies reducing demand, 28% RES share in final energy consumption is achieved. **Main policies and incentives additional to Reference:** **<u>Energy efficiency policies:</u>** **Residential and services sector** • Further increasing of energy efficiency values compared to EUCO+35. • Financial instrument and other financing measures are made more widely available on the European level lowering access to capital for investment in thermal renovation of buildings and further labelling policies for heating equipment are pursued – depicted by **reduction of the discount rates for households from 11% (in EUCO35) to 10%.** • More ambitious policies facilitating uptake of heat pumps. **Industry** • Further increasing EEVs in industry (fraction of those applied in residential and services sector) leading to deeper energy efficiency effort and heat recovery (compared to EUCO+35). • Application of more advanced (compared to EUCO+35) Best Available Techniques **Transport** • CO_2 standard for cars: 74g/km in 2025; 64g/km in 2030 and 25 gCO_2/km in 2050[72]. • CO_2 standards for vans: 106g/km in 2025; 97g/km in 2030; 60g/km in 2050[73]. 1.6% average annual energy efficiency improvements for new conventional and hybrid heavy goods vehicles between 2010-2030 and 0.9% between 2030-2050.

4.4.4 Modelling input parameters

4.4.4.1 Energy Efficiency values

As described in above, the key modelling tool are energy efficiency values (EEV) – which are modelled as shadow values of virtual energy saving constraints optionally applying by energy

[72] The level of standards corresponds to the more ambitious edge of the range of standards for cars discussed for 2025 in recent trilogue discussions.

[73] The level of standards corresponds to the more ambitious edge of the range of standards for vans discussed for 2025 in recent trilogue discussions.

demand sector. Essentially, using the EEVs in the model is a way of representing non-identified policy measures which aim at achieving energy savings in order to achieve a pre-defined target level of primary energy consumption in 2030. Instead of modelling one-by-one the broad range of energy efficiency policy measures, a practical way is to assume a non-zero value of EEVs and increase it until the non-identified measures induce an assumed amount of energy savings. EEVs were applied in residential and tertiary sector and also in industry (at a lower level in order to reflect the fact that industrial sector is already partly exposed to ETS and that many MS have so far chosen to exempt industrial sector from energy efficiency measures).

The EEV, as described above in modelling terms, are used to simulate increasing energy savings related to improving thermal integrity of houses and buildings and changing energy consumption behaviour, implying reduced consumption of fuels and electricity. Currently, such obligations are chiefly driven by the Art 7 of the EED but in addition some MS have also put in place national policies aiming at renovation of the building stock (notably information campaigns, fiscal policies and financial incentives). As EEV increase step-wise by scenario and in time, they drive a faster pace of investments in renovations (as demonstrated by renovation rates) as well as increasing depth of renovations from an energy perspective (as demonstrated by the increased energy savings of the renovations). They also induce a behavioural change towards a more efficient use of energy. Other energy efficiency policies such as ecodesign, labelling etc. act in addition to the EEV by influencing the choice of equipment technologies and their turnover over time.

In the current exercise, the national component of EEV is equal to the level of national EEV in the REF2016 for the year 2020. The national EEV reflect the assessment of the implementation of the Art 7 of the EED as well as the impact of additional national energy efficiency policies that lead to thermal renovation of buildings and curbing their fuel and electricity use. This assessment was made when preparing the EU Reference scenario 2016, i.e. in 2015 to the best available knowledge at that time.

The national component of the EEV is combined with the European component, which is alike across all Member States reflecting an equal additional incentive on the European level, i.e. continuation of Art 7 of EED or measures with similar effect. It is the European component that is increased step-wise in scenarios. As a general rule, the higher the overall energy efficiency target, the higher the EEVs reflecting a higher energy saving level e.g. under the the energy efficiency obligation (or alternative measures) to be mandated by continuation of Art 7 of EED.

The table below shows, that significant EEVs are needed to achieve higher energy efficiency levels. To achieve 23.9% of energy reductions in 2030, only €5/toe are necessary. To achieve 27%, an EEV of €338/toe is already needed. This values needs to be increased to €713/toe to achieve an energy efficiency level of 30% in 2030. €2,525/toe would be needed to achieve a level of 40%. It has to be stressed that the absolute number of EEV has no direct meaning, because its influence depends on relative values not on absolute levels. As described in chapter 4.2.2.5 above, EEVs are not an energy tax or subsidy, they represent an incentive to invest in energy efficiency or to change behaviour towards a more efficient use of energy. All energy efficiency investments induced by EEVs are fully accounted for in the energy system costs and investment expenditures are reported in chapter 5.1.5 of the main text.

Table 8: Energy efficiency values

Energy efficiency values (2030)	Ref2016	EUCO27	EUCO30	EUCO+33	EUCO+35	EUCO+40
Average energy efficiency value in the residential and tertiary sector (€/ toe)	5	338	713	1302	1677	2525

Source: PRIMES

By varying the EEVs, the projected renovation rates escalate across scenarios. In PRIMES, the economic agent can decide – based on the EEVs incentive modelled – between different renovation packages. All renovation packages describe interventions only in the building shell of a household (replacement of windows, installation of insulation materials on walls and/or the roof and/or the basement), thus affecting the overall U-Value coefficient of the building (getting decreasing U-Values the deeper the renovation package is) and therefore the useful energy consumption of the building[74]. The deeper the renovation package, the higher the energy efficiency investments costs. These investments are reflected in the energy system costs of the PRIMES model.

Table 9: Renovation rates in the residential sector[75]

(%)	Average renovation rate EU28		Average energy saving % from renovation EU28	
	2015-2020	2021-2030	2015-2020	2021-2030
REF2016	1.5%	1.5%	43.4%	33.3%
EUCO27	1.5%	1.7%	46.8%	51.8%
EUCO30	1.5%	2.1%	47.3%	55.6%
EUCO+33	1.5%	2.7%	48.0%	59.3%
EUCO+35	1.5%	2.9%	48.4%	59.5%
EUCO+40	1.5%	3.1%	50.4%	63.0%

Source: NTUA Buildings model

4.4.4.2 RES values

Renewables policies necessary to achieve 27% target (in EUCO27, EUCO30, EUCO+33 and EUCO+35) and 30% in EUCO+40 are reflected by RES values applied in electricity, heating and cooling and transport sectors. RES values are used in order to ensure cost-efficient RES target achievement at European level.

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[74] The "average useful energy for heating" is the energy needed for space heating, for the calculation of which the seasonal method of the standard EN 13790 'Energy performance of buildings - Calculation of energy use for space heating and cooling' is being used, the way it was described in the TABULA Methodology (http://episcope.eu/building-typology/webtool/). In the before mentioned methodology the "average useful energy for heating" derives from considering the thermal performance of the building shell (characteristics of building envelope), climatic data and standards on thermal comfort. The average useful energy demand for heating does not include the heating system choice.

[75] The renovation rates shown in the table below are the result of an ex-post analysis performed with the dedicated buildings model additional to the classic PRIMES suite which was used for REF2016 and the policy scenarios.

Like the energy efficiency values, the RES value is a shadow price, a signal of potential costs per unit of renewable energy not achieved (relative to the target) which is internalized in the optimizing behaviours of actors and thus leads to higher RES uptake. RES values do not describe in detail the RES supporting policies, but are introduced if needed, in addition to the supporting policies, so as to complement them and reach the RES target. The RES value should not be confused with feed-in tariffs or green certificates, because it does not model any sort of power purchasing agreement with the RES developers and the RES projects compete on equal economic grounds with other forms of energy.

As shown in the table below, RES values needed to be slightly increased with more ambitious energy efficiency efforts in 2030 to achieve a share of renewables of at least 27% at the same time as a more ambitious energy efficiency level in 2030.

Table 10: RES values

RES values (2030)	Ref2016	EUCO27	EUCO30	EUCO+33	EUCO+35	EUCO+40
Average Renewables value (€/ MWh)	11	7	16	14	12	19

Source: PRIMES

4.4.4.3 Modelling of energy efficiency policies for the industrial sector

Anticipation of enforcement of Best Available Techniques (BAT) in Industry:

Energy efficiency progress in the industrial sector in the energy efficiency scenarios occurs through the deployment of BAT (best available techniques), both vertically and horizontally; vertically refers to technologies associated with the equipment used for specific industrial process; horizontally, refers to systems that affect all industrial processes, such as energy control systems and heat recovery systems.

In modelling, the BATs are reflected in the menu of available technologies, which is the same in all energy efficiency scenarios. What varies among scenarios is the uptake of technologies, depending on the intensity of energy efficiency policies assumed and regulatory enforcement of BATs. For the former the modelling mechanism is the following: the anticipation of more ambitious energy efficiency policies results in moderation of the perception of risk associated with advanced technologies, and in acceleration of their maturity and uptake. This effect is represented in the energy efficiency scenarios through modifying the parameters that reflect the perception of cost. In other words, industry anticipates that enforcement is likely to become more stringent in the future and so in order to avoid locking-in inferior technologies increases the uptake of more efficient technologies. Regulatory enforcement of BATs makes mandatory the application of specific BATs.

4.4.4.4 Reduced discount rates due to policy implementation

As described in the chapter describing the set-up of the scenarios, decision-making discount rates are lowered in the policy scenarios. This is in order to reflect financial instrument and other measures, which are assumed to be made more widely available on the European level lowering access to capital for investment in thermal renovation of buildings and to reflect the implementation of further labelling policies for heating equipment or the further development of ESCO markets. Discount rates applied for cost-accounting remain unchanged across all scenarios and throughout the projection period.

Please see in chapter 4.2 on the Reference scenario for explanation of the application of both decision-making and cost-accounting discount rates.

4.4.4.5 Modelling of ecodesign regulations

The ecodesign policy aims at reducing energy consumption of energy-related equipment and appliances by promoting product varieties which embed higher energy efficiency. Depending on implementing measures and voluntary agreements, the eco-design regulations certify specific energy consumption by product variety and eventually provides for mandatory requirements for certain products. The requirements impose a minimum bound on energy performance of products. The bounds are set for the next two to five years. This implies that the menu of technologies for consumer choices in the future is restricted to product varieties which have performances exceeding the minimum threshold value. The menu will still allow selecting technologies which perform above minimum threshold value; the choice will depend on relative costs, perception of technical risks and the policy context. The Ecodesign regulations, combined with the labelling directive, are playing an important role to remove uncertainties regarding technical risks and those stemming from lack of information.

PRIMES considers equipment in an aggregated manner, looking at the equipment performance in heating and cooling, water heating, cooking, lighting and (white and black) appliances.

The REF2016 scenario is assumed to include the currently adopted eco-design regulations. The effects additional of ecodesign regulations are then simulated to intensify towards the 2030 horizon relative to the REF2016 in EUCO27 and EUCO30 scenarios (as beyond EUCO30 the potential for improvement stemming from ecodesign is largely exhausted). Moving from 2030 to 2050, the effects are simulated to intensify further relative to the 2020-2030 period and approach technical potential in the ambitious case. The learning effects are modelled to be relatively lower until 2030 than after 2030.

The strongest progress in ecodesign happens in heating, cooling, cooking and appliances. In the table below, it can be noticed that there are some incremental improvements in energy efficiency EUCO+ scenarios as well. In particular, for space heating and cooking there is further improvement also beyond EUCO30. Nevertheless, this is not a result of extra ecodesign progress in the EUCO+ scenarios, rather of the electrification and the specific allocation of consumers in vintages of technologies in these scenarios, in other words, more households using efficient appliances.

Table 11: Residential sector - Improvements in efficiency compared to 2005

Residential sector: **Improvements in efficiency compared to 2005** **(% change)**	**2020**	**2030**	**2050**	**2020**	**2030**	**2050**
		Heating			**Cooling**	
REF2016	8.1	20.1	29.9	6.7	20.4	52.4
EUCO27	7.8	21.8	36.3	6.7	22.2	65.1
EUCO30	7.8	24.5	39.2	6.7	55.6	95.3
EUCO+33	7.8	29.1	44.8	6.7	56.0	95.0
EUCO+35	7.8	29.2	44.8	6.7	56.0	95.1
EUCO+40	8.0	33.2	50.1	6.7	57.7	94.9
		Water heating			**Cooking**	
REF2016	6.1	20.8	31.8	2.6	6.0	8.9
EUCO27	5.6	20.5	29.3	2.4	7.7	19.4
EUCO30	5.6	21.2	30.2	2.4	11.7	24.4
EUCO+33	5.7	21.5	30.8	2.4	18.5	32.1
EUCO+35	5.7	21.5	30.9	2.5	18.7	32.4
EUCO+40	5.9	22.5	31.9	2.7	21.5	36.0
		Lightning			**White appliances**	
REF2016	155.1	325.3	374.4	23.0	38.4	41.4
EUCO27	154.5	329.1	378.8	22.5	38.0	41.3
EUCO30	154.5	327.1	378.2	22.5	43.9	50.6
EUCO+33	154.3	327.5	377.8	22.6	44.0	50.6
EUCO+35	153.7	326.7	377.7	22.6	44.0	50.6
EUCO+40	152.5	328.4	377.2	22.5	44.0	50.7
		Black applainces			**Central boilers**	
REF2016	23.9	36.1	50.5	8.0	16.8	27.9
EUCO27	24.0	35.5	49.7	8.0	16.4	27.0
EUCO30	24.0	42.6	59.8	8.0	16.1	26.9
EUCO+33	24.0	42.6	59.8	8.0	16.9	28.6
EUCO+35	24.0	42.7	59.8	8.0	16.9	28.8
EUCO+40	24.0	42.6	60.1	8.0	19.4	31.9
		Gas heaters			**Heat pumps**	
REF2016	13.0	22.1	34.2	0.0	22.8	53.6
EUCO27	13.0	21.8	33.9	0.0	25.5	56.4
EUCO30	13.0	21.5	34.0	0.0	42.0	60.5
EUCO+33	13.0	22.0	35.4	0.0	44.3	61.3
EUCO+35	13.0	21.9	34.9	0.0	44.1	61.2
EUCO+40	13.0	25.1	38.8	0.0	46.8	64.4

Source: PRIMES

Table 12: Service sector - Improvements in efficiency compared to 2005

Service sector: Improvements in efficiency compared to 2005 (% change)	**2020**	**2030**	**2050**	**2020**	**2030**	**2050**
	Heating			**Cooling**		
REF2016	11.8	28.5	39.8	3.8	12.4	45.1
EUCO27	10.8	30.5	56.4	3.7	12.6	48.9
EUCO30	10.8	33.1	57.1	3.7	22.6	64.0
EUCO+33	10.8	33.1	57.1	3.7	22.6	64.0
EUCO+35	10.7	36.4	60.5	3.7	22.4	63.9
EUCO+40	10.6	37.4	61.7	3.6	22.9	64.1
	Other use			**Lightning**		
REF2016	3.6	14.0	20.0	194.8	350.4	395.6
EUCO27	3.3	15.1	20.8	184.3	348.1	395.1
EUCO30	3.3	15.2	20.8	184.6	366.0	396.3
EUCO+33	3.3	16.3	22.9	181.7	369.4	402.9
EUCO+35	3.3	16.3	22.9	176.9	368.6	402.8
EUCO+40	3.1	16.3	22.9	161.2	369.3	403.1
	Electric appliances					
REF2016	16.9	26.5	44.8			
EUCO27	16.9	26.6	44.9			
EUCO30	16.9	28.4	45.1			
EUCO+33	16.9	28.3	45.1			
EUCO+35	16.9	28.2	45.0			
EUCO+40	16.9	28.2	45.0			

Source: PRIMES

4.4.4.6 Modelling of transport policies

CO_2 standards for new cars and light commercial vehicles.

The tightening of CO_2 standards post-2020 is a key assumption, leading to improvements in energy efficiency and CO_2 emissions reduction in transport. The CO_2 standards assumed in the policy scenarios are provided in Table 13 for cars and in

Table 14 for light commercial vehicles.

Table 13: Assumptions on CO2 standards (gCO2/km) for new cars across scenarios[76]

Scenario	CO_2 standards (gCO_2/km) for new cars		
	2025	**2030**	**2050**
EUCO27	85	75	25
EUCO30	80	70	25
EUCO+33	80	70	25
EUCO+35	77	67	25
EUCO+40	74	64	25

Source: PRIMES

[76] On current test-cycle.

Table 14: Assumptions on CO2 standards (gCO2/km) for new light commercial vehicles across scenarios[77]

Scenario	CO_2 standards (gCO_2/km) for new light commercial vehicles		
	2025	**2030**	**2050**
EUCO27	135	120	60
EUCO30	130	110	60
EUCO+33	130	110	60
EUCO+35	118	106	60
EUCO+40	106	97	60

Source: PRIMES

Vehicle efficiency of new heavy goods vehicles

The following improvements in specific fuel consumption of new heavy goods vehicles were assumed:

- 1.5% per year on average in all scenarios. EUCO27, EUCO30, EUCO+33, EUCO+35 in 2010-30 and 0.7% per year in 2030-50;
- 1.6% per year on average in scenario EUCO+40 in 2010-30 and 0.9% per year in 2030-50.

Recently adopted measures

Measures adopted after the cut-off date of Reference scenario 2016 (i.e. Directive on Weights & Dimensions[78], Fourth railway package[79], NAIADES II package[80], and the Ports Package[81]) are assumed to apply in all scenarios. The input for modelling draw on the respective Impact Assessments.

Fair and efficient pricing for sustainable transport

1. Gradual internalisation of the costs of infrastructure wear & tear, congestion, air pollution and noise in the pricing of road transport on the inter-urban network is assumed from 2025 onwards. For rail, internalisation of the costs of air pollution, noise and congestion is assumed from 2030 onwards; for inland waterways internalisation of the costs of air pollution is assumed from 2030 onwards. In scenarios EUCO27 and EUCO30, the levels of the charges are gradually increased from 2025/2030 to 2050, when they become equal to the values of the 2014 Handbook on external costs of transport.[82]
2. Full internalisation of local externalities is assumed in scenarios EUCO+33, EUCO+35 and EUCO+40, meaning that the charges are set equal to the values of the 2014 Handbook on external costs of transport from 2025 onwards for road transport (on the inter-urban network) and from 2030 onwards for rail and inland waterways.

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77 On current test-cycle.
78 SWD(2013)109 final.
79 SWD(2013) 10 final.
80 SWD(2013) 324 final.
81 SWD(2013) 181.
82 Source: http://ec.europa.eu/transport/themes/sustainable/internalisation_en.htm.

3. Modulation of the infrastructure charges according to CO_2 emissions for heavy goods vehicles (HGVs) is assumed to apply in all scenarios except for EUCO27; it is assumed to apply on the inter-urban network from 2025 onwards. Starting from the average infrastructure charge in each Member State, a linear incremental variation is assumed for HGVs with higher emissions than average; a similar linear variation is assumed for HGVs with lower emissions than average (by HGVs category). The measure is assumed to apply similarly to the Euro class-differentiation of network-wide tolls and implies revenue neutrality.

Collaborative Intelligent Transport Systems (C-ITS)

Deployment of C-ITS in road transport has been assumed in all scenarios except for EUCO27.

2. In scenarios EUCO30, the input assumption for modelling draws on the central scenario of a Cost Benefit Analysis (CBA) study carried out by Ricardo AEA[83].
3. In scenarios EUCO+33, EUCO+35 and EUCO+40 more ambitious deployment of C-ITS is assumed, designed to represent the impact of using the cellular network to provide vehicle-to-infrastructure (V2I) services. The input for modelling draws on a sensitivity developed by Ricardo AEA within the same study.

Eco-driving

Promotion of eco-driving is assumed in all scenarios except for EUCO27; the input assumption used for modelling draw on "EU Transport GHG: Routes to 2050?" project[84]. It is assumed that virtually all drivers would be trained by 2050 (for road and rail). Savings from training decline to 2050 due to technology effects. No variation in the level of intensity of the measure is assumed between scenarios.

Promotion of public procurement through the revision of the Clean Vehicles Directive.

Using a conservative approach, it is assumed that starting from 2025 the level of vehicles purchased under the Directive (i.e. the upper estimate according to the evaluation study[85]) resemble the best-performing vehicles in the market in terms of internalised external costs. Measure included in scenarios EUCO+33, EUCO+35 and EUCO+40.

Review of market access rules for road transport (road haulage).

For modelling purposes, it is assumed that the measures would lead to a share of empty vehicle-km in total vehicle-km for cabotage equal to that of domestic hauliers carrying out national transport from 2025 onwards. Increasing the load factors in PRIMES-TREMOVE model allows capturing rebound effects and possible modal shift due to e.g. lower unit costs relative to rail. Measure included in scenarios EUCO+33, EUCO+35 and EUCO+40.

Support for multimodal travel information

The input for modelling is based on a 2014 study[86], showing that more effective network management and more efficient passenger transport through more efficient journeys and optimized travel choices reduce travel time. For modelling purpose, the measure is assumed to

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83 Source : http://ec.europa.eu/transport/themes/its/c-its_en.htm

84 "EU Transport GHG: Routes to 2050?" final report is available at: http://www.eutransportghg2050.eu/cms/assets/EU-Transport-GHG-2050-Final-Report-22-06-10.pdf

85 Source: http://ec.europa.eu/transport/facts-fundings/evaluations/doc/2015-09-21-ex-post-evaluation-directive-2009-33-ec.pdf

86 Source: http://ec.europa.eu/transport/themes/its/studies/doc/20140812-july9thversion-awtfinalreport.pdf

be implemented from 2025 onwards. Measure included in scenarios EUCO+33, EUCO+35 and EUCO+40.

Promoting intermodal transport

Drawing on a 2015 study[87], the main drivers are assumed to be the decrease in the operation costs for combined transport and time costs for rail, inland waterways and short sea shipping, leading to model shift away from road (mainly towards rail); implemented from 2025 onwards. Measure included in scenarios EUCO+33, EUCO+35 and EUCO+40.

