Study on the Energy Savings Potentials in EU Member States, Candidate Countries and EEA Countries

Final Report

for the European Commission

Directorate-General Energy and Transport

EC Service Contract Number TREN/D1/239-2006/S07.66640

Project Partners:

Fraunhofer-Institute for Systems and Innovation Research (Fraunhofer ISI) (Coordinator)

ENERDATA (Grenoble, France)

Institute of Studies for the Integration of Systems ISIS (Rome, Italy)

Technical University (Vienna, Austria)

Wuppertal Institute for Climate, Environment and Energy WI (Wuppertal, Germany)

Karlsruhe/Grenoble/Rome/Vienna/Wuppertal, 15. March 2009, revised

Disclaimer:

Important notice:

The energy efficiency potentials calculated in this report as well as those presented on the website related to the project (http://www.eepotential.eu/) are based on a scenario approach which underlies the calculations. The activity drivers underlying this scenario approach have been derived mainly from European Energy and Transport Trends to 2030 (Update 2005). This document was chosen as the basis for our work because it contained the most recent EU-wide projections available by the time. During the validation of the results of this potential study with a variety of EU Member States it was noted that some of the drivers in the EU projections deviate quite considerably from drivers used at the national level. The choice of the drivers naturally impacts on the energy efficiency potentials: in fact the larger a given driver, the larger the related energy efficiency potential. The authors do not necessarily view in the same way all the development of the drivers used at the EU level. However, in order to keep this document harmonised with the EU projections, we relied on the drivers as provided. In future efforts these differences need to be investigated further to improve the precision of the work.

Contact:

Wolfgang Eichhammer
Breslauer Str. 48, 76139 Karlsruhe, Germany
Phone: 0721/6809-158, Fax 0721/809-272
E-Mail: wolfgang.eichhammer@isi.fraunhofer.de
Web: www.isi.fraunhofer.de

Project staff:

Wolfgang Eichhammer, Fraunhofer ISI
Tobias Fleiter, Fraunhofer ISI
Barbara Schlomann, Fraunhofer ISI
Stefano Faberi, ISIS
Michela Fioretto, ISIS
Nicola Piccioni, ISIS
Stefan Lechtenböhmer, Wuppertal Institute
Andreas Schüring, Wuppertal Institute
Gustav Resch, TU Vienna

Contents

List of Figures

Page

List of Tables

Abbreviations

AP	Autonomous Progress
APS	Autonomous Progress Scenario
APS+RP	Autonomous Progress Scenario + Recent Policies
BAT	Best Available Technology
BNAT	Best Not Available Technology
boe	Barrel of oil-equivalent
CFL	Compact Fluorescent Lamps
CTP	Common Transport Policy
CRT	Cathodic Ray Tube
EE	Energy Efficiency
EPBD	European Performance of Buildings Directive
ESD	Directive 2006/32/EC on Energy End-use Efficiency and Energy Services ("Energy Service Directive" ESD)
EuP	Energy Using Product Directive
FED	Field Emission Display
HDV	Heavy Duty Vehicle
HPI	High Policy Intensity
HPI-S	High Policy Intensity Scenario
ICT	Information & Communication Technologies
IM	Intermediate (building stock)
LCD	Liquid Crystal Display
LED	Light Emitting Diodes
LLCC	Least Life Cycle Cost
LPI	Low Policy Intensity
LPI-S	Low Policy Intensity Scenario
M1	Passenger cars
MF	Multi-family (house)
N1	Light duty commercial vehicles, small vans
OLED	Organic Light Emitting Diods
RES	Renewable Energy Sources
SF	Single-family (house)
SHW	Sanitary Hot Water

Summary

Objectives of the analysis

During the last years fundamental changes have occurred that conveys to energy efficiency improvements and energy conservation an even larger importance than it already had in view of mitigating climate change: The oil price and other fossil fuels have reached during some period levels of up to 147 US$ per barrel before dropping again to less than half that level in expectation of a possible economic recession period. The extreme price volatility shows that there is shortage of energy supply and as soon as the world economy turns well, the shortness of fossil fuel carriers translates to higher energy prices. At the same time prices for input fuels to electricity generation have also risen considerably, driving electricity prices up for the consumer. In addition, the European Emission Trading Scheme (EU ETS) has induced a further increase in the electricity prices and will continue to do so in the post-Kyoto period after 2012. Lastly, on the policy side with the Directive 2006/32/EC on Energy End-use Efficiency and Energy Services (ESD) an important policy instrument was introduced for energy efficiency and needs to be filled with life despite some complexity in the determination of energy savings as compared to autonomous changes.

In this context a comprehensive analysis of the technical and the economic potentials appeared as necessary as without the realisation of these potentials the targets of the Energy Efficiency Directive cannot be reached. **The main focus of this report is to prepare the analytic basis for an in-depth discussion of economic energy efficiency potentials in the different energy-end uses**. The current high energy prices and possibly powerful energy efficiency policies can strongly enhance the uptake of energy efficient technologies and procedures. In addition, they may also trigger important innovation effects such as scale en learning effects that occur when energy efficiency technologies are used in a broad manner and that will drive the cost differential of more efficient technologies compared to less efficient technologies down.

This study therefore aimed:

- To estimate in a harmonised manner (technical and economic) energy savings potentials for each EU27 Member State, as well as for Croatia and for other countries of the European Economic Area EEA (Norway, Iceland and Liechtenstein).
- To develop a tool to assess national NEEAPs and to ascertain if they sufficiently take into account the existing energy savings potential within a country, and to identify the sectors where the national savings targets established under the ESD Directive can be met most cost effectively.

In order to achieve these two objectives the following main steps described in the following section have been carried out:

- to establish a common methodology for calculating energy savings potentials and its data requirements and to develop a harmonised and interacting energy savings potential calculation model based on the MURE simulation tool.
- to identify and present the energy savings potentials in a user-friendly way. For this purpose a database[1] was developed on the Internet capable of generating and presenting present and future energy savings potentials for each of the countries involved in this study as well as for suitable groupings such as the EU27, EU25, the EU15 and EU-12 (new Member States including Bulgaria and Romania) and the EEA countries as groups.

Methodology of the analysis

The general structure of the methodology used in the study to derive energy efficiency contains the following elements:

- The project and the central part of the evaluation of energy efficiency and energy savings potentials at the demand side is based on the bottom-up ***MURE simulation tool***. MURE (Mesures d'Utilisation Rationnelle de l'Énergie, www.mure2.com) has a rich technological structure for each of the four demand sectors (residential, transport, industry and services) in order to describe the impact of energy efficient technologies. The structure described in a technological manner in MURE comprises modules for:
    - Residential Sector Buildings
    - Residential Electric Appliances
    - Transport Sector
    - Industrial Sector: Processes
    - Industrial Sector: Electric Cross-cutting Technologies (pumps, ventilators, compressed air…)
    - Industrial Sector: Electric Cross-cutting Technologies (pumps, ventilators, compressed air…)
    - Service Sector Buildings
    - Service Sector Electric Appliances
    - IT Appliances (all sectors)
    - Demand-side CHP (all sectors)

[1] The database on Energy Saving Potentials (ESP Database) is currently available under restricted access at http://www.eepotential.eu/. After a broader review of the contents the EU Commission may decide on a public access to the database.