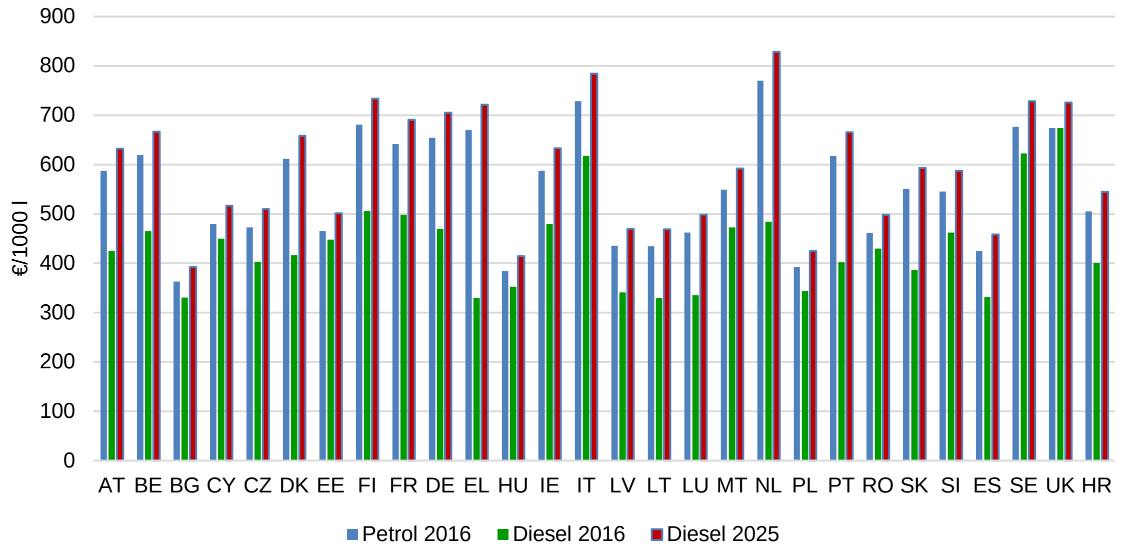
Promotion of urban policies

Urban policies aiming to curb pollutant emissions are reflected through air pollutants shadow values equal to the damage costs from the 2014 Handbook on external costs of transport; implemented from 2025 onwards[88]. Measure included in scenarios EUCO+33, EUCO+35 and EUCO+40.

Alignment of the national tax rates for petrol and gas oil used as motor fuels on the basis of energy content and CO_2 emissions

The changes in the excise duty rates affect diesel because at present this fuel is taxed at lower rates (considering the energy and CO2 content) in all Member States. The increases are assumed to be implemented from 2025 onwards and are presented in the figure below. Measure included in scenarios EUCO+35 and EUCO+40.

Figure 26: Changes in the excise duty rates for diesel (expressed in EUR per 1 000 l) by Member State from 2025 onwards



Source: PRIMES

4.4.4.7 Coordination policies

In this modelling exercise, all scenarios (except Reference) achieve decarbonisation in 2050 and hence assume an overall policy framework which enables this. Given that concrete policies will

[87] Source : http://ec.europa.eu/transport/themes/strategies/studies/doc/2015-01-freight-logistics-lot2-combined-transport.pdf

[88] Source: http://ec.europa.eu/transport/themes/sustainable/studies/sustainable_en.htm

most likely have to be proposed in order to fulfil the necessary conditions in infrastructure, technology, market coordination, the elements of this framework which go beyond the drivers and policies specified in the policy scenarios are called coordination policies. Coordination policies replace the "enabling conditions" which have been modelled in the 2030 framework impact assessment (in decarbonisation scenarios) and the 2014 impact assessment on energy efficiency target.

In the past modelling exercises, enabling conditions were present in all decarbonisation scenarios. Enabling conditions meant that because of good anticipation of future GHG emission reduction commitments, all conditions were met in infrastructure, technology learning, public acceptance and market coordination so as to enable the decarbonisation. In other words, enabling conditions enabled to maximize the effectiveness of policy instrument which aim at driving strong GHG emission cuts. These enabling conditions were fully costed in decarbonisation scenarios.

These assumptions have been revisited considering that concrete policies will most likely have to be proposed in order to fulfil the necessary conditions in infrastructure, technology, market coordination, etc. Consequently, enabling conditions are replaced by coordination policies as indicated in the list included in the table below. These coordination policies will be proposed by the Commission post 2020. Coordination policies are fully costed in the scenarios, as it was the case with enabling conditions. It is important to make a distinction between 2 types:

- coordination policies related to ongoing infrastructure developments that will enable a larger exploitation of cost-effective energy efficiency, RES, GHG abatement options after 2020.
- coordination policies related to R&D and public acceptance that are expected to be needed to meet long term decarbonisation objectives, and have effects post 2030

Table 15: Summary of coordination policies assumed

Enabling conditions in the 2030 Impact Assessment	New approach
Intelligent grids and metering (also for EVs)	Coordination policy post 2020 (Partly accomplished in the Reference scenario 2016 - implementation of the 3rd Internal Energy Market package).
Infrastructure to harvest decentralised as well as remote RES for power generation	Coordination policy post 2020
Carbon transportation and storage infrastructure and acceptance	coordination policy post-2030 (CCS is indispensable for decarbonisation towards 2050)
Gas and hydrogen: (technological progress enabling mix of hydrogen and bio-gas in gas supply and possibility to use hydrogen-based storage for balancing RES power)	coordination policy post-2030 (advanced storage is necessary and in that time perspective)
Battery technology development (for electric and plug-in hybrid vehicles) and	Reference scenario 2016 has assumptions on battery technology development and fuel cells which are rather conservative, consistent with

Enabling conditions in the 2030 Impact Assessment	New approach
fuel cells	the logic of a Reference scenario, i.e. without additional policies stimulating R&D, infrastructure or purchase. For the decarbonisation scenarios, increased R&D, expectations and learning effects lead to lower technology costs for electrification technology (for electric and plug-in hybrid vehicles) and fuel cells.
Recharging infrastructure	Coordination policy post 2020 (based on the Directive on the deployment of alternative fuels infrastructure)
Market acceptance (of electrification)	Coordination policies post 2020 (supported by the implementing measures following the Directive on the deployment of alternative fuels infrastructure)
Innovation in biofuels	Coordination policy with impacts post 2030 These are biomass related innovation and agriculture policies assumed to develop so as to allow the development of new generation bio-energy feedstock (basically lingo-cellulosic crops) at large scale. As a result, a new industry would emerge ranging from agriculture, industrial-scale collection and pre-treatment, bio-refineries with new conversion technologies, product standardization and commercialisation.
Overcoming some market barriers to Energy Efficiency in Buildings	Part of 2020-2030 policy mix as described in assumptions on policy options.
Heating equipment and appliances technology uptake in the domestic sector	As above
Energy efficiency innovation diffusion in Industry	As above

4.5 Additional PRIMES policy scenario results

Total energy system costs as described in chapter 5.1.6. from an end user perspective (as calculated in the modelling) comprise mainly three elements:

1) annuities for capital expenditure on energy using equipment,
2) fuel and electricity costs (energy purchasing costs[89]),
3) so-called direct energy efficiency investment costs[90] (not related to energy equipment itself), such as expenditure for insulation.

Average annual **capital costs** for the period 2021-2030 increase from €499 bn in the Reference scenario to €518 bn in EUCO27. Stepping up energy efficiency to 30% will lead to €7 bn additional average annual capital costs in EUCO30 and 1 billion less is necessary for a 33% target (small decline is mostly driven by transport demand management policies which lower the need for equipment purchase). Average annual capital costs would further increase for EUCO+35 and EUCO+40 scenarios.

Comparing costs between 27% and 30% target, capital costs are unchanged for industrial sectors. They increase only slightly in transport[91] and residential sectors.

Direct efficiency investment costs, representing mainly investment in the thermal integrity of buildings, increase in all scenarios already in EUCO27 scenario compared to REF2016 (€30 bn increase in average annual costs over 2021-2030). Compared to EUCO27, energy efficiency investments then increase by €25 bn for EUCO30. For more ambitious scenarios, an increase in average annual costs ranging from €73 bn to €184 bn.

Average **energy purchases** in 2021-2030 are reduced from €1,448 bn in Reference scenario to €1,415 bn in EUCO27. A further reduction of energy purchasing costs by €28 bn is possible in EUCO30 (compared to EUCO27). For more ambitious scenarios, a decrease in average annual energy purchases range from €52 to 86bn. Across all scenarios, the reductions are mainly achieved in residential and tertiary sectors.

A general shift in the structure of costs for energy consumers is observed, i.e. diminishing energy purchases (consumer paying less for fuels and electricity) and increasing investment expenditures (consumers paying for additional energy efficiency investments).

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[89] Energy purchase costs include the capital costs corresponding to power & gas infrastructure (plants & grids), refineries and fossil fuel extraction, recovered in the model through end-user prices of energy products.

[90] Direct efficiency investment expenditures include the costs relating to (a) thermal integrity of buildings, i.e. for building insulation, triple glazing and other devices for energy savings including building management systems, and (b) for the industry sector they also include the investments that relate to the horizontal (not related to specific processes) energy saving investments, such as for energy control systems and heat recovery systems. There are no direct efficiency investment expenditures in transport sectors as they are only activated by energy efficiency values.

[91] The capital costs reported for transport relate to energy services.

Table 16: Components of energy system costs in 2030 and 2050.

Components of total energy system costs (2030/2050)	Ref2016			EUCO27			EUCO30			EUCO+33			EUCO+35			EUCO+40		
Capital Costs in bn €'13 *(average annual 2021-30 and 2031-2050)*	499	/	639	518	/	704	525	/	721	524	/	721	527	/	722	539	/	739
Change to EUCO27 in billion €'13							7	/	17	6	/	17	9	/	18	21	/	35
Industry	31	/	46	33	/	54	33	/	56	35	/	60	37	/	62	44	/	80
Residential	262	/	317	258	/	309	262	/	319	263	/	319	263	/	319	262	/	317
Tertiary	60	/	81	58	/	70	57	/	72	55	/	68	54	/	67	52	/	64
Transport[92]	146	/	194	169	/	271	172	/	273	171	/	273	173	/	274	181	/	278
Direct Efficiency Investment costs in bn €'13 *(average annual 2021-30 and 2031-2050)*	6	/	2	36	/	162	61	/	155	109	/	223	142	/	258	220	/	339
Change to EUCO27 in billion €'13							25	/	-7	73	/	61	106	/	96	184	/	177
Industry	0	/	0	0	/	0	0	/	0	0	/	0	0	/	0	0	/	0
Residential	4	/	1	24	/	115	40	/	109	70	/	151	90	/	173	134	/	220
Tertiary	2	/	1	12	/	47	21	/	46	40	/	72	53	/	85	86	/	118
Transport	0	/	0	0	/	0	0	/	0	0	/	0	0	/	0	0	/	0
Energy Purchases in bn €'13 *(average annual 2021-30 and 2031-2050)*	1,448	/	1,483	1,415	/	1,408	1,388	/	1,386	1,363	/	1,352	1,360	/	1,349	1,329	/	1,312
Change to EUCO27 in billion €'13							-28	/	-22	-52	/	-56	-55	/	-59	-86	/	-96
Industry	272	/	284	271	/	303	269	/	300	267	/	297	264	/	295	261	/	286
Residential	417	/	434	410	/	402	397	/	393	386	/	378	380	/	370	365	/	352
Tertiary	249	/	265	243	/	243	235	/	236	226	/	224	222	/	219	213	/	209
Transport	510	/	539	491	/	477	486	/	472	484	/	470	494	/	481	489	/	477

Source: PRIMES

92 The capital costs reported for transport relate to energy services.

4.6 Comparison with 2014 energy efficiency analysis

When comparing the Commission's 2014 analysis[93] of different levels of the energy efficiency target for 2030 (27%, 28%, 29%, 30%, 35% and 40% targets were analysed in 2014) and the analysis in this Impact Assessment, it has to be noted that several scenario assumptions have changed considerably.

The REF2016 has, notably:

- lower projections of international fossil fuel prices;
- slightly lower economic growth assumptions;
- updated technology cost curves (e.g. RES technologies such as PV are substantially less costly reflecting the changes observed in the last years) and
- more already adopted policies (notably in the field of energy efficiency but also for GHG emissions reduction such as the now adopted F-gas Regulation).

Consequently the REF2016 achieves 24% EE compared to 2007 baseline whereas it was only 21% in Reference scenario 2013). Furthermore, the period 2021-30, the REF2016 has slightly lower system costs but higher investment expenditure than the Reference scenario 2013.

The construction of policy scenarios has slightly changed as well. In 2014, the policy scenarios had exactly the same policy mix that was, as a general rule, intensified step-wise as scenarios became more ambitious (mostly through the increase of the energy efficiency values). While CO2 standards for LDV were intensified step-wise, other transport policies were, however, not. Some energy efficiency policies on the supply side were included and all scenarios included policies targeting non-CO2 emissions.

In the current analysis as well, as a general rule, the same policy mix is intensified step-wise as scenarios become more ambitious (mostly through the increase of the energy efficiency values). Transport policies are, however, also intensified progressively. Some additional transport and industrial policies are added only in more ambitious (EUCO+) energy efficiency scenarios. Standards for products are intensified mostly between EUCO27 and EUCO30 scenario, which demonstrate the cost-efficiency of energy efficiency standards based on internal market principles. A new policy featured in the policy mix is assumed for the promotion of electric heat pumps.

Looking at investments costs, the analysis shows that, in the period 2021-2030, the REF2016 has higher investment expenditure than the Reference scenario 2013 mostly because of investments in tertiary and residential sectors reflecting the most recently adopted national energy efficiency policies. On the other hand, generation and grid investments are somewhat lower reflecting notably lower costs of RES technologies and lower demand. Looking at policy scenarios, the additional investments mostly happen in tertiary and residential sector both in 2014 and current analysis. Very similar increases in investment expenditure can be observed comparing scenarios with 27% and 30% target and also comparing more ambitious scenarios to the one with 27% target. In 2014 analysis, the more ambitious scenarios had a somewhat more pronounced increase in investment as they incentivised more costly options in industry and tertiary sectors due to slightly different policy mix.

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[93] SWD (2014)255.

Comparing system costs of scenarios with 30, 35 and 40% targets to scenario with 27% target, the overall picture is also similar to the 2014 analysis, although differences among scenarios are less pronounced than in 2014 analysis. As in 2014, increasingly higher targets mean increasingly higher investments, which are only partially recuperated through energy savings in 2030, and hence translate in higher system costs. Both analyses point to the same finding that as the targets become more ambitious, system costs in 2030 grow more than proportionally. However in this Impact Assessment, for the 30% target such higher system costs in 2021-2030 are more than balanced by lower system costs after 2030.

Next to other reasons mentioned above, the changed approach to bring cost accounting discount factors on the demand side more in line with supply side discount rates (WACC) result in a less pronounced increases in system costs.

4.7 Sensitivities

In this modelling exercise only one sensitivity has been performed combining the 30% energy efficiency target with 30% renewables looking at the impacts of combining two ambitious policy options. This sensitivity is described below.

Additional sensitivities could have been performed, notably on GDP growth, technological progress and fossil fuel prices developments. In the past modelling exercises, it has been observed that reasonable changes in assumptions (i.e. faster/slower economic growth, faster/slower technology learning, higher/lower fossil fuel prices), do not change key results of the analysis.

For example, reduction in energy imports will always be higher in EUCO 30 than in EUCO27 although with higher fossil fuel prices assumptions, the monetised impacts would be more pronounced. Likewise, investments in EUCO30 need to be higher than in EUCO27 although with faster technology progress, the investment expenditure difference might be less pronounced.

Looking at economic growth assumptions, it is clear that with faster economic growth, more effort would be needed to achieve desired targets but there will be always a step-wise increase going for more ambitious targets. Importantly, stronger economic growth has impact on energy demand but ETS acts as counterbalance on the amount of emissions. It should also be taken into account that increased economic growth will lead to a more rapid rate of replacement of products and a higher level of investment in new construction and building renovation, leading to more rapid "natural" diffusion of energy efficient products and buildings.

As already explained, EUCO scenarios assessed in this Impact Assessment achieve RES shares of 27% in 2030 by assumption and EUCO+ scenarios overshoot this target slightly (achieving 28%) . However, to test the implications of a combination of more ambitious energy efficiency and renewable energy policies, a sensitivity was modelled where both the energy efficiency and renewable energy targets reach 30%. This reflects the call from the European Parliament. The corresponding impacts of such a sensitivity on the energy system was assessed as described below:

EUCO3030

Compared to 2005 levels, GHG emission decrease by -43% overall; in the ETS sector by -48% and non-ETS by -31%. The reason for such a breakdown is due to the fact that this scenario achieves mostly additional GHG reductions in the power generation sector, where additional capacity would be installed. The increase in RES-E share is quite significant: 54% by 2030, a 5pp increase compared to EUCO30.

Mostly driven by the shift to RES in the power sector, additional reduction in primary energy consumption is achieved of 0.8 pp (-30.8% instead of -30% in EUCO30), while final energy consumption remains constant, due to similar energy efficiency policies as in EUCO30.

Due to the higher rate of RES deployment, import dependency is reduced compared with EUCO30, with the import dependency ratio 1.5 pp below than in EUCO30. The carbon intensity of power generation (t of CO_2/MWh) is also reduced by almost 15% compared with EUCO30, mostly due to the decrease of gas use.

Energy system costs only marginally increase compared to EUCO30 over the 2021-2030 period, with 0.23% increase, i.e. 5bn € increase in average annual costs. However, EUCO3030 becomes as cost-efficient as EUCO30 (0.12% difference) when looking at the 2021-2050 perspective. It is also to be noted that EUCO3030 remains less costly (both in short and long term perspective) than any scenario assuming more than 30% energy efficiency target.

As expected, investment increase in 2030 for power generation compared to EUCO30. Electricity prices increase by 2.5% in 2030 compared with EUCO30, but are the same as in EUCO27.

Table 17: Sensitivity on 30% RES and 30% in 2030

2030 results	REF	EUCO27	EUCO3 0	EUCO3030	EUCO33	EUCO35	EUCO40
Change in primary energy consumption in 2030 compared to PRIMES 2007 Baseline (1887 Mtoe in 2030) (% change)	-23,9	-27,4	-30,0	-30.8	-33.2	-35.3	-40.1
Final Energy Consumption in Mtoe	1.081	1.031	987	986	929	893	825
GHG reductions wrt 1990 (%)	-35,2	-40,7	-40,8	-43.2	-43.0	-43.9	-47.2
GHG emissions in ETS sectors wrt 2005 (%)	-37.7	-43.1	-43.1	-48.1	-44.3	-44.2	-48.3
GHG emissions in non-ETS sectors wrt 2005 (%)	-23.7	-30.2	-30.3	-30.7	-33.7	-35.5	-38.7
RES share in final energy consumption (%)	24.3	27.0	27.1	30.2	28.1	27.9	28.4
RES-H&C	25	27	26	29.9	28.6	28.5	28.3
RES-E	42	47	49	54.2	48.9	48.4	51.1
RES-T	14	18	19	20.7	19.2	20.0	22.4
Security of supply							
Import dependency (%)	57	54	53	52	53	52	52
Environmental impacts							
Carbon intensity of power generation (t of CO2/MWh)	0.2	0.18	0.18	0.16	0.18	0.19	0.18
Electricity and ETS impacts							
Net Installed Power Capacity - Thermal power in GWe	379	369	359	357	354	352	347
Average Price of Electricity (€/MWh)	158	161	157	161	158	157	159
ETS carbon price (€/t of CO2-eq)	34	42	27	27	27	20	14
Investments, energy purchasing costs and system cost impacts							
Total energy related investment expenditures in bn €'13 (average annual 2021-30)	938	1,036	1,115	1,128	1,232	1,324	1,565
Investment in power plants (average annual 2021-30) (bn € '13)	33	42	42	52	40	37	36
Investment in power plants (average annual 2031-50) (bn € '13)	38	58	57	59	60	60	279
Energy purchase (average annual 2021-30) (bn € '13)	1,448	1,415	1,388	1,391	1,363	1,360	1,329
Energy purchase (average annual 2031-50) (bn € '13)	1,483	1,408	1,386	1,409	1,352	1,349	1,312
Total System Costs (average annual 2021-30) (bn € '13)	1,928	1,943	1,952	1,956	1,977	2,014	2,077
Total System Costs (average annual 2031-50) (bn € '13)	2,130	2,264	2,255	2,257	2,290	2,324	2,384

Source: PRIMES

4.8 Description of modelling set-up for the policy scenarios for macroeconomic models

Macroeconomic and sectoral economic impacts are assessed using two macroeconomic models: E3ME of Cambridge Econometrics and GEM-E3 of E3M-Lab at the National Technical University of Athens. Similar to previous relevant Impact Assessments[94], the choice in this Impact Assessment has been to use two macroeconomic models that represent two main different schools of economic thought that have been frequently used in the macroeconomic assessment of energy and climate policies. This helps to effectively manage analytical uncertainties and reflect a more robust way of assessing the corresponding impacts. The application of two different macro-models enables not only to establish a range of possible impacts, but also to identify the conditions necessary for realising potential benefits.

Differences between the two models arise from their underlying assumptions and respective structures. E3ME is a macro-econometric model, based on a post-Keynesian demand-driven non-optimisation framework; GEM-E3 is a global computable general equilibrium model that draws strongly on supply-driven neoclassical economic theory and optimising behaviour of economic agents. However, the two macroeconomic models have many similarities, such as the inclusion of substantial sectoral detail, the assessment of complex interactions between the different sectors of an economy, markets and agents, as well as the simulation of inter-linkages between world economic and energy systems and the environment.

In this Impact Assessment, the approaches have been enhanced compared to previous analytical work. Notably, GEM-E3 has been enhanced with an explicit representation of the financial sector for each country and at the global level, allowing economic agents to borrow from banks in order to finance their required energy efficiency investment expenditures. E3ME, on the other hand, has further analysed the role of "crowding out" and capacity constraints in affecting investments in other productive sectors of the economy. This is all the more relevant in the case of more ambitious energy efficiency investment efforts, as investment expenditures represent an increasing share of overall GDP. Both models also allow for the modelling of unemployed labour resources. Thus, both models have been improved compared to the versions used in the energy efficiency Impact Assessment 2014, such that they permit an even more realistic representation of macroeconomic mechanisms that may be triggered by increasing the ambition of EU energy efficiency policies.

On the macro-side, E3ME and GEM-E3 have been aligned as best as possible in their assumptions, both taking as inputs the energy-specific policy scenario results from PRIMES. In addition, assumptions on the financing of energy efficiency investments in the two models have been better harmonised, such that:

a. Both models respect the fiscal neutrality assumption in their scenario setups. This means that energy efficiency policy interventions do not have any direct (first-order) impacts on public budgets. The method used to achieve this is that the scenarios are built such that costs to the public sector of initial energy efficiency investments are compensated by additional revenues from auctioned ETS allowances, as well as taxes if necessary.

[94] SWD(2014)255 final.

b. When changes in taxation are required (in order to achieve fiscal neutrality), both models target changes in general indirect taxation on products that affect both firms and households[95].

c. Both models make sure that energy efficiency investments in the private sector are privately financed, i.e. firms and households pay for improving energy efficiency. In the case of government sectors, investments are financed through EU ETS revenues and higher taxes on products if needed[96].

d. Both models can assume loan-based financing: businesses and households can borrow from the banking system and contract loans to cover their energy efficiency expenditures. GEM-E3 provides for an explicit representation of the banking system and can assume that private agents use a mix of own funds and loans to finance their expenditures. E3ME has only an implicit assumption on financing sources, and assumes that businesses borrow to make the investments[97], whereas households are assumed to self-finance (by reducing other expenditures).

Two versions of each macro-model have been run in order to provide a comprehensive picture of potential macro-benefits and constraints. In the case of E3ME, these refer to *"no crowding out"* and to *"partial crowding out"*, and in the case of GEM-E3, the two versions refer to *"loan-based"* finance and *"self-financing"*. The details of these model setups have been briefly described in the main text of this Impact Assessment.