- We also determined the potentials for decentral renewables such as solar thermal collectors and decentral PV. We used for this purpose the **Green-X model** run by TU Vienna in cooperation with Fraunhofer ISI. It must be emphasised, however, that the main focus of the work has been on the final demand sectors, given that they are the focus of the EU Directive for Energy Efficiency and Energy Services. Biofuels used for the transport sector where not taken into account although they may potentially reduce green-house gas emissions.
- We developed a ***flexible and user-friendly database*** which (i) gathers the data inputs (scenario data and technology data) ***for communication with the MURE simulation model*** and (ii) ***allows for a suitable presentation and structuring of the main model inputs and results concerning the analysis of energy saving potentials for external communication purposes***. This database was developed newly based on the current input/output structures of the MURE demand simulation model.
- We developed further an interface that allows ***feeding data to the two input databases and the output database***. Again it is important to distinguish whether the data fed to the database are for communication with the models and the potential analysis or for external communication purposes. For the latter, data were prepared in a more aggregate manner allowing to present results in a user-friendly way. Concerning the technology database behind the potentials this relies mainly on updated information in the MURE simulation tool, on further national sources and on the Odyssee database, supported by additional information from auxiliary sectoral models such as the residential model run by the Wuppertal Institute or an industrial model run by Fraunhofer ISI. Concerning the scenario inputs we made use of the official projections and statistical data available at both the EU and the national levels although adaptations needed to be considered. However, we limited these adaptations to data not available in the PRIMES model used for the official EU projections in order to remain compatible, despite the fact that one or the other figure in the official projections could give rise to substantial debate (such as for example the future development of transport mobility which, in our view, appears largely overestimated. The Odyssee database was used as an essential tool to calibrate future scenario data as well as social drivers such as increased comfort factors, general rebound effects etc.

Classification of energy efficiency potentials and development of scenarios

The following Table shows a possible classification of the potentials to be calculated and the scenario approach derived from this classification. This classification distinguishes in a matrix approach the dependence of the potentials on drivers and policies to enhance technology diffusion on one hand (vertical classification in the matrix) and technological/economic restrictions on the energy savings potentials on the other hand (horizontal classification in the matrix).

Selection of energy saving potentials

		Restrictions on the energy saving potentials		
		Best available technologies and practices *	Cost-effectiveness for the whole country	Cost-effectiveness for the consumer with usual market conditions
		1	2	3
Dependence on drivers, technology innovation and policies to enhance technology diffusion	static	(X)	X	X
	Dynamic			
	(autonomous)	-	-	X
	(autonomous + recent policies)	-	-	X
	Dynamic (additional): (1) high barriers / high transaction costs (energy price or policy induced)	X	X	X
	Dynamic (additional): (2) low barriers / low transaction costs (energy price or policy induced)	X	X	X

Baseline (1) - Autonomous Progress + Older policies (APS)

Autonomous Progress + Recent Policies (APS+RP)

Technical Potential (4) (TP)

Economic Potential - High Policy Intensity (3) (HPI)

Economic potential - Low Policy Intensity (2) (LPI)

The **technological/economic restrictions on the energy savings potentials** can be distinguished as follows:

- *No restrictions, maximum technical potentials*: what can be achieved with the best available technologies available whatever the costs and prices.
- *Cost-effectiveness for the whole country*: what can be achieved with the best available technologies available, which are economic on a country-wide basis (typically a discount rate of 4 % could be used for energy saving investments for this case). Also barriers would be largely removed in such a context.

- *Cost-effectiveness for the consumer with usual market conditions*: what can be achieved with the best available technologies, which are economic for the consumer with the usual market conditions today and reflecting consumer preferences and barriers (typically a discount rate of 8-15 % or higher could be used for energy saving investments for this case).

In the vertical classification in the above matrix needs word "dynamic" has three dimensions:

- whether or not the energy saving potentials *depend on the future development of drivers* such as the economic or social development (e.g. the stock of existing buildings, appliances, equipment of a type may be increasing or decreasing over time etc.)
- whether or not the energy saving potentials takes into account that *technology diffusion is a process in time* which might occur autonomously during normal reinvestment cycles or could be influenced by market energy prices or energy efficiency policies
- whether or not *technological innovation* (learning by searching) and *scale effects* (learning by doing) is taken into account that leads to a decrease in the cost of energy saving technology over time.
- The dynamic dimensions of the potentials **lead to the necessity to define scenarios to realise the potentials**.

In order to reduce complexity in the definition of the potentials it was necessary to reduce the number of potential definitions to present a clear picture of the potentials.