The scenario inputs are taken from the PRIMES policy scenario results, such as energy savings and energy efficiency investments associated with each energy efficiency policy option. In other words, the macro-economic scenarios that have been modelled and built upon the PRIMES energy modelling scenarios of 27, 30, 33, 35 and 40% energy efficiency targets, presented in detail in chapter 4.4 of the Impact Assessment. The path and magnitude of investment in energy efficiency in each scenario is taken from projections made in PRIMES. In addition, other important drivers that are taken from projections made in PRIMES and used as inputs into E3ME and GEM-E3 include energy prices or overall energy balances. The E3ME and GEM-E3 models are then calibrated to represent these changes in the energy system so that their economy-wide impacts can be modelled.

Importantly, this Impact Assessment further improves the comparability of the macroeconomic results by better aligning the assumptions on fiscal neutrality and the financing of energy efficiency investments underpinning the two macro-modelling approaches.

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[95] GEM-E3 targets a general tax on products and E3ME targets the value added tax.

[96] Private financing for firms means that there is an increase in costs that may be passed onto prices (or taken out of profits) depending on cost pass through ratios specific to each model.

[97] E3ME being post Keynesian draws on the endogenous money theory (money is created by commercial banks through the advancement of new loans that do not necessarily need to be backed by additional deposits because of leverage effects), and does not assume any competition for loans as is typically assumed in CGE models.

4.8.1 Modelling set-up for the E3ME model

4.8.1.1 Calibrating the E3ME model to the EU Reference scenario 2016

The term calibration is used differently for E3ME as for a CGE model. Calibration allows the model to match a given projected pathway. It does not determine the model parameters, which are econometrically estimated. The E3ME macroeconomic model was first calibrated to match the energy system projections associated with the EU Reference Scenario 2016 (REF2016) derived from PRIMES. E3ME takes the following indicators from the REF16 projections directly:

- GDP, consumer expenditure and sectoral economic output
- Energy and ETS prices
- Projections of energy demand by sector and by fuel
- Total CO_2 emissions

E3ME's energy sub-model (FTT-Power) which looks in detail at the power generation sectors has been fixed so that its outputs are fully consistent with the PRIMES results for the REF2016 scenario (given differences in model classifications, etc.). The main outputs from the FTT sub-model that have been calibrated to match PRIMES are:

- Fuel inputs into thermal power plants
- Electricity capacity
- Investment by the electricity supply sector
- Electricity prices

E3ME is frequently calibrated to match published PRIMES / Reference Scenario projections and the software routines to do the matching are now well established and have been documented as well in previous Impact Assessments[98]. In short, the calibration procedure has two main stages.

- In the first stage, the REF2016 projections are stored on one of the E3ME databanks as annual time series. The model is solved with all the econometric equation sets forced to match the figures that are stored. The differences ('scaling factors') between what the model would have predicted on its own and the figures on the databank are calculated and saved. These are then written on to another databank.
- In the second stage, the model is solved with the equation sets allowed to predict the outcomes. However, the scaling factors are applied to these results, with the result that they reproduce the energy-related reference or the policy scenarios produced by PRIMES. It is now possible to change the model inputs and use the equations to obtain different model outcomes, while maintaining consistency with the reference.

[98] SWD(2014) 255 final "Energy Efficiency and its contribution to energy security and the 2030 Framework for climate and energy policy", Commission Staff Working Document Impact Assessment accompanying the document Communication from the Commission to the European Parliament and the Council, Part 2/3.

4.8.1.2 Implementing the energy efficiency policy scenarios in E3ME

This section focusing on the way PRIMES energy-related results for the energy efficiency policy options or scenarios were integrated as inputs to E3ME.

Power generation, electricity prices and CO_2 prices

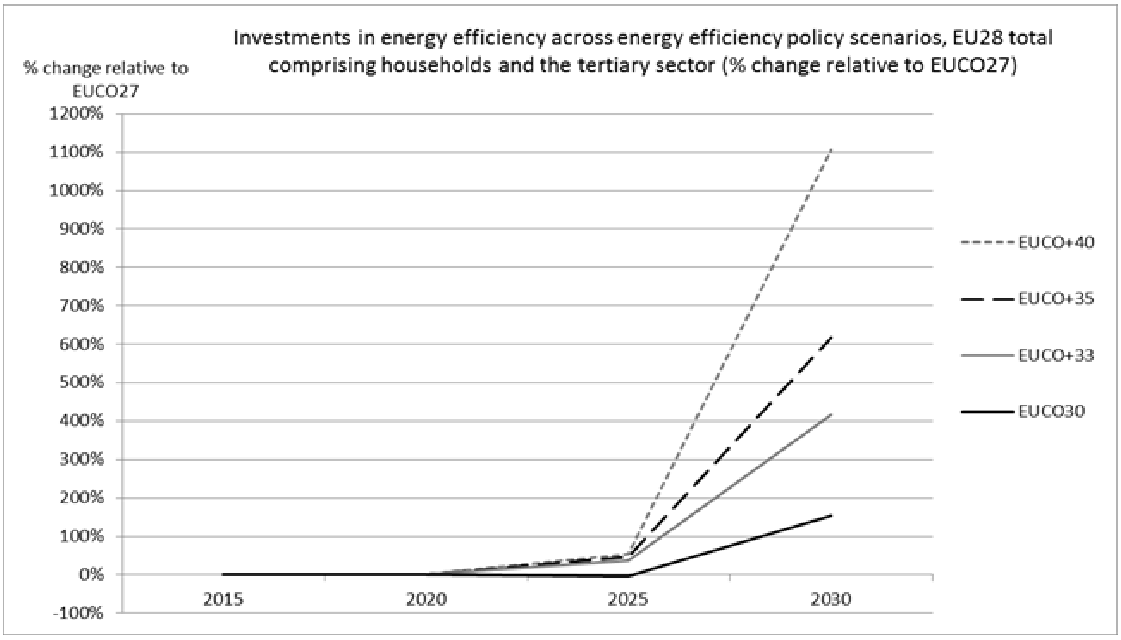
For the purpose of the macro-modelling assessment, the power generation sector is treated as exogenous in E3ME. In both the E3ME reference and energy efficiency policy scenarios the power generation results are set to match those from the PRIMES model, reflecting that model's more detailed representation of the sector.

An important input to the scenarios is the amount of investment required to bring about the changes in the power generation mix. Additional investment by the electricity supply sector used to bring about the change in power generation was added exogenously into E3ME. It is assumed to be financed by higher electricity prices, which are also taken from PRIMES. The EU ETS prices in each scenario that are used in E3ME are consistent with the prices used in the energy sector assessment with the PRIMES model.

Energy efficiency and investment

In E3ME, the energy-efficiency savings were entered exogenously in the model and were set to match the PRIMES results as closely as possible. Changes in energy efficiency investment (relative to the EU Reference scenario) resulting from PRIMES are added in E3ME's policy scenarios. The figure below charts the level of energy efficiency investments across the energy efficiency policy options compared to the EuCo27. The change in final energy demand from PRIMES was used as a guide for the level of energy efficiency savings. These savings were then distributed among sectors and energy carriers, using as a guide the level of investment made by each sector and the shares between energy carriers in proportion to energy consumption.

Figure 27: EU28 investments in energy efficiency across energy efficiency policy options relative to EuCo27 used as inputs into the E3ME macro-model, 2020-2030



Source: PRIMES results, E3M-Lab, National Technical University of Athens

Financing energy efficiency investments

The energy efficiency investments required to achieve the corresponding level of energy efficiency targets are assumed to be financed out-of-pocket, i.e. mostly from private financing. Households pay for the energy efficiency investment out-of-pocket. Consumer expenditure on energy efficiency goods increases, but spending on other consumer goods may be reduced by an equivalent amount (depending on other savings made from lower energy use). Firms pay for energy efficiency investment out-of-pocket. This is modelled as an increase in costs, some of which may be passed on to prices. Government sectors finance the energy efficiency investment from EU ETS revenues and increased VAT if needed.

Revenue recycling

The general approach is that the scenarios are directly revenue neutral with regard to costs to the public sector of energy efficiency investment and changes to the revenues from auctioned ETS allowances. VAT is adjusted as well when needed in order to ensure that the scenarios are directly revenue neutral. In other words, government sectors finance their energy efficiency investments from EU ETS revenues and increased VAT if needed. However, the scenarios are not fully budget-neutral (e.g. no corrections to changes in income tax receipts are made to ensure this) and the model allows for second-order effects of energy efficiency policy intervention on the overall public budget (e.g. via changes in the tax base resulting from changes in economic activity or reduced public expenditure on energy).

Crowding out

When discussing crowding out, it is important to make the distinction between supply constraints in different markets. The standard treatment in E3ME is labelled "no crowding out" and refers to not imposing a constraint on the maximum level of production due to potential capacity constraints in the products markets, as described below:

- Product markets: There is no maximum level of production but there are increases in prices as production levels increase (determined by estimated relationships) – hence there is partial crowding out. In other words, it is assumed for instance that the construction industry is able to increase its output as a result of EU policies targeting energy efficiency.
- Labour markets: The maximum employment level is determined by the size of the working age population. As employment increases and unemployment decreases, wages will increase causing employment reductions elsewhere. There is therefore partial crowding out, and full crowding out in situations of full employment.
- Financial markets: There is not a fixed amount of finance in the economy and so new loans can be issued without substituting from other sectors. There is therefore no financial crowding out in the model as standard.

Finally, further analysis was performed in E3ME by assuming that a certain share of partial crowding out occurs in the product markets. In this case ("partial crowding out"), a constraint on activity expansion has been inserted in the model by introducing a rule that would set a maximum amount that the sectors benefiting from energy efficiency policies would be allowed to increase without adversely affecting other economic activities. This rule is 5% over three years starting from 2021. For example, if in the year 2025, output is projected to increase in the construction sector by x% in EUCO27 relative to the Reference case, then in the next year (2026), the output of the respective sector is allowed to increase by a maximum of x% + (5/3)% without crowding out effects. In other words, the modelling of constrained expansion aims to implicitly mimic the effects of partial crowding out. The choice of 5% over three years starting in 2021 (translating in a 15% limit on additional / energy efficiency policy induced output growth by 2030) is arbitrary but suggests that first, firms keep enough spare capacity to cover 2-3 years of growth, and, second, that market players become aware of the increased investments in energy efficiency and try to adapt (the 3-year period allowing for the incorporation of changing expectations). Beyond that, physical and financial capital bottlenecks appear, constraining the potential for additional growth. Macro-results for GDP and total employment are presented in the main text of this Impact Assessment for both versions "no crowding out" and "partial crowding out" of E3ME.

4.8.1.3 Key model mechanisms driving the results

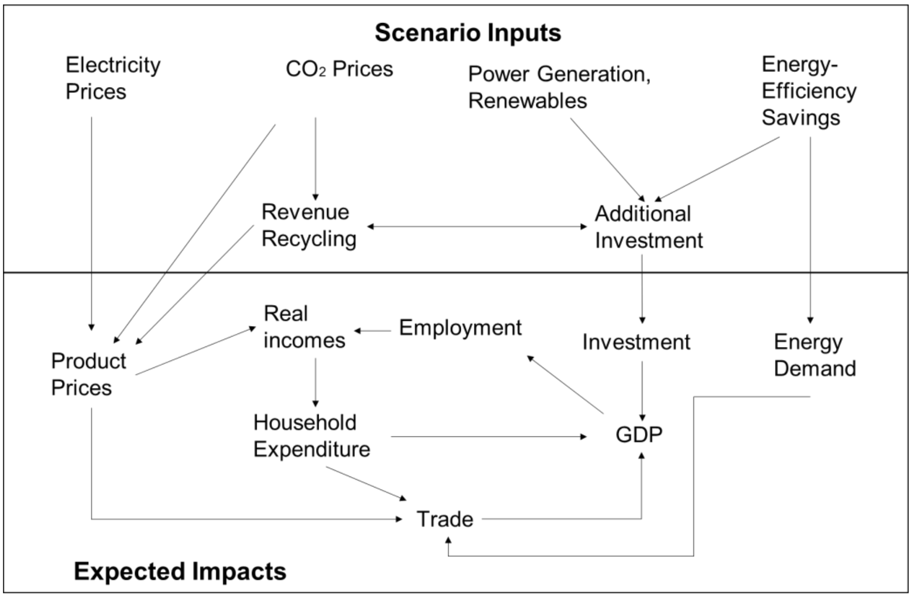
Figure 28 summarises how the policy scenario inputs from PRIMES (the top half of the diagram) affect key macroeconomic indicators in the model (the lower half). Although it is not possible to capture all the interactions in a single diagram, the most important ones are included.

<u>GDP and other macro-impacts</u>

The main ways in which GDP and other macro-aspects are affected are:

- Changes in electricity prices and CO_2 prices, which feed through to the prices of final products, depending on the rate of cost pass-through in the sectors involved (which is estimated empirically). Higher product prices would both reduce the purchasing power of domestic households (leading to lower real incomes and expenditure) and would adversely affect the competitiveness of European firms (leading to a worsening trade balance). In both cases the result will be a reduction in GDP.
- The revenue recycling, through changes to VAT rates, will also affect household income and expenditure. In the scenarios with high levels of public sector energy efficiency, VAT rates must increase to fund the measures. Reduced household income will lead to lower rates of spending and lower GDP.
- High rates of household energy efficiency will lead to a substitution effect of consumption towards energy efficiency equipment. This will not alter total consumption but the composition of consumption will be weighted more towards products that boost energy efficiency.
- Higher rates of investment will provide a boost to output in the construction and engineering sectors and their associated supply chains. Investment itself is a component of GDP and so the changes in investment have a direct impact.
- For most European countries, a reduction in energy demand will lead to reduced imports of fossil fuels, as long as Europe remains dependent on imported fuels. Resources that would have been spent on imported fuels may instead be spent on domestically-produced goods (households) or returned in the form of higher profits (businesses), in both cases providing a boost to GDP.

Figure 28: Main interactions between energy efficiency scenario inputs and expected macro-impacts in E3ME



Source: E3ME, Cambridge Econometrics

The net impact on GDP is the sum of these separate impacts. The impacts on employment are determined by a combination of the GDP impact and the sectoral pattern of output. As the scenarios modelled in this IA are based on a shift from energy to labour-intensive activities it is reasonable to expect employment to increase. As described below, this outcome is conditional on labour being available and wage rates not increasing to any significant extent.

Employment and multiplier effects

As noted above, E3ME does not assume an optimal starting point so it is possible for output to increase unless there are capacity constraints (see below). In addition, multiplier effects are a standard feature of the modelling results.

Type I multiplier effects occur through the supply chains that are represented in the model's input-output structure. In these scenarios, it is mainly the basic manufacturing sectors (e.g. metals, cement) that supply the sectors that produce and install energy efficiency investment goods. These supply chains may cross borders, with activity levels in one country allowed to influence those in its trading partners.

Type II multiplier effects relate to the loop from GDP to employment, real incomes and household expenditure. Essentially, higher employment levels and incomes are able to stimulate spending in other parts of the economy (e.g. in the retail sector), leading to further output and job creation. A positive feedback from this loop depends on there being available workers to meet an increase in the demand for labour; otherwise the result will instead be higher wages and inflation.

Capacity constraints

The issue of capacity constraints relates strongly to crowding out, as described above. Economists engage in efforts to estimate the 'output gap' and economic capacity at national level but there is no agreed definition and very few estimates at sectoral level. Over time, new investment can add to capacity. E3ME's equation structure allows prices to increase as output moves beyond a ‘normal’ or expected level, but does not attempt to estimate or impose an absolute level of capacity for industry production. This approach is in contrast to the CGE modelling approach, where the economy as a whole is typically assumed to be effectively operating at full capacity to begin with.

The exception to this in E3ME is the labour market, where there is a clear constraint imposed by the available labour force. As the economy moves towards full employment, further increases in labour demand translate into higher wage rates, leading to a crowding out of labour (increases in one sector drive up wage rates and reduce employment elsewhere). Nevertheless, this representation is still not complete; as with other modelling approaches, there is an implicit assumption that the workforce has the necessary skills to fill the available vacancies.

Overall, it is up to the model user to determine whether the scenarios that are being modelled breach constraints that are likely to exist in reality but are not recognised formally in the modelling framework. For marginal changes it is reasonable to assume that it would be possible to adjust production patterns to meet the additional demands placed on the economy. For the more ambitious energy efficiency scenarios, however, there is a much higher degree of uncertainty around the E3ME model results. For this reason, E3ME has also been run by assuming a gradual or partial crowding out of investments as the scenarios become more ambitious (as described above).

4.8.2 Modelling set-up of the GEM-E3 model

4.8.2.1 Dynamic calibration

GEM-E3 uses reduced-form consumption and production functions to find the mix of products in various sectors, whereas the PRIMES model uses complex formulations which represent engineering details together with economic behaviours. For this reason, it was decided that for the macroeconomic impact assessment, the energy projections of PRIMES will have to be replicated as much as possible by GEM-E3.

This is a complex task from a modelling perspective, called dynamic calibration. It was implemented mainly by modifying the values of parameters of production and consumption functions specifically for the Energy Efficiency policy scenarios or options and for the EU Reference scenario 2016 (REF2016). However, the replication cannot be exact, as the simultaneity of GEM-E3 involves complex relationships between the variables.

To facilitate dynamic calibration to PRIMES energy scenarios, the structure and nomenclature of GEM-E3 has been extended so as to be as close as possible to the classifications by sector followed by the energy model. For example, the GEM-E3 model version used in this assessment, includes modelling of power generation by technology in addition to the modelling of consumption of fuels in generation, split of transport activity in sub-sectors, inclusion of appropriate categories of durable goods in households’ consumption function with distinct representation of equipment categories depending on efficiency and technology, representation of biofuel production in agriculture, and energy efficiency cost-potential curves by sector. The latter are nonlinear functions with positive slope relating cumulative expenditure for energy efficiency and the achieved rate of energy savings. Finally, GEM-E3 includes learning-by-doing (and RTD) functions specifically for key energy technologies, to capture policy-driven technology progress in an endogenous manner.

First, GEM-E3 is first calibrated to the energy system projections provided by PRIMES for the Reference scenario case. In other words, the GDP, employment and other macro-economic projections provided by GEM-E3 reference scenario are fully consistent with those that served as input for REF2016 (i.e. based on DG ECFIN's Ageing Report 2015). In addition, GEM-E3 produced for REF2016 a projection until 2050 of activity split in 28 sectors of 46 countries or regions (28 of which are the EU Member States) covering the entire global economy. The energy related projections for the EU countries are calibrated to replicate REF2016 projections performed using PRIMES. For the non-EU countries the energy related projections are calibrated to Prometheus global energy model scenario built in the context of REF2016 to project fossil fuel prices at global level.

The next steps involve dynamically calibrating the GEM-E3 model to the energy projections provided for each of the Energy Efficiency policy scenarios (also based on the PRIMES model). The energy and emissions projections for the non-EU countries use the same assumptions in the Energy Efficiency policy scenarios as in REF16.

4.8.2.2 Implementing the energy efficiency policy scenarios in GEM-E3

Five energy efficiency policy options or scenarios are used in this analysis, namely EUCO27, EUCO30, EUCO+ 33, EUCO+ 35 and EUCO+ 40. They differ particularly in the definition of the energy efficiency target for 2030. EuCo27 aims at achieving 27% energy consumption reduction in 2030, EUCO30 aims at 30%, and so forth, with the most ambitious being EUCO+40 that aims at 40%. All the corresponding energy efficiency targets are defined as percentage change of total primary energy requirements of the EU relative to a projection performed in 2007 using the PRIMES model.

Achieving the targets within the energy efficiency policy scenarios mainly calls upon significantly higher investment in all sectors compared to energy related investment in the context of the Reference scenario. Households have to spent higher amounts as upfront costs to renovate houses, to purchase more efficient equipment and electric cars. Conversely, they will spend much less in fuel and electricity purchasing, due to higher energy efficiency, once the investment is implemented. From a macroeconomic perspective nonetheless the increase of upfront costs puts pressure on households’ budgets, depending on availability of external financing. Similarly, firms will have to spent higher amounts as upfront costs and lower amounts as running costs for getting the energy services. Financing the upfront costs may exert a crowding out effect, to the detriment of productive investment, at a degree which again depends on external financing and the availability of borrowing. Financing is also an issue in public finance and for utilities as they are also requested to spent higher amounts than in REF2016 for building infrastructure, such as grids, smart systems, battery recharging networks and others.

Energy efficiency improvement in industrial and services sectors, and in houses is modelled using the energy efficiency cost-potential curves, which are defined by sector. The dynamic calibration consists in varying cumulative expenditures in energy efficiency by sector until the energy saving performance is close to the figures projected using PRIMES for each energy efficiency policy scenario. The change of cumulative energy efficiency expenditures per year represents investment. To implement these investments, goods and services are needed. In GEM-E3, it is assumed that there are fixed proportions of the kinds of goods and services used to deliver energy efficiency improvement by sector. Such goods are construction, materials (ferrous and non-ferrous metals, chemical products, non-metallic minerals), and equipment, whereas the services required are mainly market services. For firms, expenditures in energy saving improve their energy intensity and do not add to their capital stock (as opposed to productive investments). Households' expenditures in energy efficiency improvements do not impact directly on their utility but indirectly through the income effect from the reduced energy costs. Households undertake the largest share of energy efficiency expenditures from all non – ETS sectors (near 70% of total expenditure).

Implementing the infrastructure, manufacturing the equipment and renovating the houses and buildings require increased domestic production of goods and services, as well as higher use of capital and labour, than in REF2016. Essentially, the low emission pathway is a continuous process of substitution of imported fossil fuels by domestically produced goods and services. The increased domestic activity acts positively on the economy through an activity multiplier effect, but also exerts pressures on markets for primary production factors, such as capital and labour. The prices of capital and labour will tend to increase due to higher demand. The magnitude of the increase depends on supply, namely financing supply concerning rates of return on capital and labour force supply concerning wage rates.

Overall, the transition to a low carbon economy is essentially a restructuring process which from a macroeconomic perspective depends on financing. For this purpose, the GEM-E3 model has been enhanced to include a detailed financial sector, learning-by-doing and research and technological development (RTD) mechanisms and a high resolution nomenclature to capture the energy-related details.

The GEM-E3 model is a global model. In this assessment, it is assumed that while the EU pursues the strong emission reduction policy, the rest of the world implement only the Cancun-Copenhagen pledges, as they also do in REF2016. The evaluation of macroeconomic consequences has a horizon until 2050.

The Emission Trading Sector is explicitly represented in GEM-E3. The auctions clear by adjusting ETS carbon prices which apply to sectors belonging to ETS. The model takes into account whether the allowances are distributed free or have to be purchased in auctions. The auction clearing prices are calculated in the model depending on the amount of allowances. The assumed shares of ETS revenues for auctioning in the period 2020 to 2050 are 100% in power generation, 70% in industry & energy branch and 30% in air transport. These are not assumed to change across scenarios analysed.