- The **Static Potential** all in all does not appear as very meaningful, even considering the economics of the energy saving measures.
- Considering the **Dynamic Autonomous Potential** for energy savings appears as necessary, especially in the light of the Directive for Energy Efficiency and Energy Services, which tends to make a distinction between autonomous savings and policy-induced savings, although this distinction may lead to some subjective choices. The dynamic autonomous potential may also be titled in a short-hand way as the **Baseline**. As already mentioned previously the baseline excludes very recent policies where the success is not yet given for granted. In order to show the impacts of these policies, a variant was defined which adds the supposed impacts of the policies to the Autonomous Potential.
- In the third line of dynamic parameters in the Table the most adequate choice is a potential which is characterised by a **low policy intensity**, i.e. by considering an **additional technology diffusion of BAT beyond autonomous diffusion only to a realistic level driven by increases in market energy prices and comparatively low level energy efficiency policy meas-**

ures as in the past in many EU countries. In this case it is rather likely that consumer decisions will be motivated by cost-effectiveness criteria based on usual market conditions. Barriers to energy efficiency will persist.

- From the last line there are two types of potentials which are important in the selection: They describe the **additional technology diffusion of best energy saving technologies (BAT) to the maximum possible, either technically or economically**. In the case of maximum economic potentials the most suitable choice of the economic criteria is to consider cost effectiveness from a country perspective, given the fact that one can assume in such a case a **high policy intensity** which reduces transaction costs for the consumer by suitable measures. Barriers to energy efficiency are mostly removed.

For the calculation of these potentials the following three steps were carried out for each energy use:

- **Step 1: Set up saving options.** For this step it was necessary to define first possible saving options and then describe their technical performance as well as their possible penetration in the future
- **Step 2: Describe cost development.** For each of the technology options identified in the previous step it is necessary to describe the investment costs and maintenance costs of each option. These cost categories are described in general as differential costs compared to a standard technology or standard development, unless there is an acceleration of the investment cycle beyond the usual values. In such cases the full costs, or a larger cost may be applied to the options scaled to the acceleration of the penetration of the energy efficient technologies. In addition it is also necessary to consider that the differential costs will evolve dynamically over time. Over the past decade an important body of empirical evidence has been gathered on energy efficient demand technologies which shows this important effect.
- **Step 3: Set up the scenario mix.** The different options defined in Step 1 may generally be realised altogether in a certain mix up to a given time horizon. It is therefore necessary to describe different scenarios of how they mix, depending on the potential considered.

Drivers for the reference scenario

In order to ensure compatibility with official DG TrEn projections, it was decided to rely for this exercise on the choices of drivers of the baseline scenario calculated with the PRIMES model. From these projections drivers such as the number buildings, energy prices, the development of value added of industry etc was chosen in order to be consistent with these projections. However, the future development of unit consumptions, intensities etc. was allowed to evolve according to the knowledge implemented in the MURE model because otherwise it would have been difficult to maintain consistency in the figures. Hence it cannot be expected that the overall energy consumption evolves totally in the same way as in the PRIMES projections.

The version of the PRIMES projections used was European energy and transport: Trends to 2030 – Update 2007 [2]. The new baseline takes into account policy developments up to the end of 2006 and is based on higher energy import prices compared to the 2005 edition of the baseline.

Prices for EU imports of fossil fuels in $ / boe in US$2005

	2005	2010	2015	2020	2025	2030
Oil	54.5	54.5	57.9	61.1	62.3	62.8
Gas	34.6	41.5	43.4	46.0	47.2	47.6
Coal	14.8	13.7	14.3	14.7	14.8	14.9

Source: European Commission (2008)

The 2007 Baseline scenario includes policies and measures implemented in the Member-States up to the end of 2006. Differences with the present work may arise from the fact that the PRIMES baseline includes impacts from the building directive, while our baseline excludes the impacts from the Directive only the Autonomous Progress Scenario + Recent Policies does include this. On the other hand, in difference to previous PRIMES projections no success was assumed any more for the CO_2 agreement for cars, although some further progress was assumed.