The auction revenues of the states are re-injected into the economy after accounting for the energy efficiency investment expenditures made from the public purse. In all Energy Efficiency policy scenarios, it is assumed that the revenues of the ETS carbon auctions are used to finance energy efficiency investments undertaken by the public sector, with the difference being recycled back to the economy through changes in general indirect taxes (decreases in indirect taxation if ETS revenues collected are greater that the energy efficiency investment expenditures spent by the public sector or vice-versa).

Furthermore, and most importantly, the GEM-E3 scenario setup and model features have been enhanced with new features that account for the explicit representation of financial flows. This is because the transition to a decarbonized and energy efficient system is a capital intensive process. Financing availability and their impact on interest rates are thus critical for the assessment of macroeconomic implications. The remainder of this section describes how financing assumptions have been dealt with in GEM-E3.

For the implementation of five energy efficiency policy scenarios or options, two alternative financing schemes have been considered for funding the required energy efficiency and equipment purchasing expenditures at amounts above Reference scenario (as described below). For investment in grids and energy supply including power generation no particular financing scheme has been assumed, as in these sectors tariffs increase in an endogenous manner to recover capital and other costs. However, the capital needs in these sectors, which are higher than in the Reference, add to the overall capital financing requirements of the economy. The same applies to all transport sectors providing transport services and to the industry as a whole. Of course, not all industrial sectors see increasing capital requirements for production purposes in the energy efficiency policy scenarios. Nonetheless, what is most relevant for this Impact Assessment is the additional investments in energy efficiency when comparing more ambitious energy efficiency policy efforts to EUCO27.

For energy efficiency investment expenditures, the following two finance variants have been considered.

- Self-financing variant: all expenditures are self-financed by the sectors undertaking investment; and
- Loan-based finance variant: agents use a mix of own funds and loans to finance the expenditures.

In the first self-financing variant, economic agents use their revenues to finance energy efficiency expenditures, such that:

- Households[99]: Household reduce consumption of other products to collect the funds required to finance their own energy efficiency expenditures.
- Firms (Non-ETS): Firms increase their selling price to finance their energy efficiency expenditures.
- Non-Market Services: The sector is subsidized for its energy efficiency expenditure by the government. The public retains its surplus/deficit neutrality by raising indirect taxes.

The self-financing variant corresponds to immediate financial closure and thus implies that the model will show the full crowding out effect.

In the second, loan-based finance variant, all agents receive a loan from the banking sector to finance their energy saving expenditures. To design the financial aspects of the scenarios, it is also important to define a financial sustainability rule for the loans which have to be repaid beyond the modelling horizon, i.e. 2050. For this purpose, it was assumed that the indebtedness of the sectors by 2050 as a share of their revenues should not exceed a certain threshold, which is calculated using the REF2016 projection. To calculate the threshold of the share of debt to GDP that remains after 2050 in the EUCO scenarios, the following variables are used: the reference GDP growth rate, the household income growth rate, the lending interest rate, and the accumulated debt level. To decide on the level of self-finance and the sustainability of debt is

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[99] Self-financing of the energy efficiency expenditures by households may not always be feasible as low income households may not have sufficient resources (i.e. subsistence minima expenditures may exhaust all their income). In the GEM-E3 model no income classes are identified but a representative household per member state is considered.

based on two rules: 1) Debt sustainability: Any debt is treated as sustainable that is increasing at a lower rate than the growth rate of the sectors' income; and 2) The second rule regards the equalization of the monetary unit net present value of interest payments across scenarios (the net present value of all interest payments paid, during the loan period, for each monetary unit taken as loan should be equal across scenarios). This means that each euro borrowed requires the same interest payments across scenarios, bearing also in mind that an increasing level of loans increases also the total amount of interest to be paid. This rule helps the model to determine in an endogenous manner the upper limit of the loan schedule. Also this financing rule ensures that the energy efficiency policy scenarios and the REF2016 are comparable to each other. The rules apply across the energy efficiency policy scenarios, implying that thresholds are adjusted by scenario as interest rates change. In particular, in the EUCO+40 scenario where the majority of the payments takes place up to 2030, there is a smaller than EUCO debt left to be repaid after 2050 (around 4%).

As such, by assumption, the loan starts in 2020, it covers 90% (the upper limit) of total expenditure in 2020, and its share decreases after 2020, reaching 70% of total expenditure in 2035; afterwards the percentage remains constant. The loan lasts for 10 years and repayment starts one period after it is issued. The loan involves equal payments over time, covering principal and interests, the latter being calculated at market clearing interest rates of the year of payment. The simulations found that the additional requirement for financing has a small upwards effect on the EU interest rates for all energy efficiency policy scenarios. It is assumed that all European countries share the same currency (or have fixed currency exchange rates) and that there is a single financial market in the EU with sufficient liquidity. Country-specific differences have been ignored in this exercise. The justification is that the analysis has a long-term orientation and that the currently observed financial disequilibria are of short term nature and will not persist in the future.

Loans that are received up to 2035 are fully paid back (incl. interest) by 2050. Loans received in 2045 are partly paid back whereas those in 2050 are assumed to create debt beyond 2050. Overall households and firms pass on to the next period a debt that amounts to 6% of their total income (this debt can be considered sustainable as yearly savings of the private sector surpasses yearly instalments of the loan). In addition, as the full economic benefits (in the form of energy savings) of the 2050 expenditures are not "*capitalized*" within the year the results on macroeconomic adjustment (GDP) do not fully reflect the impact of the policies. In both finance variants, indirect taxes readjust to render energy efficiency policy interventions public revenue neutral as compared to REF2016. Key macro-results (GDP and total employment) have been presented in the main text of the IA for both "loan-based" and "self-financing" variants

4.8.2.3 Key model mechanisms driving the results

The macroeconomic impacts of the energy efficiency policy scenarios are the net result of the following positive and negative impacts:

- Positive effects on domestic activity due to reduced imports of fossil fuels,
- Positive effects on domestic activity due to increased demand for goods and services which implement higher efficiency and lower emissions,
- Cost benefits due to high learning rates for certain technologies,
- Negative impacts (reduction of non-energy consumption and losses in industrial competitiveness) due to higher average electricity prices and generally due to higher levelized cost of energy services and transport,

- Negative impacts due to crowding out effects arising from pressures in capital markets,
- Negative costs due to higher wage rates driven by pressures in labour markets, where applicable.

Industrial competitiveness is not only related to relative prices but also it depends on the ability to produce higher quality products, as compared to its competitors. The low carbon transformation is an opportunity for the EU industry to produce higher quality equipment goods of various types, which in addition will be environmentally cleaner. However, international demand for such improved goods will depend on whether the rest of the world countries will also pursue strong emission reduction policies. By assumption, this is not the case in the present assessment, and therefore the industrial opportunities raised in the context of the energy efficiency policy scenarios are exploited only in the EU internal market without any further benefit from exporting equipment goods. As a consequence, the impact on industrial competitiveness of the EU on the degree at which firms can compensate the energy saving expenditures and the higher energy costs (carbon prices in ETS sectors) are driven by the cost savings due to energy efficiency improvement and the cost mitigation due to acceleration of technology learning.

In the energy efficiency policy scenarios the economy replaces imported fossil fuels (including parts of gas) with domestically produced goods and service, hence the first order effect on employment is expected to be positive[100]. However, the total effect on employment depends also on:

- The magnitude of the negative impacts on domestic activity due to losses in industrial competitiveness driven by higher costs of energy
- The magnitude of the increase in wage rates due to pressures on labour market driven by higher domestic demand for certain goods and services
- The magnitude of the negative impacts of the crowding out effects (due to capital market pressures and to reduction of non-energy consumption because of higher energy costs) on domestic activity.

The comparative statics analysis of general economic equilibrium suggests that any upwards deviation from optimal investment plan requires that either consumption is reduced (so as to increase savings) or that other investment projects cancel out. Both are crowding out effects.

Depending on the liquidity of the financial sector, it is possible to mitigate the crowding out effects by means of deferring the immediate impacts to next periods. Theoretically, unlimited liquidity may even cancel out crowding out effects. In the model, the degree of mitigation is closely related to the impact that the additional financing requirements have on interest rates. The broader the geographic area of financial closure (e.g. EU as a whole), the lower is the impact on interest rates. Instability effects, for example, via adjusting currency exchange rates, can be another cause of rising interest rates, but in the modelling we have ignored such effects.

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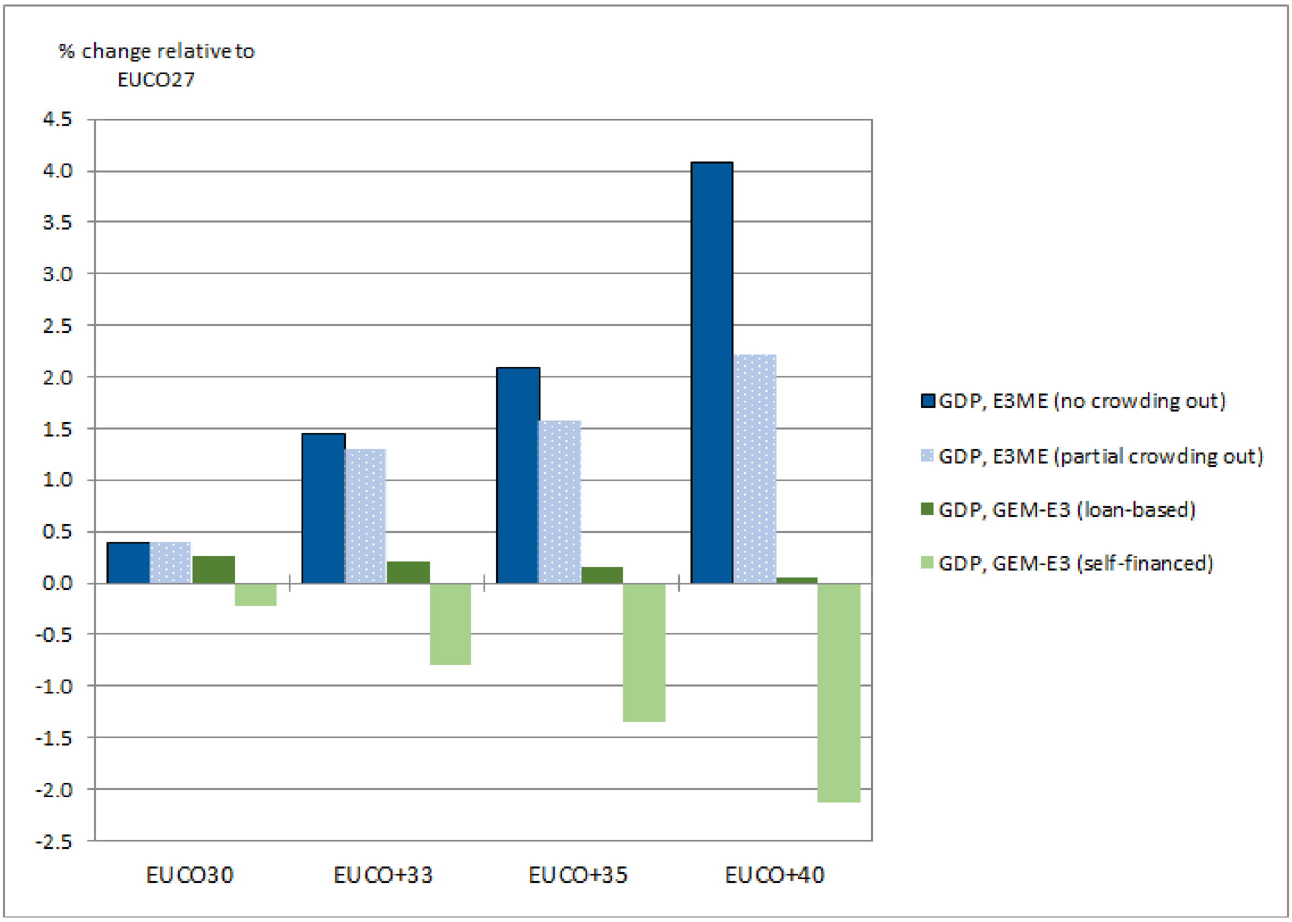
[100] As the model explicitly represents unemployment the demand for additional labour is covered by the pool of unemployed persons.

4.9 Additional macro-economic results

4.9.1 GDP impacts across time

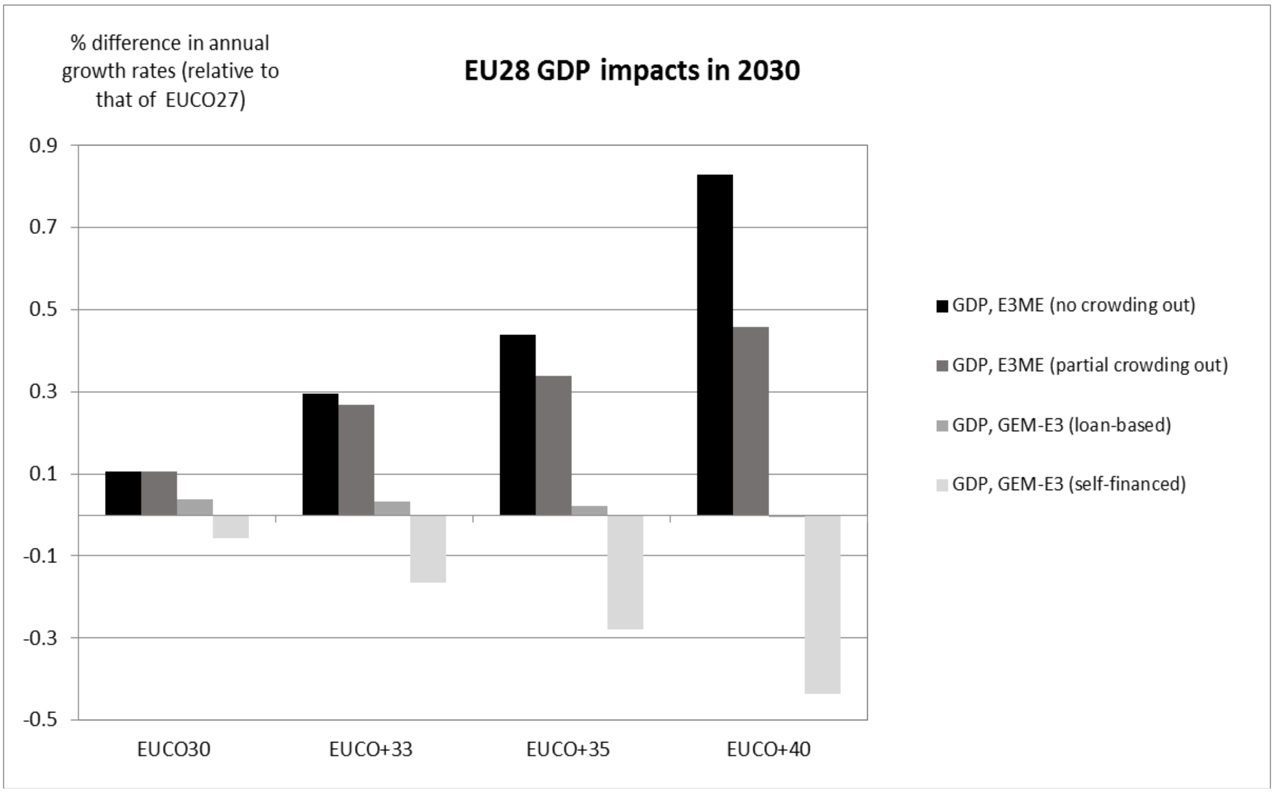
The two figures below show GDP impacts for the year 2030 across the two model versions for each of the two macro-models in terms of % change relative to EUCO27, and, respectively, in terms of % difference in annual growth rates relative to the projected GDP growth rate in the baseline policy EUCO27 scenario. They mirror the discussion on GDP impacts presented in the main body of this Impact Assessment and provide a clearer visualisation of the range of GDP impacts from increasing the ambition level of energy efficiency investments.

Figure 29: Range of GDP impacts in EU28 in 2030 depending on macro-model used and on financing and crowding out assumptions



Source: E3ME, Cambridge Econometrics and GEM-E3, National Technical University of Athens

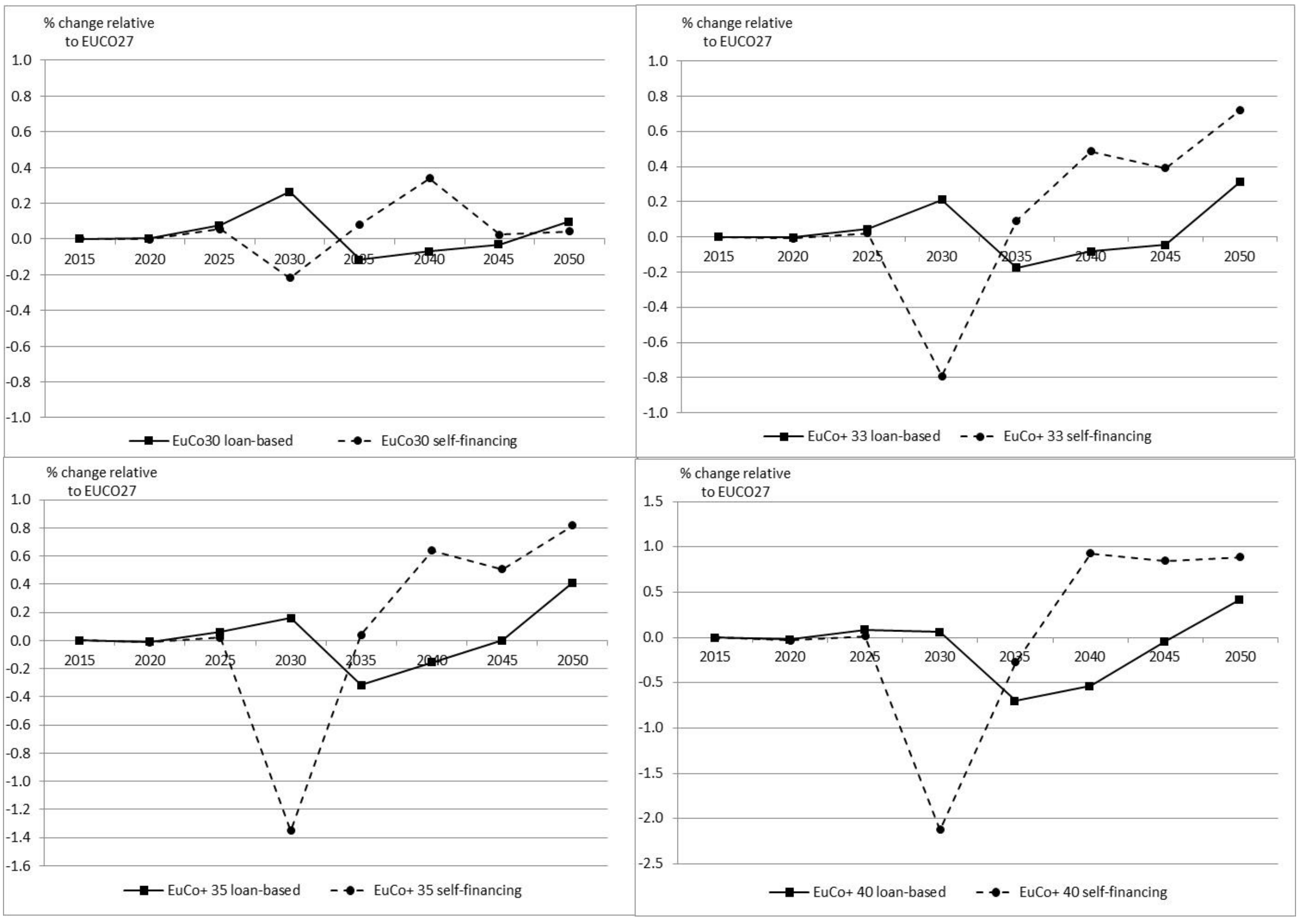
Figure 30: Range of GDP impacts in EU28 in 2030 when translating into differences in annual growth rates



Source: E3ME, Cambridge Econometrics and GEM-E3, National Technical University of Athens

The figure below shows the temporal GDP impacts for the two finance variants modelled in GEM-E3 ("loan based" and "self-financing") across the projected time period for the four energy efficiency policy options (all relative to the EUCO27 baseline). It can be seen that GDP impacts are more favourable in the 2030 horizon in the loan-based compared to the case self-financed variant (after 2030, impacts are mixed). The "self-financing" assumption implies that there is a strict closure between investments and savings, that re-orientating or increasing expenditures (for households) or investments (for firms) means that fewer funds are available for other productive purposes. These assumptions make the economy being very sensitive to crowding out effects, i.e. GDP is negatively affected in 2030 (when energy efficiency investment expenditures peak), and increasingly negative as the level of energy efficiency ambition increases. However, in the "loan-based" case, financing of energy efficiency expenditures is effectively leveraged via the banking system putting less pressure on capital markets in 2030 and allowing agents to smoothen their consumption and investment patterns. Nonetheless, beyond 2030, the economy is influenced by the repayment of the debt accumulated for energy efficiency investments before 2030. This means that over the period 2035-2045, GDP impacts are largely more favourable, this time, in the self-financed variant compared to the loan-based case. This is because energy efficiency benefits brought in by earlier investments pre-2030 that materialise post-2030 outweigh any adverse crowding out effects of new investments, the latter diminishing substantially post-2030. In the long term, the two financing assumptions tend to lead to converging GDP impacts in 2045-2050, depending on scenario.

Figure 31: GEM-E3 results showing the implications of borrowing versus no borrowing for EU GDP across time (2015-2050, %change in GDP relative to EUCO27)

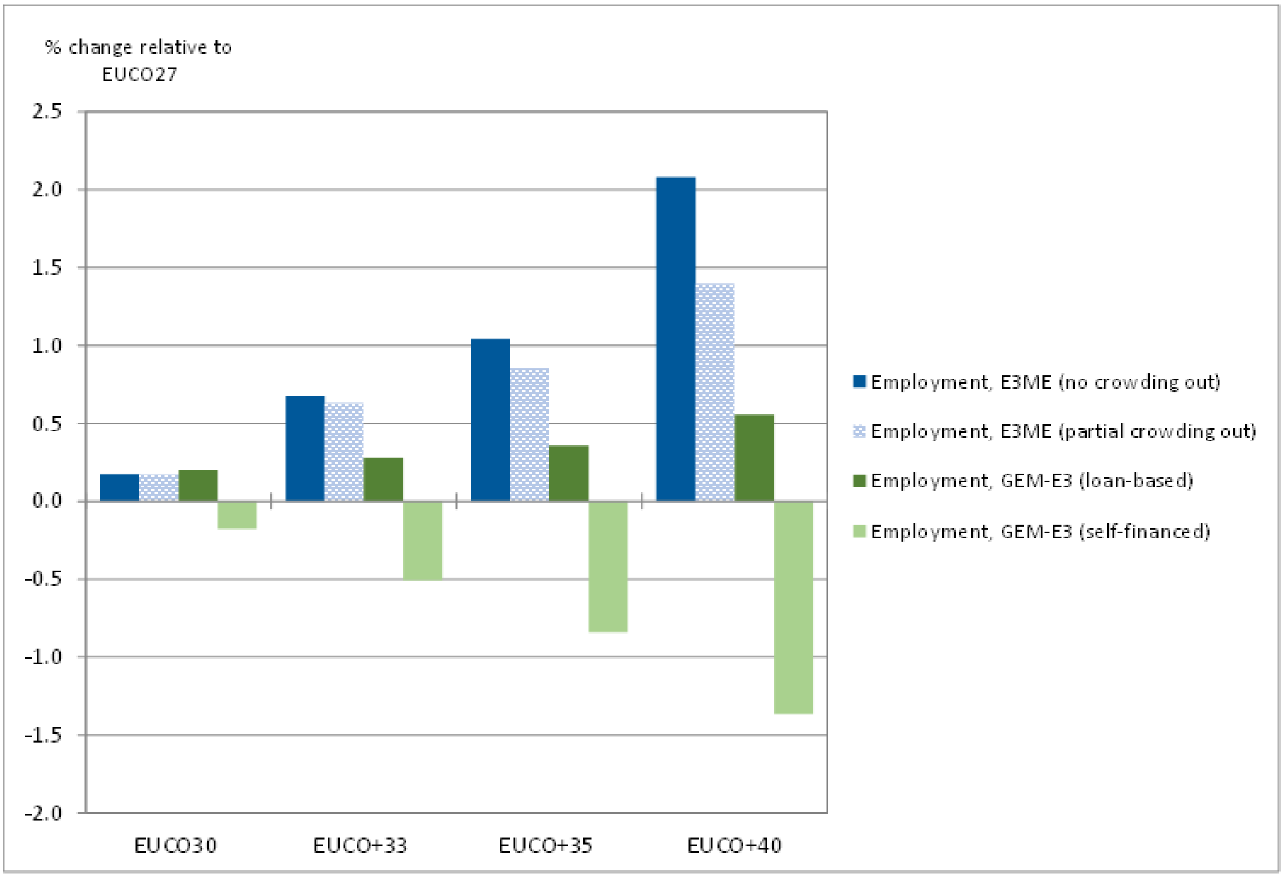


Source: GEM-E3, National Technical University of Athens

4.9.2 Sectoral output and employment impacts

The figures below display impacts by sector for the two models across the four energy efficiency policy scenario alternatives relative to the EUCO27 baseline. Results are reported for the "no crowding out" version of E3ME and the "loan-based" version of GEM-E3.

Figure 32: Range of employment impacts in EU28 in 2030 depending on macro-model used and on financing and crowding out assumptions



Source: E3ME, Cambridge Econometrics and GEM-E3, National Technical University of Athens

Increased energy efficiency expenditures lead, in both models, to increased demand in sectors providing goods and services to energy efficiency projects. Results show that higher energy efficiency ambition drives consumption expenditures towards sectors producing energy efficient equipment and energy savings projects (i.e. more efficient electrical appliances for households, retrofits, materials and insulation projects to improve thermal integrity of buildings, etc.).

Although the two models display a different sectoral classification, it can be noted that in both cases the sectors most likely to benefit activity-wise from energy efficiency policies are the construction sectors, engineering sectors as well as some basic manufacturing sectors (such as non-metallic industries and the iron and steel sector). When transiting from EUCO27 to EUCO30, the models show sectoral output increases in 2030 (relative to EUCO27), particularly for construction (1.4% in E3ME and 2.9% in GEM-E3), engineering (1.1% in E3ME and 2.1% in GEM-E3), and basic manufacturing (0.3% increase in E3ME), such as non-metallic products (3.3% in GEM-E3) and iron and steel (3.3% in GEM-E3). These sectors are projected to further increase their output (for the year 2030) with more ambitious energy efficiency investment efforts. The direct positive effect of increased energy efficiency expenditures on domestic activity is further strengthened by multiplier effects that reflect the increased intermediate demand for goods and services due to sectorial interconnections and long supply chains. Sectors with low exposure to foreign competition record relatively higher increases in their activity (e.g. construction), while for sectors characterised by higher trade exposure (e.g. engineering and transport equipment), part of the increased demand is satisfied by imports, depending on the degree of exposure to foreign competition. Thus, the positive effect of increased expenditures on their activity is weakened.

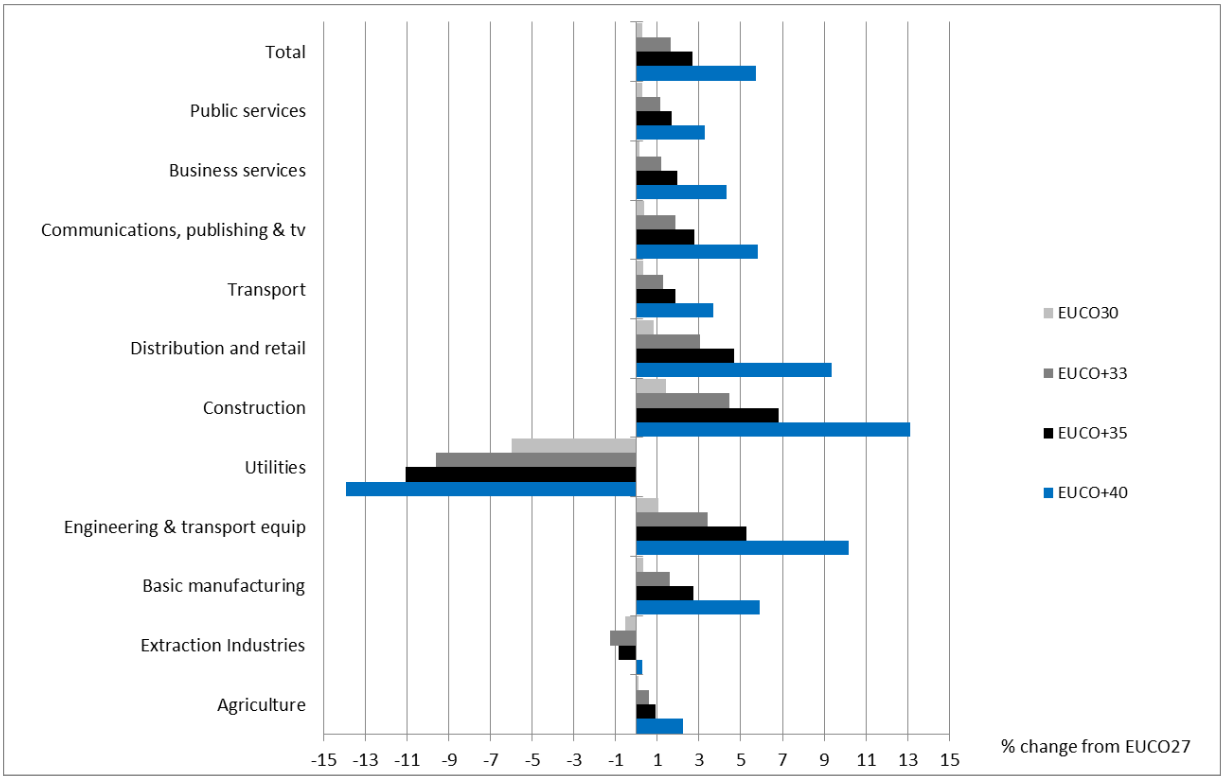
Demand for energy products or the use of electricity and gas declines in all scenarios in both models causing domestic energy production and imports to decrease. In other words, the shift in demand towards sectors which provide inputs to energy efficiency projects occurs at the expense of particularly energy-related sectors, such as the utilities and the extraction industries sectors. Again, when comparing to the 2014 European Council conclusions, in GEM-E3, changes in output for energy sectors and for power supply are projected to range from -2% in EUCO30 to -11.5% in EUCO+ 40 (relative to EUCO27). In E3ME, output is projected to contract the most in the utilities sector (ranging from -6% in EUCO30 to -14% in EUCO+ 40) and to some extent in the extraction industry (ranging from around -0.5% in EUCO30 to -1% for more stringent energy efficiency).

Overall, employment tends to increase in sectors that provide inputs to energy efficiency projects, and/or have significant forward and backward linkages with other sectors of the economy (e.g. construction sector, engineering, or non-metallic industries). The largest increase in employment, according to both models, is expected in the construction sector as a large share of the investment will require construction or installation activities. Also when taking into account both models, relatively more modest increases are also projected in the engineering and transport equipment sector, as well as in overall basic manufacturing. However, for the latter, more disaggregated GEM-E3 results show important employment gains for the non-metallic industries and iron and steel. Sectoral employment is projected to decrease in energy-related activities (such as the fossil fuel extraction and electricity supply industries) in line with the projected fall in output in these sectors.

Output and employment effects on other sectors are more nuanced, depending on the macro-modelling approach pursued and the level of sectoral aggregation. For instance, the E3ME model projects an increase in employment with the level of energy efficiency ambition for the "utilities" sector, despite its projected decrease in the sector's output, whereas the GEM-E3 model projects a decrease in employment for the "power supply" sector. This is because, E3ME bundles together under the "utilities" sector, electricity supply, gas steam & air con, water supply, and sewage & waste, while the GEM-E3 model singles out the power supply sector. In addition, the E3ME model portrays the renewable energy generation subsectors (favoured under the EUCO scenarios relative to REF2016) as being more labour intensive than their high-carbon counter-parts101. This, in combination with the projected increase in the output and employment of the "water supply" and "sewage & waste treatment" subsectors of the "utilities" sector more than counteracts the negative impacts on "electricity supply" and employment.

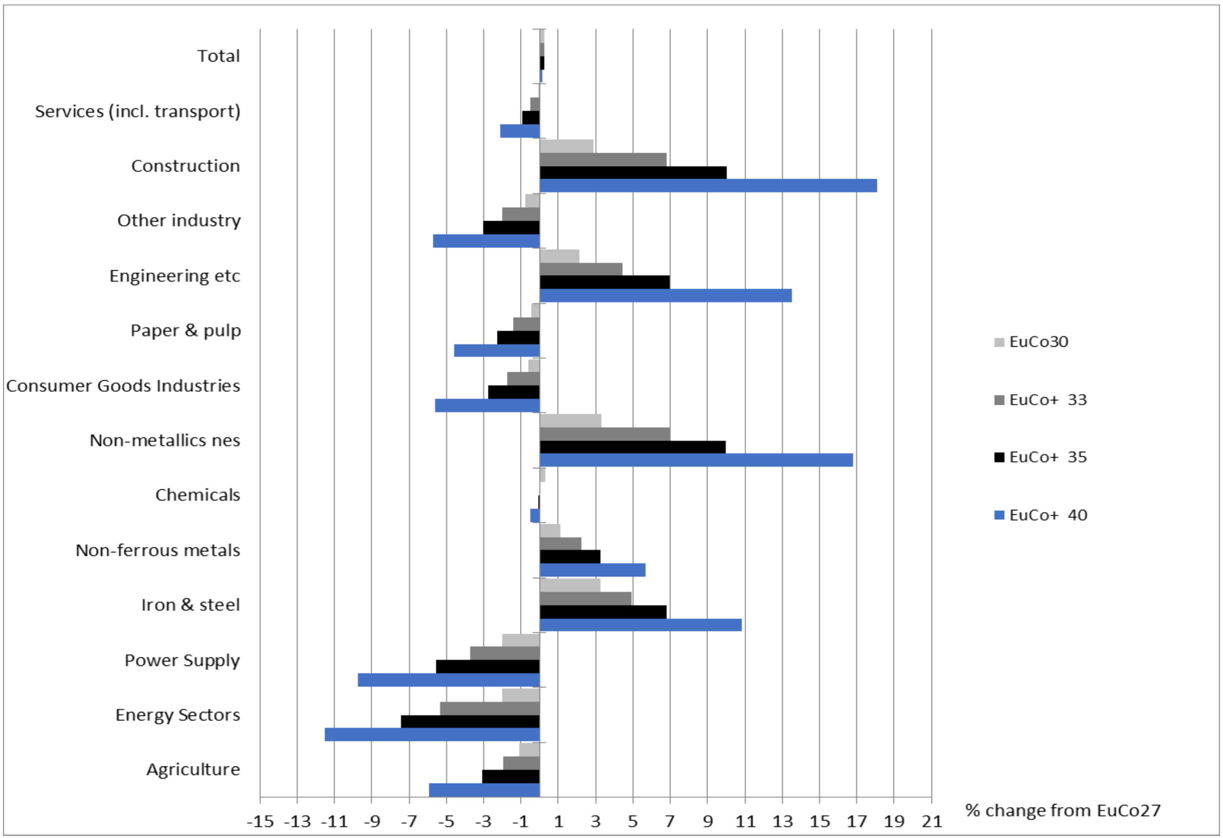
[101] See for instance the study by Institute for Sustainable Futures (2015) "Calculating Global Energy Sector Jobs: 2015 Methodology Update" (Jay Rutovitz, Elsa Dominish and jenni Dowes) that provides employment rations by type of low-carbon and high-carbon technologies, data upon which the E3ME model draws: http://opus.lib.uts.edu.au/bitstream/10453/43718/1/Rutovitzetal2015Calculatingglobalenergysectorjobsmethodology.pdf

Figure 33: E3ME sectoral output impacts in 2030 at the EU level (% change relative to EUCO27)



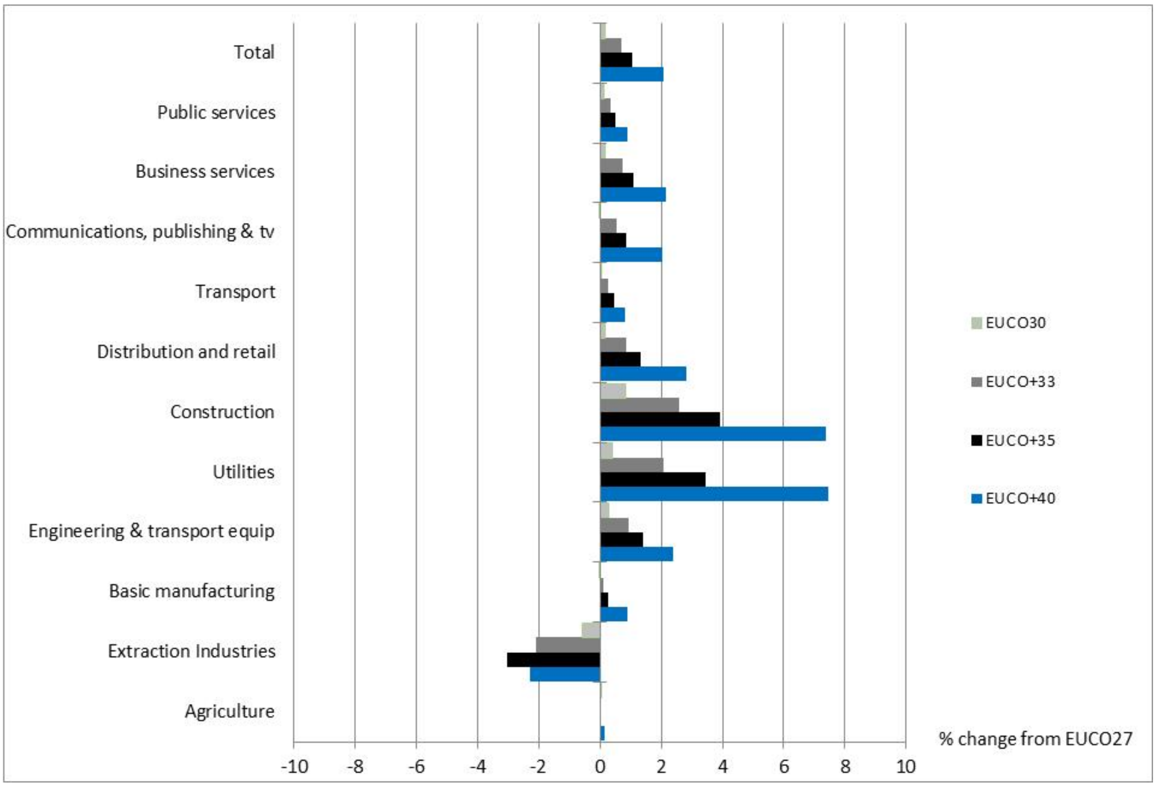
Source: E3ME (no crowding out), Cambridge Econometrics

Figure 34: GEM-E3 sectoral output impacts in 2030 at the EU level (% change relative to EUCO27)



Source: GEM-E3 (loan-based finance), National Technical University of Athens

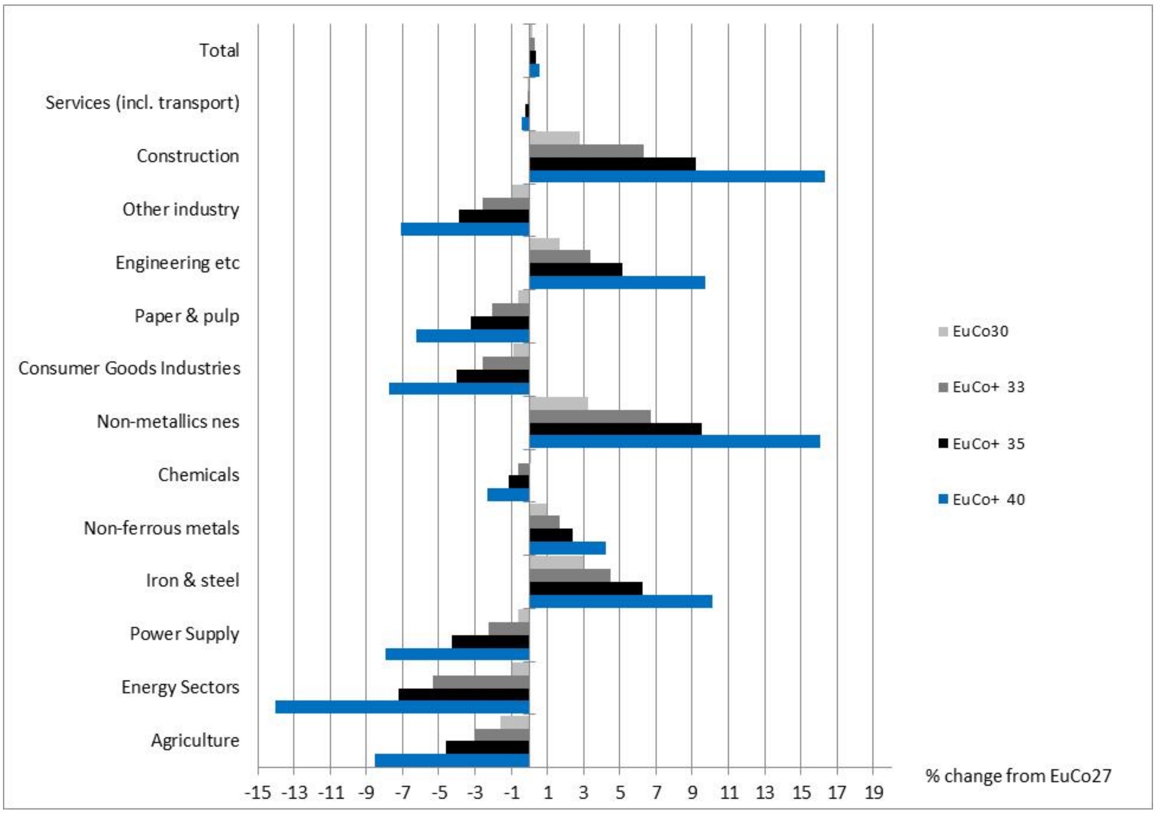
Figure 35: E3ME sectoral employment impacts in 2030 at the EU level (% change relative to EUCO27)[102]



Source: E3ME (no crowding out), Cambridge Econometrics

102 The positive results for the utilities sector are mainly due to an assumption that operation and maintenance of renewable technologies for elerctricity generation are more labour intensive than technologies that are supplanted.Cambridge Econometrics has based their modelling in part on the report "Calculating Global Energy Sector Jobs: 2012 Methodology".
http://cfsites1.uts.edu.au/find/isf/publications/rutovitzharris2012globalenergyjobsmethycalc.pdf

Figure 36: GEM-E3 sectoral employment impacts in 2030 at the EU level (% change relative to EUCO27)



Source: GEM-E3 (loan-based finance), National Technical University of Athens

4.9.3 Trade, competitiveness and other core macroeconomic indicators

The table below shows the impacts of increasing energy efficiency investment efforts on trade and other relevant macroeconomic indicators in both models (again only for the "no crowding out" case in E3ME and the "loan-based finance" case in GEM-E3)[103]. In both models, trade increases with the level of energy efficiency efforts, although imports increase at a more rapid pace than exports. Energy savings lead to a decrease of fossil fuels imports in E3ME and GEM-E3, but imports increase in total. This is because there is an increasing demand for other goods due to higher GDP levels of overall demand for goods (particularly in E3ME), as well as for equipment products contributing to the realisation of energy efficiency projects. Exports increase with the stringency of the energy efficiency target because of overall GDP growth, and increased competitiveness in sectors (such as engineering) benefitting from lower energy costs and learning effects on energy efficient equipment.

The increase in EU exports may indirectly reflect an improvement in the region's overall competitiveness stance resulting from the economy-wide effects of energy efficiency investments. In other words, from an economy-wide level perspective, macroeconomic competitiveness via changes in extra-EU exports is projected to improve because of two push factors. First, increased macroeconomic activity spurred by energy efficiency investments increases the growth potential of high value-added firms and sectors. Second, sectors delivering energy efficiency investment goods (e.g. engineering) are incentivised to move closer to their production frontier via improved technologies and learning effects, which improves overall extra-EU export growth prospects.

However, a more direct link to competitiveness could be made by relating to changes in energy costs incurred by energy-intensive industries (i.e. sectoral competitiveness)[104]. For this purpose, changes in the ratio of total energy related costs (including capital costs, energy purchases and auction payments) to the value added for energy intensive industries projected by the PRIMES model are displayed in the tables below[105]. These are projected to decrease marginally with the stringency of energy efficiency policies relative to EUCO27, indicating that energy efficiency investment efforts may not adversely impact the competitiveness of energy-intensive industries. This is because any projected increase in the capital cost component is more than outweighed by the decrease in energy purchases (including auction payments).

[103] Import/export, income, investment and consumer expenditure differences in REF2016 projected levels between the two models expressed in billion €2013 are partly due to differences in definitions, differences in databases between the two models and partly due to each model endogenously modelling the respective macro-variables.

[104] Energy-intensive industries include iron and steel, non-ferrous metals, chemicals, paper and pulp, and non-metallic minerals.