Assumptions on discount rates used in this study are reported in the following table together with PRIMES discount rates. All these rates are in real terms, i.e. after deducting inflation.

Discount rates used in PRIMES and the present study

		Present study	
	PRIMES	LPI	HPI
industry	12%	30%	8%
services and agriculture	12%	8%	6%
Households	17.5%	8%	4%
Private passenger transport	17.5%	8%	4%
trucks and inland navigation	12%	8%	6%
Public transport energy investment	8%	8%	4%

Source: EU Commission (2008) for the PRIMES column

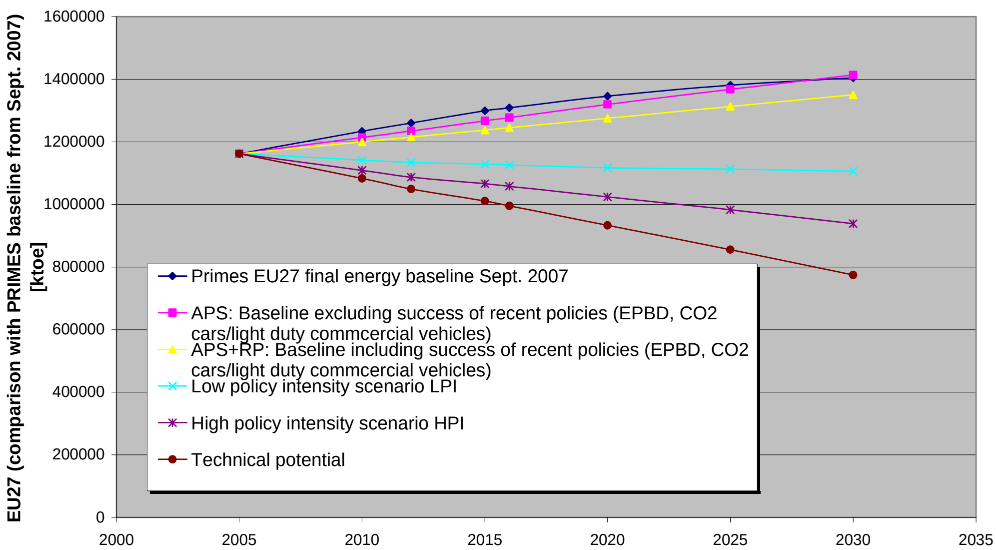
2 European Commission (2008): European energy and transport: Trends to 2030 – Update 2007. Luxembourg: Office for Official Publications of the European Communities, 2008. http://ec.europa.eu/dgs/energy_transport/figures/trends_2030_update_2007/index_en.htm

Results

Scenarios

- 4 scenarios were considered: **Autonomous Progress Scenario APS** (which comprises autonomous progress and earlier policies such as the labelling Directives for electric appliances but excluding the success of important recent EU policies which are not yet fully implemented such as the EU Performance Directive for Buildings and the CO2 standards for cars and light duty commercial vehicles). A **variant of the Autonomous Progress Scenario** which includes the success of these recent policies (**APS+RP**). **Low Policy Intensity Scenario LPI** (which implies continued high barriers to energy efficiency, a low policy effort to overcome the barriers and high discount rates for investments in energy efficiency). **High Policy Intensity Scenario HPI** (which implies removing barriers to energy efficiency, a high policy effort to overcome the barriers and low discount rates for investments, options are economic on a life cycle basis). **Technical Scenario** (includes also more expensive but still fairly realistic options; no exotic technologies).
- Energy price assumptions are conservative, for crude oil as the leading energy around 61$2005 in 2020 (real prices), 63$2005 in 2030 (real prices). The 61$ in 2020 implies a price of 83$ in nominal terms in 2020 (assuming an inflation rate of 2 % annually), while the 63 $ in 2030 correspond to 105 $ nominally in 2030.
- Final energy consumption is still on the rise in the APS+RP scenario. It stabilises in the LPI Scenario, while the HPI and the Technical Scenarios curb the final energy demand by 2020 as compared to the baseline (APS).