[105] These ratios take into account only the initially assumed value added growth for these industries that serve as an input into the PRIMES energy system model and which do not vary across policy scenarios. However, there are additional feedback effects from interactions between the energy sector and the macro-economy, and the positive impacts on the output for some of these sectors (e.g. iron and steel, non-metallic minerals) described in the macroeconomic sectoral output results are not included in the calculation of these ratios. As such, the competitiveness of these sectors could be further improved via positive economy-wide impacts on the value added of the industries involved in providing energy efficiency investment goods.

Table 18: Other macroeconomic impacts in EU28 in 2030 (billion €2013)[106]

% change from EUCO27	Type of macro-model	REF2016	EUCO27	EUCO30	EUCO+33	EUCO+35	EUCO+40
Investment	E3ME	4,078.7	4,131.2	4,200.7	4,339.7	4,448.8	4,750.8
	GEM-E3	2,927.0	2,968.5	3,025.9	3,129.9	3,216.1	3,453.1
Consumer expenditure	E3ME	10,193.8	10,255.2	10,263.3	10,348.1	10,388.5	10,537.7
	GEM-E3	10,105.8	10,080.4	10,068.3	9,958.1	9,864.0	9,609.2
Real disposable income	E3ME	11,371.4	11,446.7	11,464.5	11,561.1	11,609.6	11,776.6
	GEM-E3	11,332.7	11,354.1	11,387.7	11,387.8	11,381.7	11,354.8
Extra-EU imports	E3ME	2,916.8	2,920.8	2,929.0	2,959.2	2,986.6	3,059.7
	GEM-E3	2,986.2	2,979.3	2,988.1	2,998.5	3,008.9	3,037.1
Extra-EU exports	E3ME	3,720.4	3,722.2	3,722.4	3,727.4	3,730.6	3,741.7
	GEM-E3	3,395.7	3,379.9	3,388.1	3,395.9	3,405.4	3,434.1

Source: E3ME, Cambridge Econometrics; GEM-E3, National Technical University of Athens

Table 19: Ratio of energy related costs to value added for energy intensive industries in EU in 2030

	REF2016	EUCO27	EUCO30	EUCO+33	EUCO+35	EUCO+40
Total energy related costs (% of value added)	40.3%	40.8%	40.1%	40.0%	39.8%	40.6%

Source: PRIMES, National Technical University of Athens

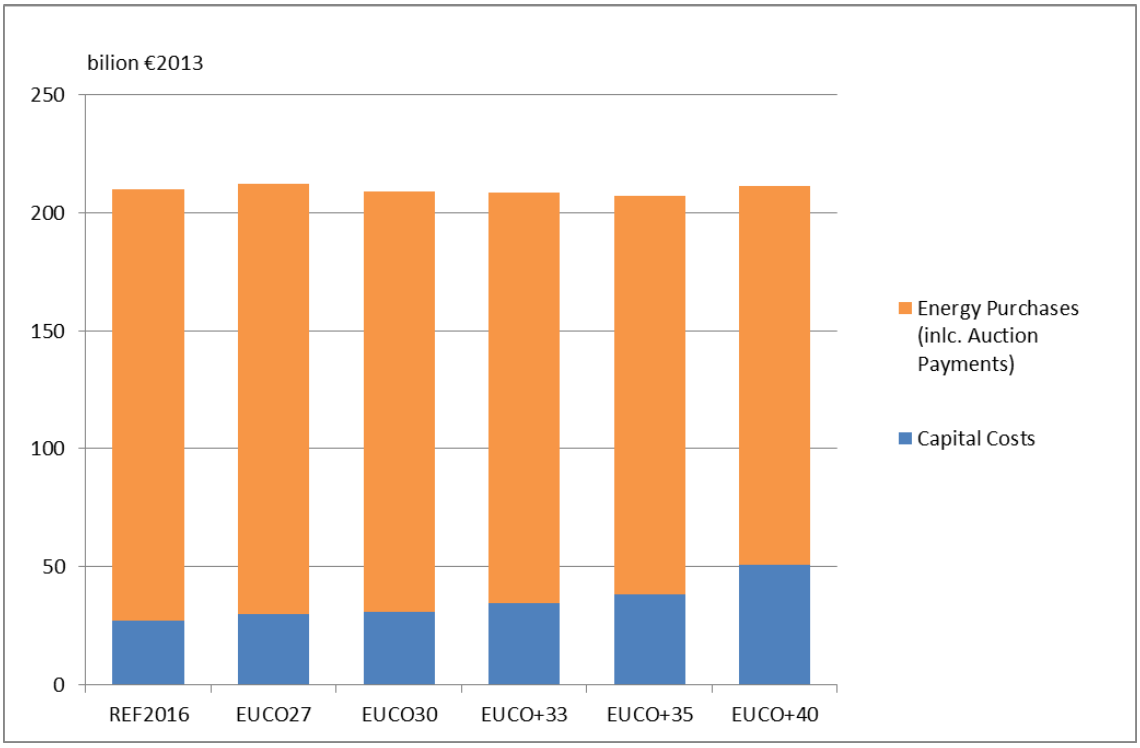
Table 20: Total energy-related costs for energy-intensive industry at EU level broken down by cost component in 2030 (billion €2013)

	REF2016	EUCO27	EUCO30	EUCO+33	EUCO+35	EUCO+40
Capital Costs	27.2	29.8	30.9	34.7	38.4	50.6
Energy Purchases	176.9	175.7	173.4	169.5	165.6	158.7
Auction Payments	5.7	6.8	4.5	4.2	3.1	2.1
Total energy-related costs	209.8	212.4	208.8	208.4	207.2	211.4

Source: PRIMES, National Technical University of Athens

106 Impacts above are reported for E3ME in the case of no-crowding out and GEM-E3 for the loan-based finance case.

Figure 37: Total energy-related costs for energy-intensive industry at EU level broken down by cost component across scenarios in 2030 (billion €2013)



Source: PRIMES, National Technical University of Athens

Both models show an increase in total investments in the EU as energy efficiency policies turn more ambitious. In the case of E3ME, total investments are stimulated by the initial energy efficiency investments that positively impact economic growth which in turn leads to further increases in investments. In other words, investments in E3ME are driven by the expectations of future production levels that are formed from current GDP growth rates. In GEM-E3, investments are largely explained by higher expenditures on energy efficiency projects and the increased return on capital.

Real disposable income increases in both models[107]. In E3ME this is partly due to higher employment levels and partly attributed to changes in prices (either higher wage demands because of a tighter labour market, or lower prices because of companies passing on efficiency savings). Adjustments in wage rates drive income results to a lesser extent in GEM-E3 due to the assumed wage stickiness[108]. Nonetheless, in both models, higher employment levels overall and a lower rate of unemployment lead to an increase in disposable income.

As energy efficiency efforts increase, consumption expenditure drops in GEM-E3, whereas it increases in E3ME. In GEM-E3, consumption expenditure decreases since households are obliged to allocate a larger part of their income towards the repayment of loans (interest rate increases) and towards more expensive energy efficient appliances. In E3ME, consumer

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[107] Real disposable income is defined in both models as real household income after tax and equals to wages plus benefit payments + other sources of income (e.g. rents, interests) minus income tax minus employees' social security contributions. It refers to gross household income in the sense that it includes savings.

[108] That is, the assumption that wages rates are not much affected by changes in labour demand.

expenditure projections follow the patterns in real income developments. In addition, energy efficiency investments are not assumed to have an impact on interest rates, and household expenditures are projected to increase due to the savings they make from energy efficiency.

4.9.4 Public budgets

The table below shows the impacts of increasing energy efficiency investments on Member States public budgets for the "no crowding out" and "partial crowding out" cases in E3ME. The numbers shown are percentage changes in the public budget for the specific scenario in question, compared to the baseline scenario REF2016 (a positive number showing an improvement in the budget balance). In these cases, it is essential to recall that there are no first order (direct) effects on the public budget balance, as governments' expenditure to support more energy efficiency is unaffected by fiscal neutrality assumption. Therefore, only second order effects are captured by the model.

Such second order effects are manifest as there are changes in public budgets due to changes in GDP and the associated tax base. In the "no crowding out" case, public budgets improve at the aggregate EU level due to increases in GDP and the tax base for the more ambitious energy efficiency scenarios. Conversely, the impacts in the "partial crowding out" scenario are negative on the public budget balance. The small positive GDP impacts that the model projects are not sufficient to generate enough tax revenues to compensate for the loss in energy excise duties due to lower energy consumption.

Table 21: Public budget in EU28 in 2030

% change relative to EUCO27	Type of macro-model E3ME	REF2016	EUCO27	EUCO30
Public budgets	no crowding out	-	0,2	0,4
	partial crowding out	-	-0.3	- 0,7

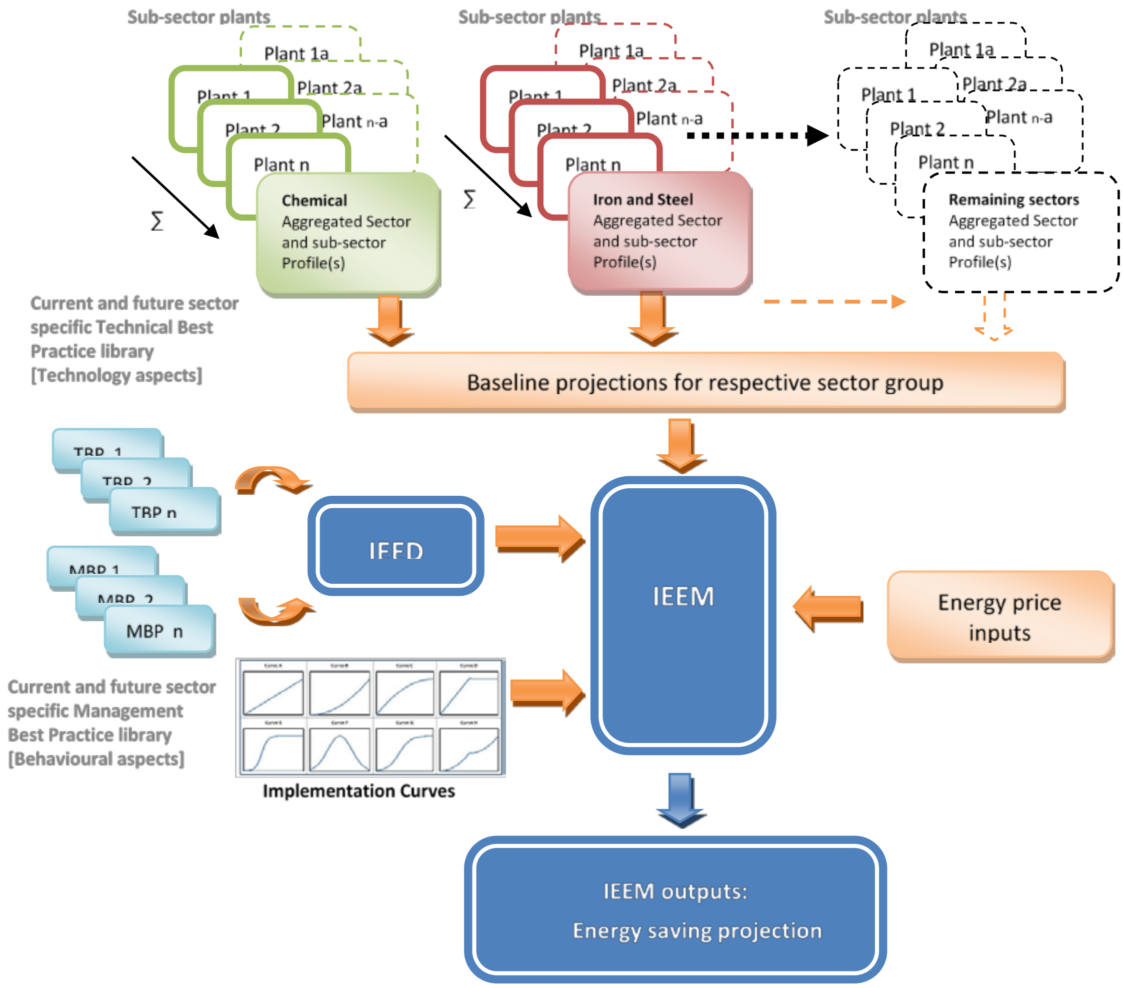
Source: E3ME, Cambridge Econometrics

4.10 Industrial Energy Efficiency Modelling (IEEM)

The Industrial Energy Efficiency Model (IEEM) operated by ICF is a bottom-up model for accounting for energy saving potentials based on a defined list of energy saving opportunities applicable to the respective industrial sector group.

The model applies data available in ICF's Industrial Energy Efficiency Database (IEED), which holds a comprehensive list of potential energy saving opportunities. The energy saving opportunities include savings potentials due to both Technical Best Practices and Management Best Practices. Each energy saving opportunity is applied in the IEEM to quantify energy saving potential as an output. The figure below provides an overview of IEEM modelling framework.

Figure 38: Overview of IEEM modelling framework



Source: ICF

A baseline projection is the starting point for the analysis and provides a detailed description of "where" and "how" energy is currently used in the selected sector group, including a breakdown of energy by end use. The baseline projection is the benchmark against which the energy savings are calculated.

For each Energy Saving Opportunity, one of eight "standard" uptake curves is applied by defining a starting point (current market penetration rate) and final point (estimated or target final market penetration rate). Application of the uptake curve takes into consideration the maturity of technology, capital, operating expenditures and complexity in implementation and operation.

IEEM can evaluate all the defined Energy Saving Opportunities individually for economic viability based on optional financial metrics. For this modelling work, a payback approach was applied, since it is still a widely utilized metric and not subjected to the complications associated with discount rates or Weighted Average Cost of Capital which differ widely among industries and Member States.

The economic benefits of the Energy Saving Opportunities account only for the direct energy saving benefits expressed in monetary value. It does not include any other direct or indirect benefits such as avoided carbon taxes, improved production or improved competitiveness, reduced maintenance costs, etc. The Energy Saving Opportunity cost includes the capital, Operating and Maintenance (O&M), and implementation costs. An energy price outlook is used as a main input to quantify the monetary value of energy savings, since the benefit of the ESO is dependent on the energy price.

For each Energy Saving Opportunity that meets the economic threshold (e.g. 2-year payback or 5-year payback), IEEM will account for it by subtracting its respective energy saving potential from the respective baseline projection. The accumulated energy savings for each ESO are added together to present the overall energy saving potential for the sector group, based on economical Energy Saving Opportunities being taken up at its respective pre-defined rate and trend.

IEEM computes energy savings based on the respective Energy Saving Opportunity applied. This accounting process is then repeated multiple times to account for multiple Energy Saving Opportunities applied. As a result, IEEM generates cumulated energy savings based on the Energy Saving Opportunity.

4.11 Modelling of international fuel price impacts

The impacts of different 2030 energy efficiency levels have been analysed with the POLES model from the Joint Research Centre of the European Commission.

POLES is a global energy model that covers the entire energy balance, from final energy demand, transformation and power production to primary supply and trade of energy commodities across countries and regions. It allows assessing the contribution to future energy needs of the various energy types (fossil fuels, nuclear, renewables) and energy vectors.

In addition, it calculates the evolution of GHG emissions: endogenously for the energy-industry sectors and through linkage with specialist models for GHG emissions from agriculture and land-use.

The model includes a detailed geographical representation, with a total of 66 regions modelled; that includes all G20 countries, detailed OECD and the main non-OECD economies. It operates on a yearly time step, allowing integrating recent developments.

The POLES model is well suited to evaluate the evolution of energy demand in the main World economies and international markets as well as to assess climate and energy policies. De facto it has been used for several Directorates General of the European Commission, as well as for national authorities. The POLES model has been applied in numerous research projects, and analyses based on POLES have been published widely[109].

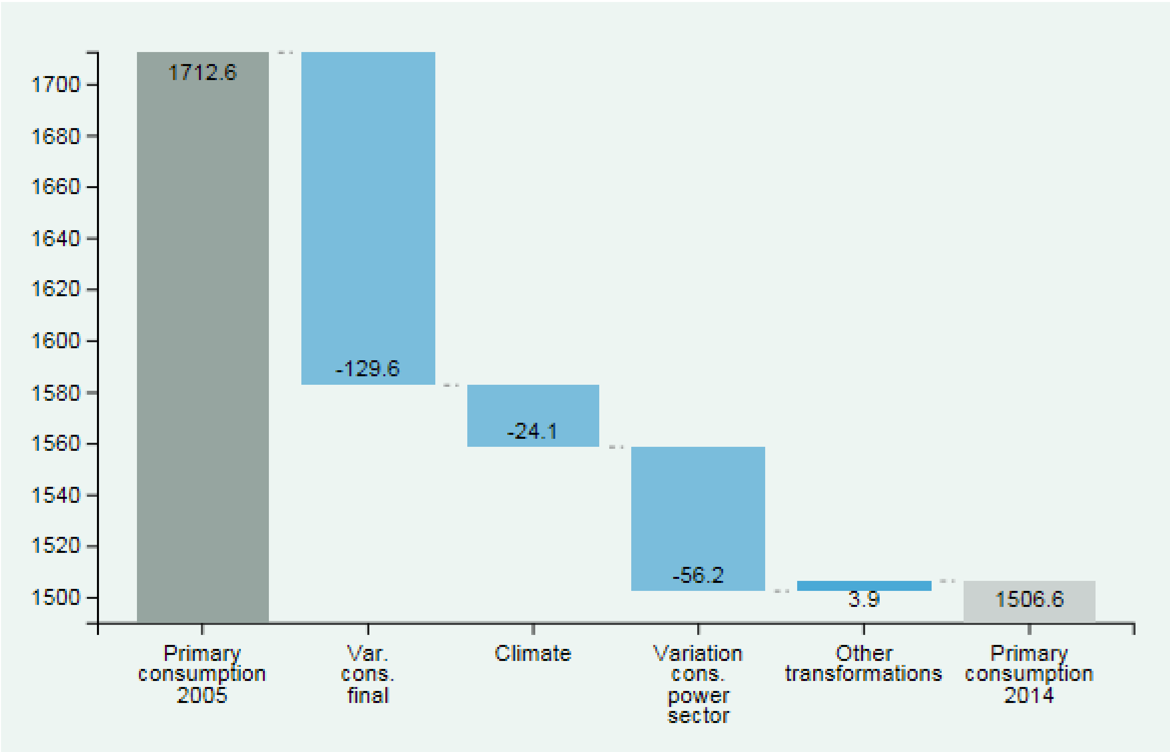
The energy situation of non-EU countries and regions is derived from the GECO 2016 Reference scenario (Global Energy and Climate Outlook). This scenario includes climate and energy policies announced by countries before the Paris Climate Agreement[110].

[109] More information can be found on: www.ec.europa.eu/jrc/poles.
[110] The GECO report is accessible on : www.ec.europa.eu/jrc/geco.

5 Annex - Additional information – decomposition analysis

A decomposition analysis of past trends was performed under the Odyssee-Mure project financed as one of the Horizon 2020 projects[111]. The results of the decomposition of the energy consumption 2005-2014 can be found below:

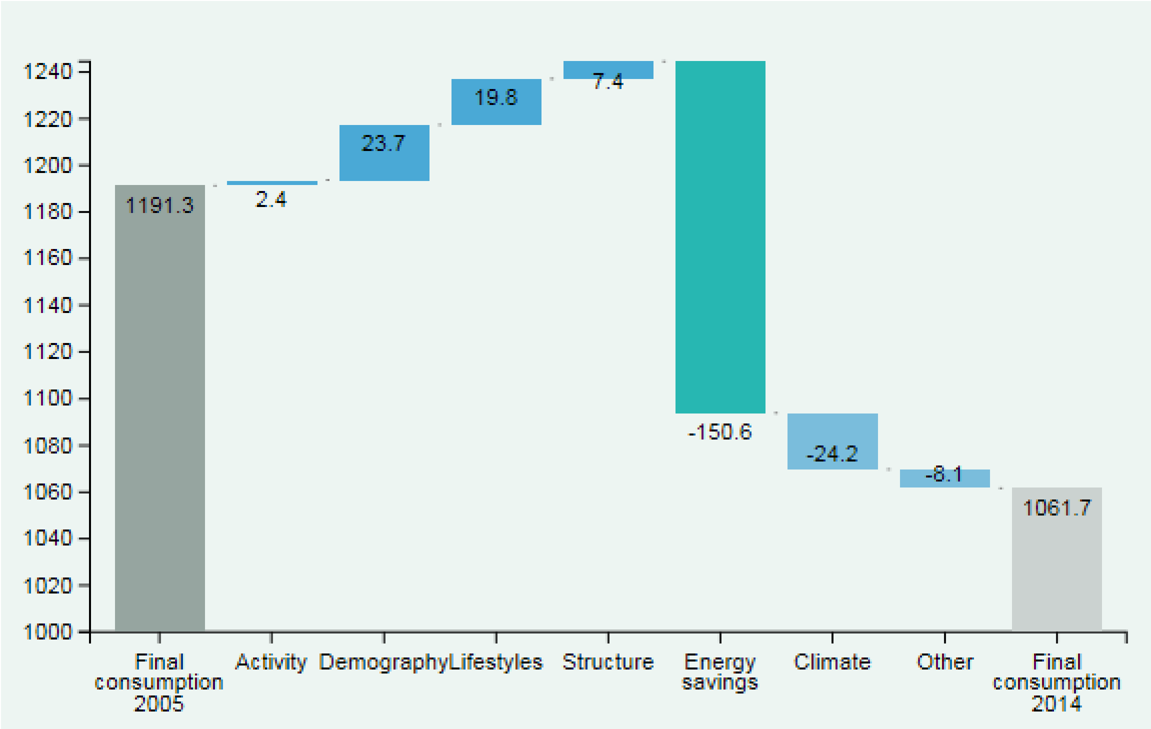
Figure 39: Variation primary energy consumption - European Union - Mtoe (2005-2014)



Source: Odyssee-Mure

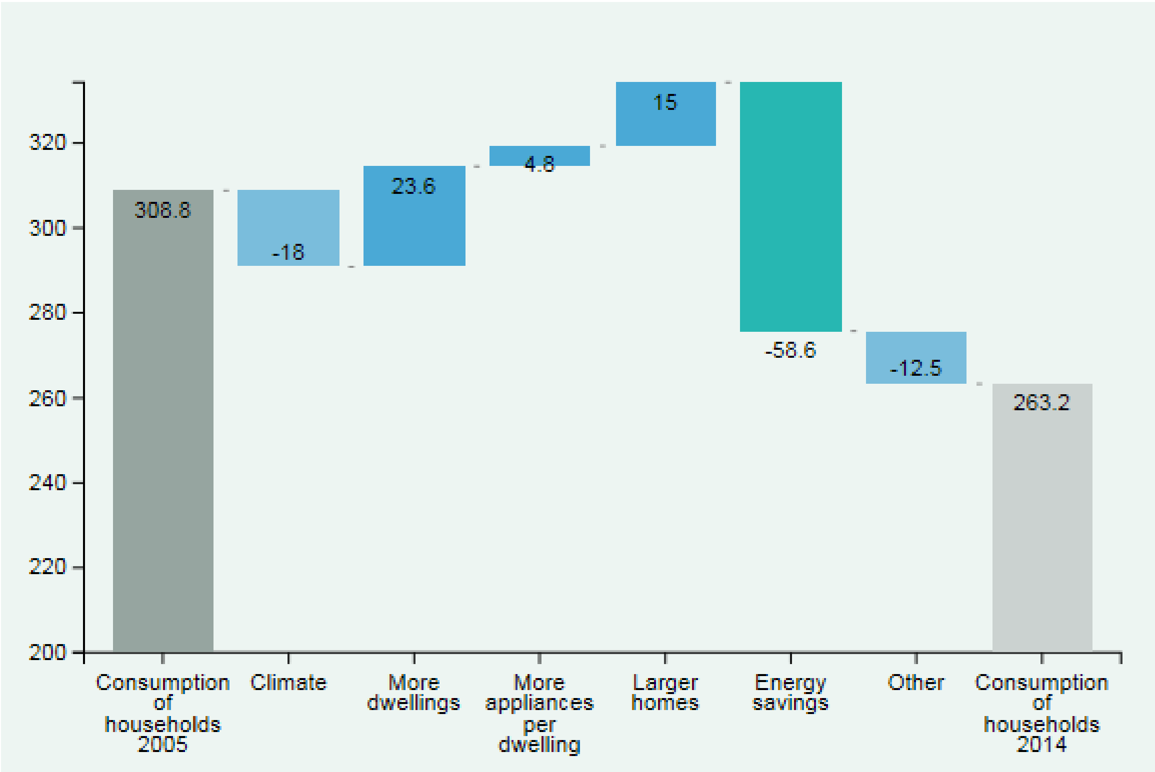
[111] Details on the methodology can be found here: http://www.indicators.odyssee-mure.eu/php/odyssee-decomposition/documents/interpretation-of-the-energy-consumption-variation-glossary.pdf.

Figure 40: Variation final energy consumption - European Union - Mtoe (2005-2014)



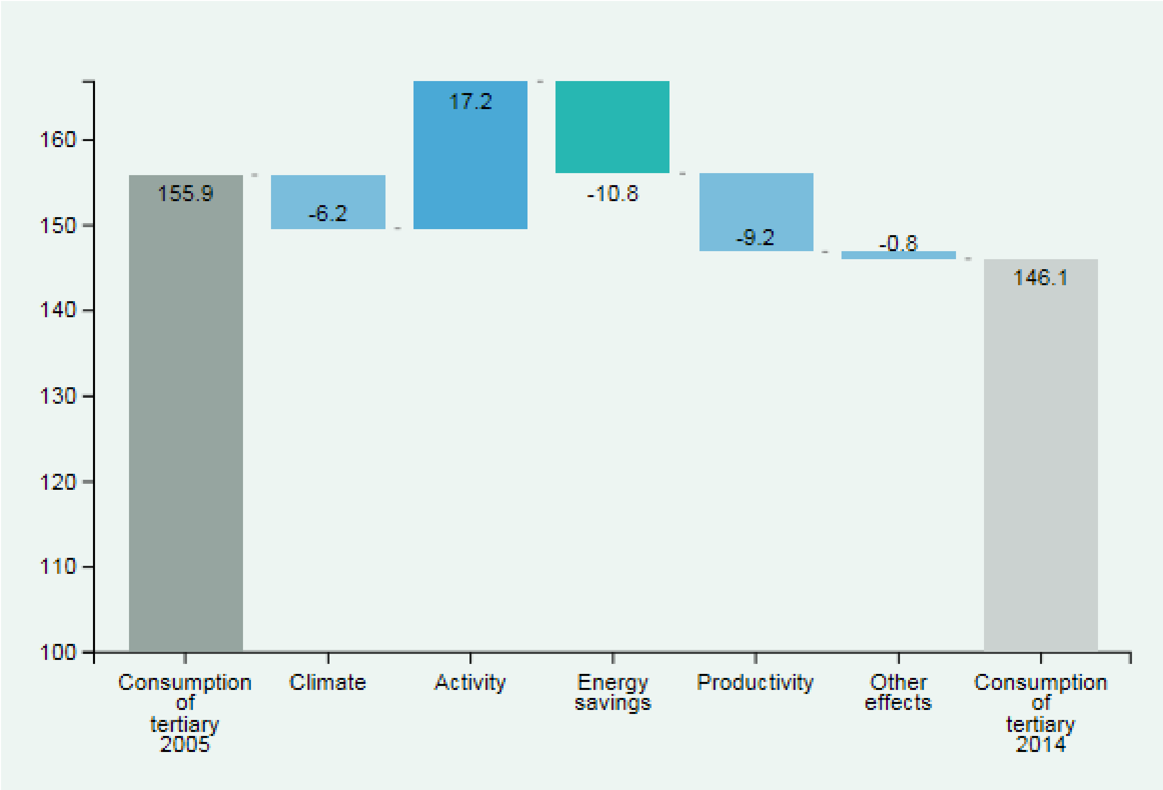
Source: Odyssee-Mure

Figure 41: Variation residential consumption - European Union - Mtoe (2005-2014)



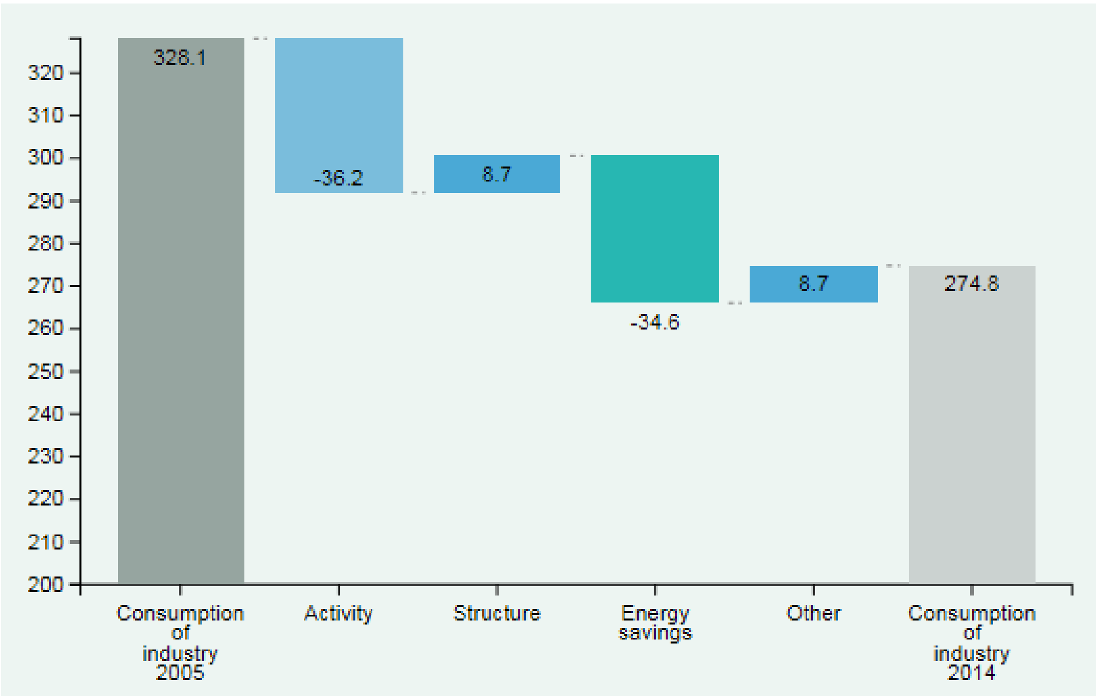
Source: Odyssee-Mure

Figure 42: Variation tertiary consumption - European Union - Mtoe (2005-2014)



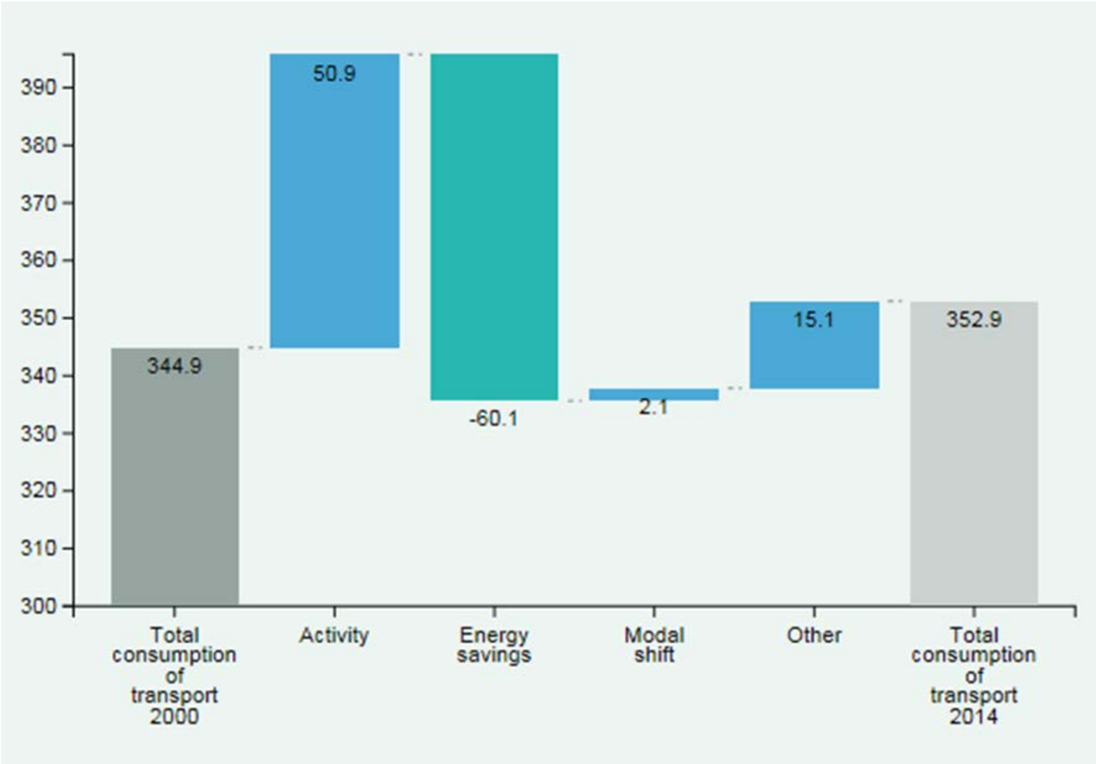
Source: Odyssee-Mure

Figure 43: Variation industry consumption - European Union - Mtoe (2005-2014)



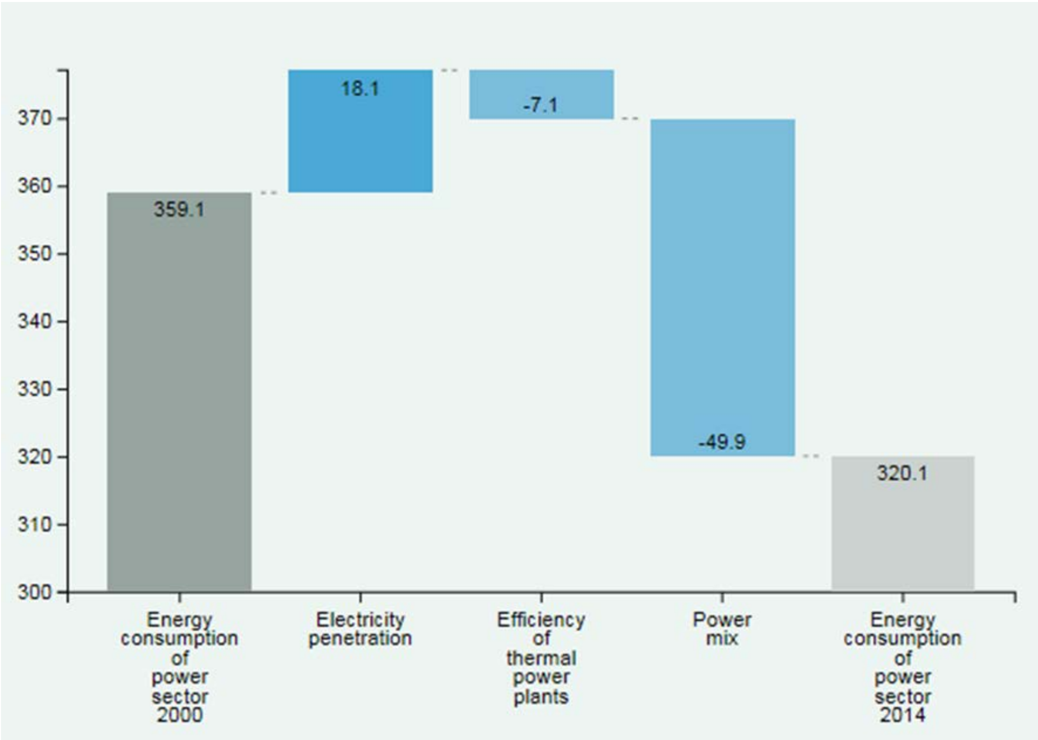
Source: Odyssee-Mure

Figure 44: Variation transport consumption - European Union - Mtoe (2005-2014)



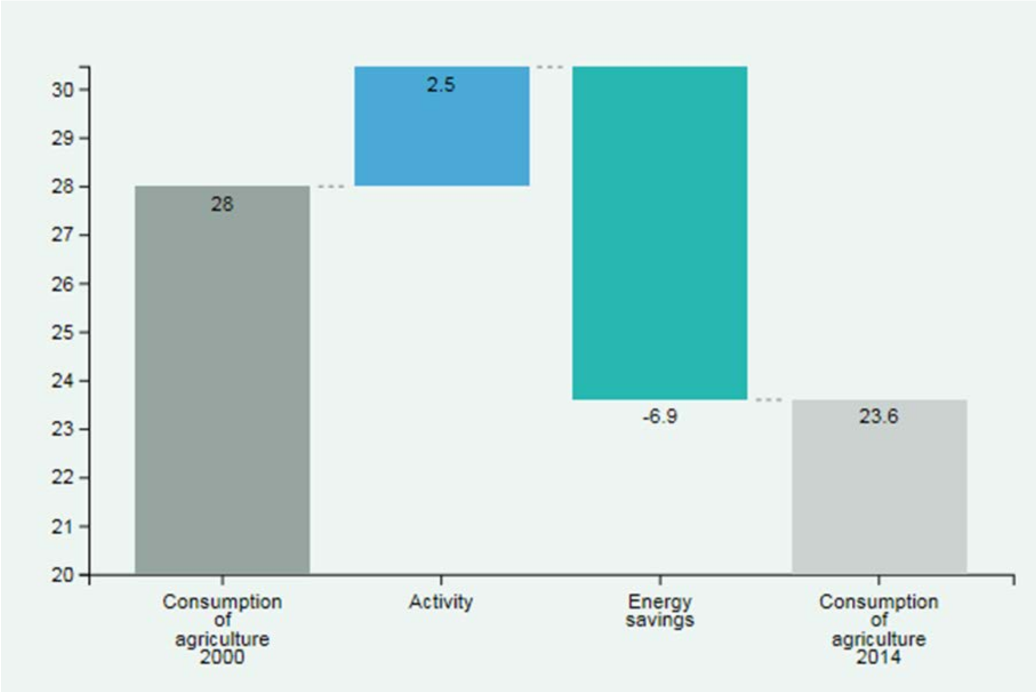
Source: Odyssee-Mure

Figure 45: Variation power sector consumption - European Union - Mtoe (2005-2014)



Source: Odyssee-Mure

Figure 46: Variation agriculture consumption - European Union - Mtoe (2005-2014)



Source: Odyssee-Mure

6 Annex –Analytical approach used for Articles 7 and 9-11

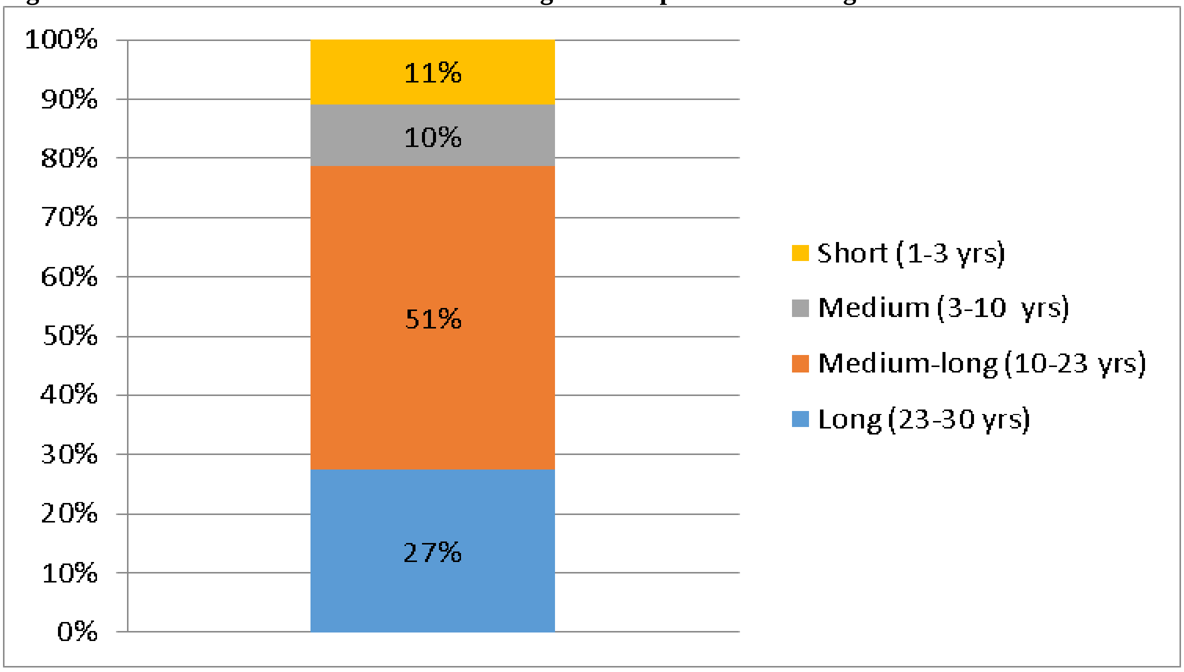
6.1 Analytical approach for Article 7

The quantitative estimates of the amount of energy savings expected from implementation of the measures (in the existing period 2014-2020) and estimates for the new period starting from 2021-2030 if Article 7 is extended were based on a bottom-up spreadsheet-based model developed by the contractor Ricardo AEA/ CE Delft under a specific contract[112]. A brief description of the methodology is outlined below.

Calculation of the baseline scenario - Article 7 expires post 2020

This analysis is based on the notified savings (cumulative amount of 250.3 Mtoe by 2020) from the policy measures that Member States have planned in order to fulfil their Article 7 energy savings requirement by 2020. The analysis is based on the notified annual savings per policy measure and the assigned lifetimes during which they will deliver energy savings based on CEN-values[113], as the savings notified by the Member States at the policy measure level contained actions with different lifetimes, which were not split per specific type of these energy saving actions. The data notified by the Member States enabled an attribution of only 57% of the savings to one of the four lifetime categories: with relative contributions of 27% long, 51% medium long, 10% medium and 11% short lifetimes (see Figure 47).

Figure 47: Distribution of notified annual savings in 2020 per lifetime categories



Source: Ricardo AEA/ CE Delft

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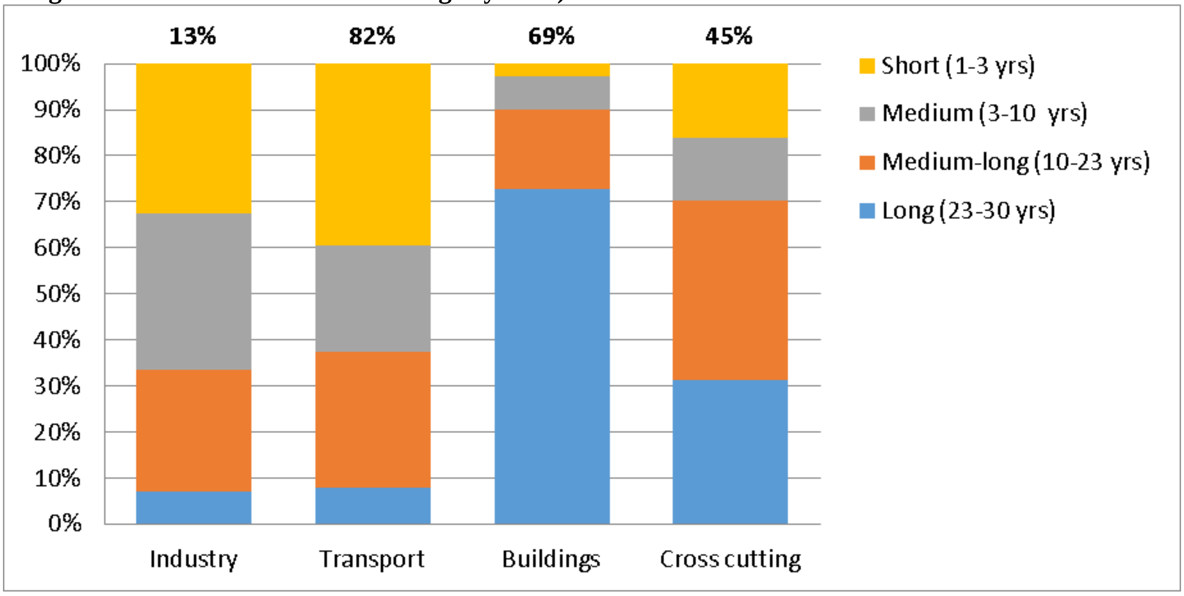
[112] Detailed explanation of the methodology is provided in the Final Report on the Study evaluating implementation of Article 7 of the EED (chapter 3), Ricardo AEA/ CE Delft (2016).

[113] CEN, 2007: Saving lifetimes of energy efficiency improvement measures in bottom-up calculations, CWA 15693. [NB: CEN evaluates every three years whether the norm should be updated. This has happened twice since the publication in 2007. Both times, the outcome of the evaluation was that there was no need yet for an update of the lifetimes.]

Figure 48: Distribution of savings by lifetime categories per sector (% of savings with attributed lifetime categories to notified cumulative savings by 2020)



Source: Ricardo AEA/ CE Delft

The assumptions for the remaining 43% of the notified savings to the lifetime categories were made using the methodology described below.

In the absence of any more detailed information in the notifications, the relative contributions of the individual actions to the overall energy savings, and the associated lifetime of these energy savings, has been estimated based on the expert judgement by Ricardo AEA/ CE Delft. This took into account information that was available on sectors that were targeted by the measure (e.g. buildings, industry) and the types of actions that would be stimulated (e.g. technical measures, behavioural actions). However, in some cases there was limited evidence to make the judgement.