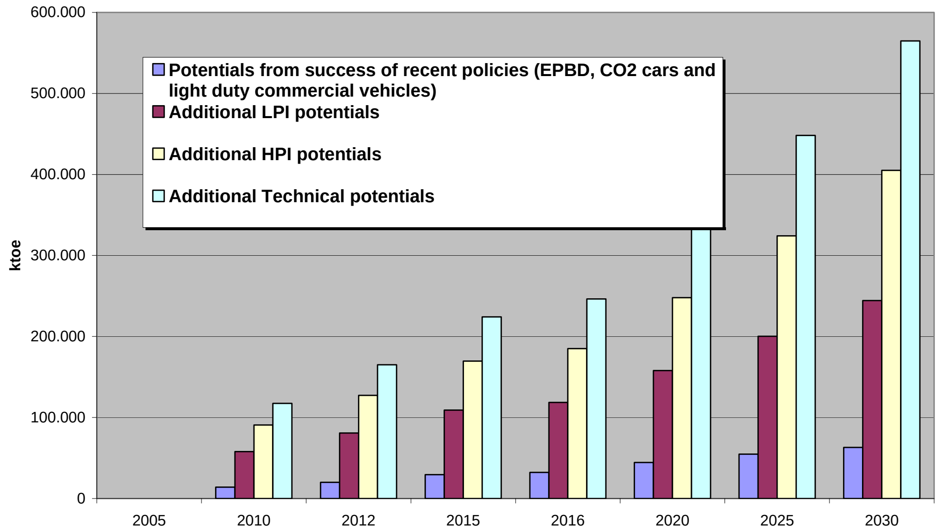
Scenario development and comparison with the PRIMES baseline



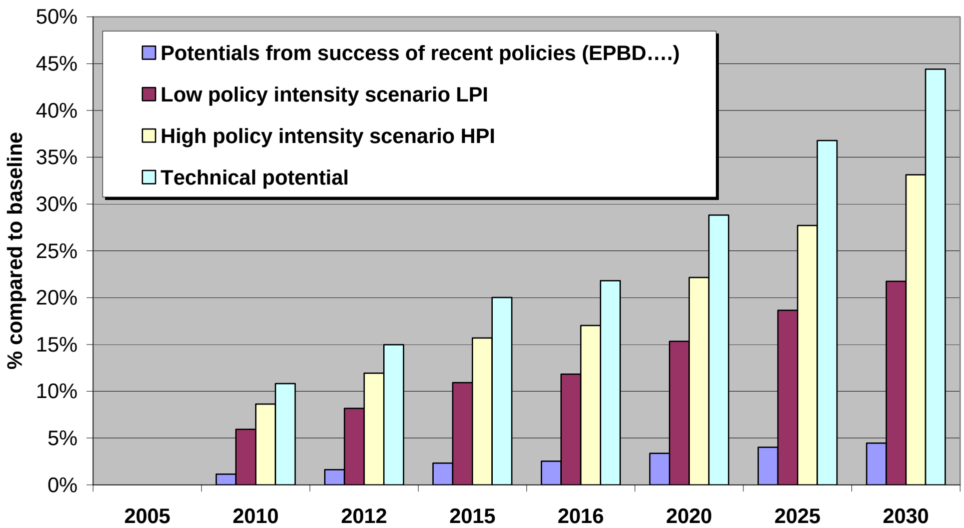
Potentials

- In 2020 the **LPI potentials** may reach 158 Mtoe for the EU27 (15 % compared to APS); in 2030 244 Mtoe (22 % compared to APS) are achievable in economic terms. In 2020 the **HPI potentials** may reach 248 Mtoe for the EU27 (22 % compared to APS); in 2030 405 Mtoe (33 % compared to APS) are achievable in economic terms. In 2020 the **Technical Potentials** may reach 336 Mtoe for the EU27 (29 % compared to APS); in 2030 565 Mtoe (44 % compared to APS) are achievable. Potentials from the (still supposed) success of recent policies (EPBD, CO2 standards for cars and light duty commercial vehicles) reach 44 Mtoe in 2020 and 63 Mtoe in 2030.

Energy efficiency potentials in the different scenarios (ktoe, compared to APS)



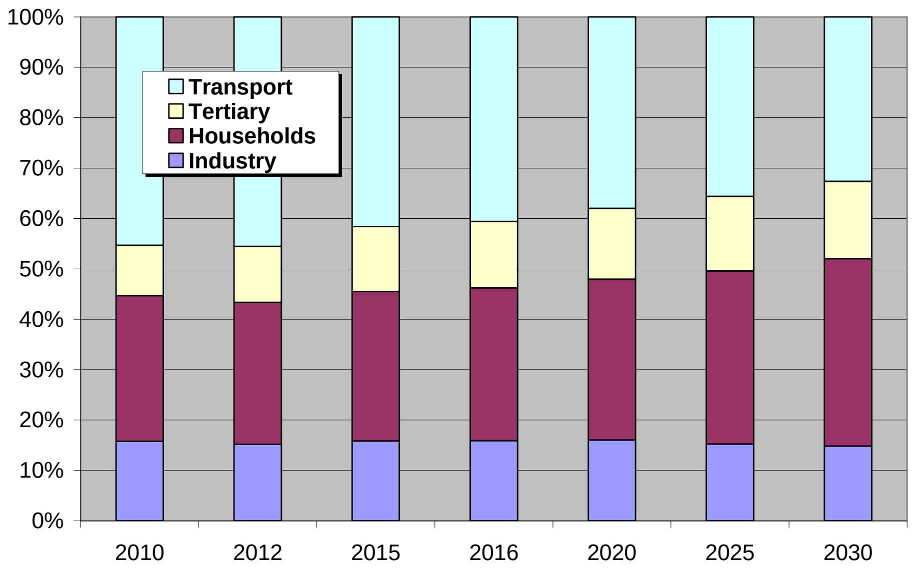
Energy efficiency potentials in the different scenarios (% compared to APS)