To help ensure a consistent approach when approximating the lifetime of the savings of each policy measure, a set of default factors was used to represent the different types of energy saving actions. This categorised different types of action, and then attributed typical lifetimes to each category. In estimating the energy savings it was therefore necessary to approximate the percentage of the energy savings that were expected to fall into each category. This approach is simplistic, but does ensure a degree of consistency in the assessment, and in the absence of precise data enables an approximation of the potential lifetimes associated with each of the individual policy measures.

The default lifetime categories were based on the detailed standardised lifetimes for energy efficiency actions provided by CEN. The CEN lifetimes were chosen since they provide the best available generally accepted overview of lifetimes of energy efficiency actions. They have been subject to an independent review by relevant experts and are impartial. Every three years, the CEN norms are evaluated on actuality. Some Member States have developed their own catalogue of savings and associated lifetimes which may be more applicable to their national circumstances, but may be less applicable to the circumstances in other Member States. In practice, lifetimes used by Member States are in most cases very similar to the CEN-lifetimes as they draw upon similar datasets (see).

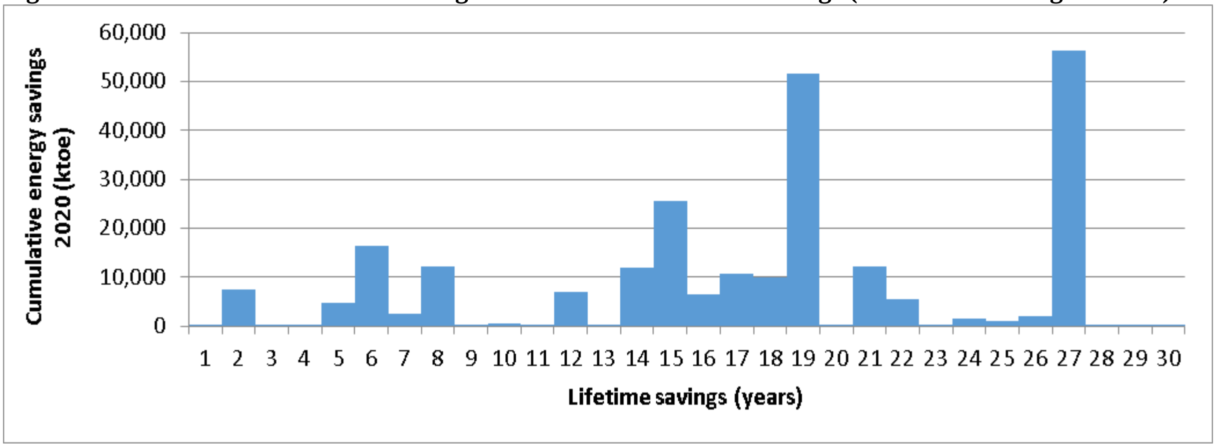
Table 22: Lifetime categories based on CEN-values

Lifetime category	Range (years)	Example	Lifetime used in the analyses (years)
Long lifetimes	23-30	e.g. Investments in building envelope	27
Medium long lifetimes	10-23	e.g. Investments in building installations	15
Medium lifetimes	3-10	e.g. Consumer electronics	5
Short lifetimes	1-3	e.g. Behavioural changes	2
Unclear	N/A	N/A	Average per policy measure category, based on attributed lifetime categories to the policy measures that were not 'unclear'

Source: Ricardo AEA/ CE Delft

CEN-values were used to ensure a uniform and harmonised approach in the assumptions made throughout the analysis. The assumptions for these remaining 43 % of the notified savings to the lifetime categories were made on the basis of CEN values.

Figure 49: Distribution of notified savings over the lifetimes of the savings (cumulative savings in 2020)

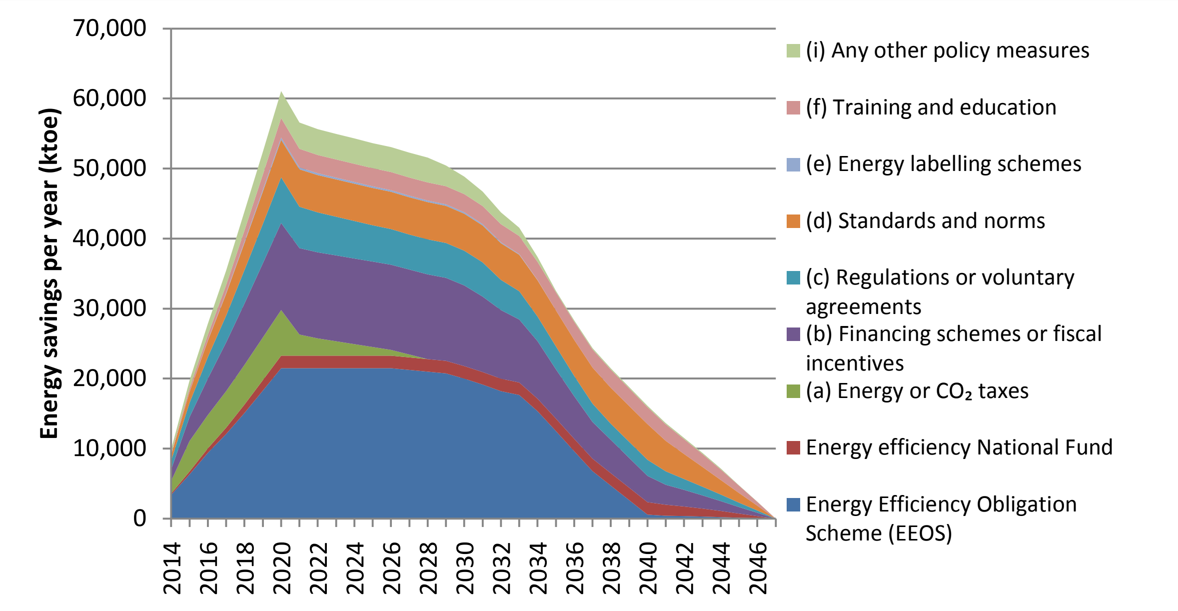


Source: Ricardo AEA/ CE Delft

The distribution of the savings over time was calculated therefore on the basis of the notified savings and their attributed lifetimes (see

Figure **50**).

Figure 50: Annual savings notified for the period 2014-2020 (per type of policy measure)[114]

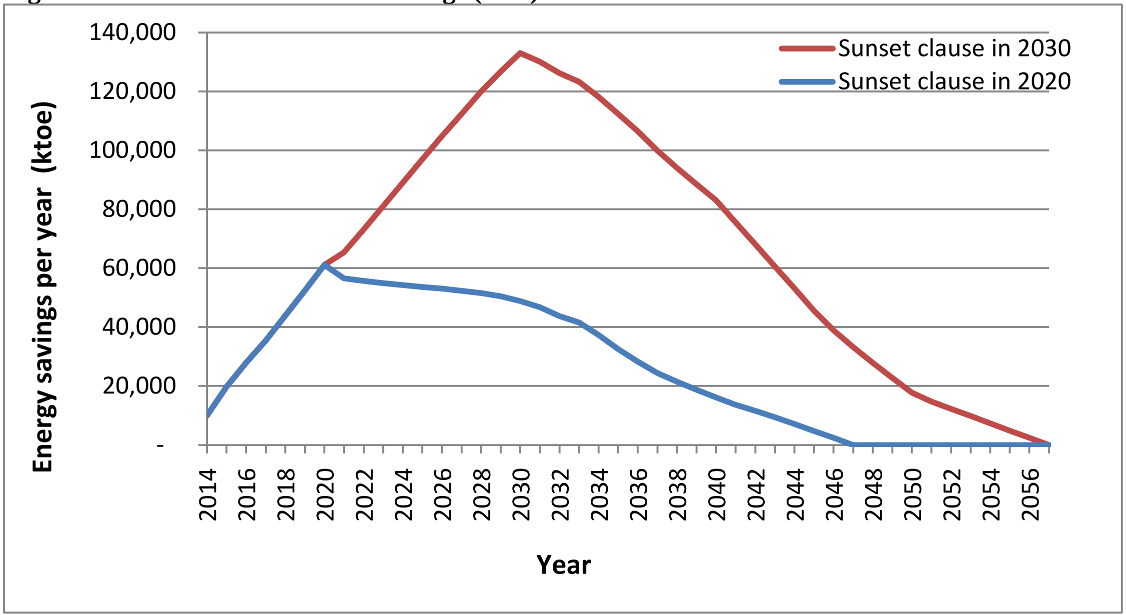


Source: Ricardo AEA/ CE Delft

Results as presented in Figure **50** show that the policy measures notified for the period 2014-2020 will continue to deliver some savings even up to 2046. As shown in the same Figure **50**, the annual energy savings in year 2020 are estimated to reach 61 Mtoe. From 2020 onwards, the annual energy savings from Article 7 will decline, as without extension this policy will no longer provide stimulus for triggering 'new' savings per year (see Figure 51). According to the bottom-up engineering estimate some 49 Mtoe savings will continue to be delivered in 2030 as a result of the long term measures (e.g. renovation of buildings) introduced in the 2014-2020 period. As indicated in the section on impacts (5.4.1) of the main report, this engineering projection is optimistic, and is based purely on notified values and does not take into account a reality check.

[114] Calculated on the basis of the baseline used for the 2014-2020 period (energy sales averaged over 2010-2012).

Figure 51: Estimated cumulative savings (ktoe) with and without extension of Article 7



Source: Ricardo AEA/ CE Delft

Calculation of the scenario with extended Article 7 to 2030

As described in the dedicated chapter on impacts for Article 7, the estimation of the amount of savings for the next period 2021-2030 was based on the same 1.5 % level of ambition, and considering also the maximum use of flexibilities (i.e. exclusion of energy sales in transport and exemptions up to 25 % limit under paragraph 2 and 3) currently allowed under Article 7.

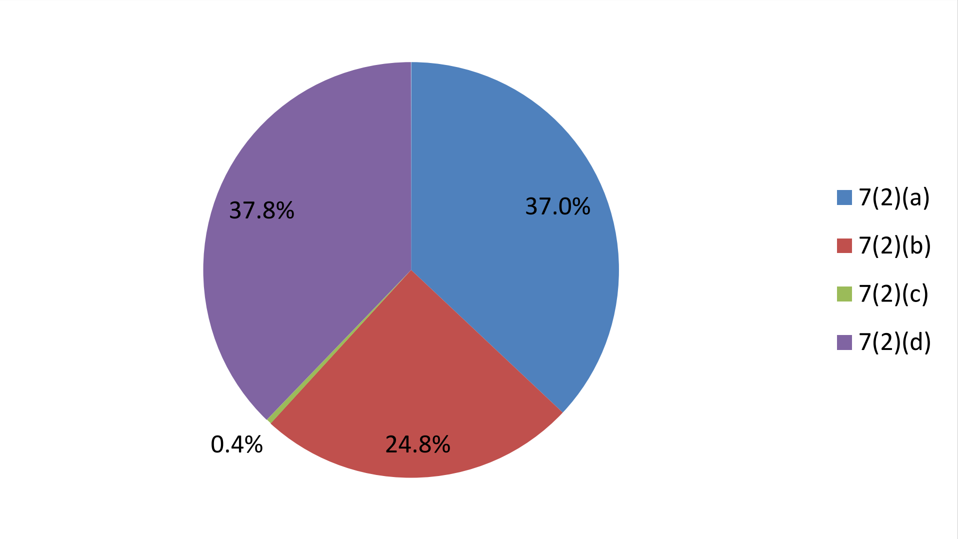
The effect depends on how the Member States will apply the flexibilities (i.e. excluding sales in transport) and exemptions under paragraph 2 which have a direct impact on the national savings contributions (see Annex 7) and were used by Member States in the current obligation period 2014-2020 as follows:

- **Self-generation** and **self-consumption** were excluded by 14 Member States (amounting to 46 Mtoe);
- Sales of energy in **transport** were excluded by 27 Member States (except for Sweden; the Netherlands and Bulgaria did not indicate the exact amount) which reduced the baseline by 332 Mtoe (from the total amount of energy sales of 1,101.5 Mtoe notified).
- **Exemptions under paragraph 2** of Article 7 such as (a) allowing lower rates in the beginning of the obligation period; (b) excluding sales to ETS industries; (c) allowing achieving certain savings from supply side option, and finally (d) allowing savings from early actions, resulted in almost full use of the maximum 25% reduction of the savings

requirement, since 24 Member States used the full 25% exemption provision (Denmark used 3%, and Sweden and Romania used 21%[115])..

As a result of the notified exemptions, the sum of the notified cumulative energy savings requirements decreased by 90 Mtoe (from 320 Mtoe[116] to 230 Mtoe). Exemption (a) ('slow start') was used the most, by 22 Member States amounting to 45 % of the total exemptions (33 Mtoe). As regards exemption (b) of energy sales to ETS industry, 15 Member States notified that they exclude energy use from industry under ETS from their target calculation for Article 7 amounting to about 22 Mtoe, or 24.8 % of the total exemptions (see Figure 52). Compared to the current 2020 cumulative target without exemptions, this amounts to 5 % reduction. For comparison, it is estimated that the share of energy consumption by industry covered by the ETS in the total final energy consumption in the EU-28 would amount to 16 % in 2020[117].

Figure 52: share of exemptions used by Member States under paragraph 2



Source: Ricardo AEA/ CE Delft

The share of exemption (c) allowing achieving savings in the supply side was 0.4 Mtoe (or 0.4 %) used only by 3 Member States. Early actions under exemption (d) amounted to 34 Mtoe (or 37.8 %) of all exemptions applied by 13 Member States using this possibility under paragraph 2.

As mentioned above, the effect of extending Article 7 to 2030 was calculated on the basis of 1.5 % annual savings rate, assuming that the total amount of cumulative savings that Member States will be required to achieve by 2030 will have the same distribution of energy savings actions (and therefore lifetimes) as in 2020. As a result, the expected new savings would amount to 81 Mtoe in year 2030 (with the maximum reductions applied) and in cumulative terms it would amount to 443 Mtoe for the whole period 2021-2030 (see Table 23). This is a

115 Updated figures on the basis of the information received through the structured dialogue with the Member States and in the Annual Reports 2016.
116 Amount of savings (before exemptions applied) - all figures are rounded up.
117 PRIMES (2016) reference scenario.

conservative estimate based on 2016 PRIMES reference scenario on how final energy consumption would evolve over the next years by 2020. In reality Member States might have higher reduction levels in final energy consumption which would thus result in lower amount of energy savings required by 2030.

Table 23: Calculation of the 1,5% savings requirement for the period 2021-2030 (ktoe)[118]

	2015	2020	Average 2015-2020	2030
Total final energy consumption	1,133,457	1,133,797	1,133,627	
Transport	360,838	353,833	357,336	
Self-generation for own use[119]	54,100	65,100	59,600	
Adjusted baseline (energy sales in transport and self-generation for own energy use excluded)	718,519	714,864	716,691	
Total amount of cumulative savings for the whole period				591,270
Exemptions with max 25% applied				147,818
Total cumulative savings for the whole period, max 25% cap applied				**443,453**
Annual savings in year 2030				**80,628**

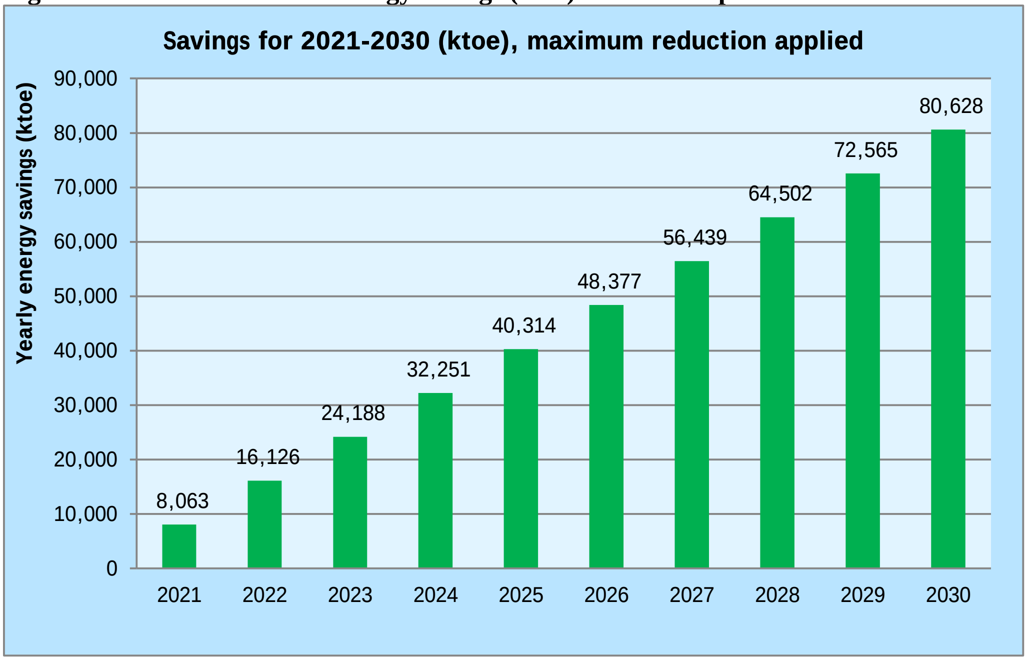
Source: Ricardo AEA/CE Delft (2016)

In terms of annual distribution of the new energy savings for the period 2021-2030, these are depicted in Figure 53 on the assumption that each year 1.5% of new savings are achieved. In reality Member States are flexible how they phase the savings as long as the overall amount of the end use savings for the whole obligation period is achieved.

[118] Calculation based on the final energy consumption averaged over 2015-2020 (2016 PRIMES reference scenario).

[119] Estimation based on interim Results of the Study for Realisation of the 2016 Report on Renewable Energy, Öko-Institut (2016). This figure is indicative and the estimated baseline should be taken as a theoretical reference, as it might differ when the actual data on final consumption become available in view of the calculation the national savings requirements for 2021-2030 period.

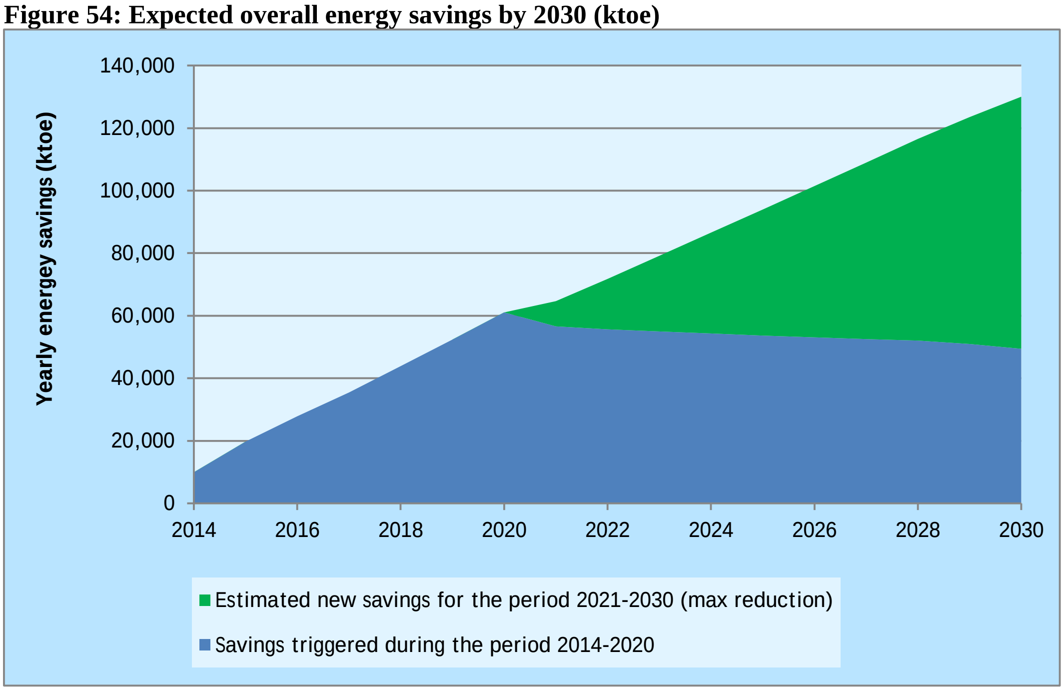
Figure 53: Estimated annual energy savings (ktoe) for the new period 2021-2030



Source: Ricardo AEA/CE Delft (2016)

It is important to recognise the long-term impact from certain measures with long lifetimes such as savings stemming from the renovation of buildings which will continue to have an effect also after 2020 in addition to the savings triggered by new policy measures or individual actions put in place to achieve the required savings requirement for the period 2021-2030. The overall impact of the energy savings generated under Article 7 is depicted in Figure 54.

Figure 54: Expected overall energy savings by 2030 (ktoe)



Source: Ricardo AEA/CE Delft (2016)

The Guidance note on Article 7[120] provides a step-by-step explanation how to calculate the overall amount of energy savings to be achieved by 2020 commitment period, which if retained at the same level of intensity, will apply in equivalent way up to 2030.

Member States first had to establish the baseline which equals the average of the annual **energy sales** by volume, to final consumers of all energy distributors or all retail energy sales companies over the three years before 1 January 2013 (i.e. 2010-2012). Energy sales in transport sector can be fully or partially excluded from the baseline. Energy volumes transformed on site and used for own-use and those that are used for the production of other energy forms for non-energy use are excluded.

The next step is to multiply by 1.5% the average final energy consumption (over 2010-2012) in order to obtain the "new" annual amount to be saved. In addition, under the concept of lifetimes in Annex V, part 2, point (e), each individual energy-saving action is considered to deliver savings not only in the year of implementation, but in also in future years up to 2020.

For this reason, the required amount of savings has to be 'cumulated' year-on-year (if not, one year's actions could be considered enough to fulfil the entire requirement). The overall amount to be reached over the whole new period is therefore a sum of the following cumulative percentages: 2021 – 1.5%; 2022 – 3%; 2023 – 4.5%; 2024 – 6%; 2025 – 7.5%; 2026– 9%; 2027 – 10.5%; 2028 – 12%; 2029 – 13.5% and 2030 – 15%. For example, if the total amount of energy sales (averaged over 3 year period) is 100 Mtoe, then this implies that the total cumulative amount of energy savings required over the whole ten-year period would be 82,5 Mtoe (see table below).

Table 24: Total cumulative amount of energy savings required 2021-2030

Year	Energy savings [Mtoe]										Total
2021	1.5										1.5
2022	1.5	1.5									3.0
2023	1.5	1.5	1.5								4.5
2024	1.5	1.5	1.5	1.5							6.0
2025	1.5	1.5	1.5	1.5	1.5						7.5
2026	1.5	1.5	1.5	1.5	1.5	1.5					9.0
2027	1.5	1.5	1.5	1.5	1.5	1.5	1.5				10.5
2028	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5			12.0
2029	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5		13.5
2030	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	15.0
Total:											**82.5**

Section B4 of the Guidance on Article 7 provides a detailed description on how each of allowed four exemptions under paragraph 2 subject to paragraph 3 can be applied once the total amount of savings to be achieved has been established.

[120] SWD(2013) 451 final (section B2, page 5).