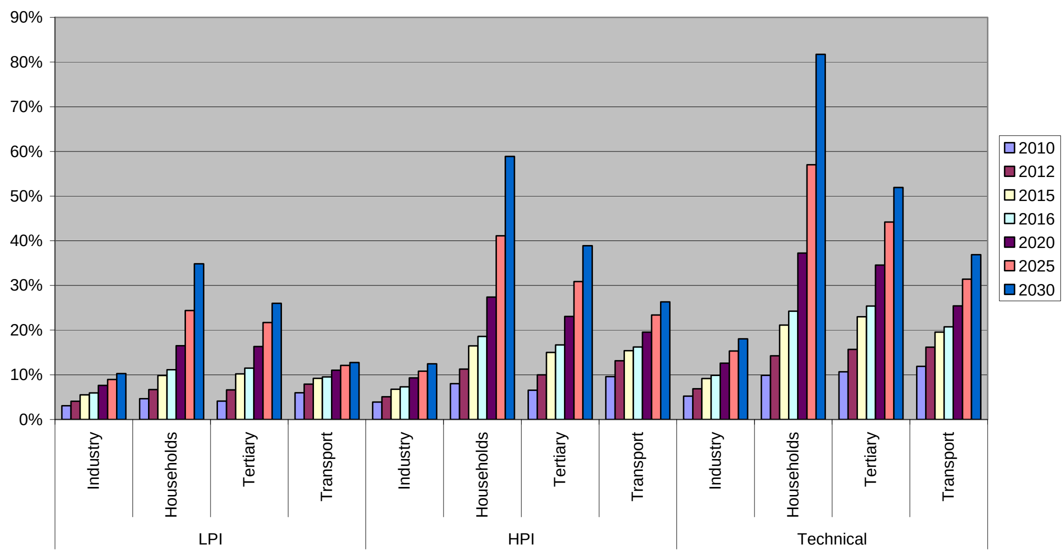
Sectoral contributions

- At the short term (2010) transport, non-EU ETS sectors (in particular cross-cutting technologies such as electric motor applications) and electric applications in the residential/tertiary sectors may have the largest potentials. At medium term (2020) the contribution from the building sector (residential and tertiary) to the potentials grows larger. The contribution of the buildings to the potentials is largest in the HPI and Technical Potential scenarios and for the longer term up to 2030. This would imply an early mobilisation of these potentials through measures due to the longer lead times.

Sectoral contributions to the potentials over time in relative terms



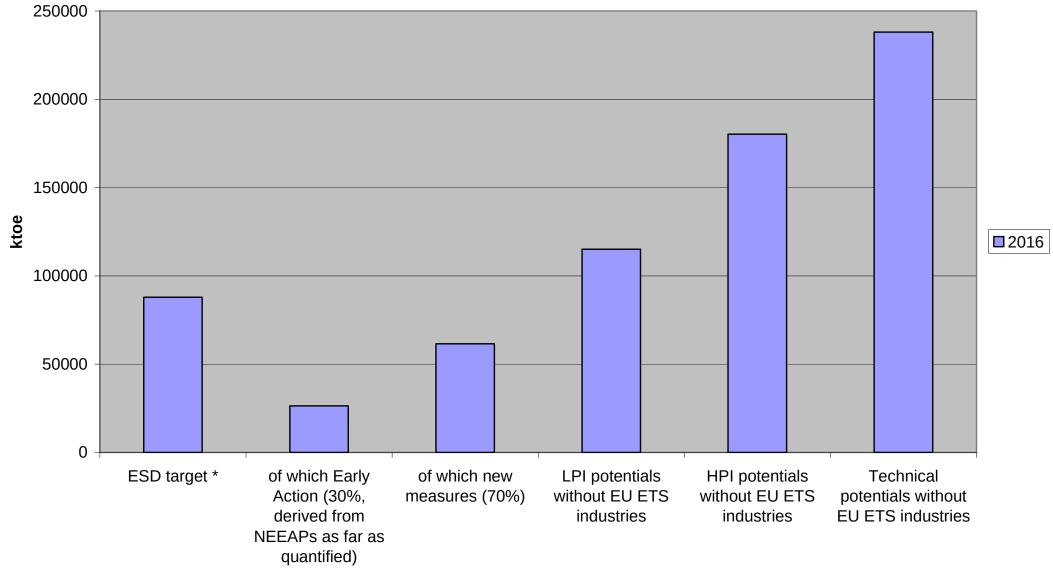
Sectoral potentials over time compared to the APS inpercent



Comparison with ESD Targets in 2016

- For the comparison with the 9 % target of the ESD, the target was calculated as average for the period 2001-2005 from Odyssee data, excluding EU ETS industries. It should be noted that the ESD target is calculated on a historic 5-years period while the potentials calculated here are calculated with respect to the Autonomous Progress Scenario.
- Potentials for this comparison are also without EU ETS industries. Potentials in non EU ETS sectors are considerably larger than for the EU ETS sector, especially for electricity
- If all proposed measures in the National Energy Efficiency Action Plans (NEEAPs) will be new measures than they represents an effort broadly in the range of the LPI scenario.
- Early action measures undertaken 1995 to 2007 are admitted under the ESD. They are not included in the potentials as calculated here. In fact, they are part of our baseline. If Early Actions represent 30 % which is rather realistic when looking at the NEEAPs then the new effort represents less than the LPI potentials. Some countries have even 50 % Early Action. This implies that between the new action and the HPI potentials there is still some gap open for further action in future NEEAPs. If there is in addition autonomous progress included in the actions than the effort is even less.

Comparison of the potentials (excluding EU ETS industries) with the targets of the Energy Service Directive in 2016

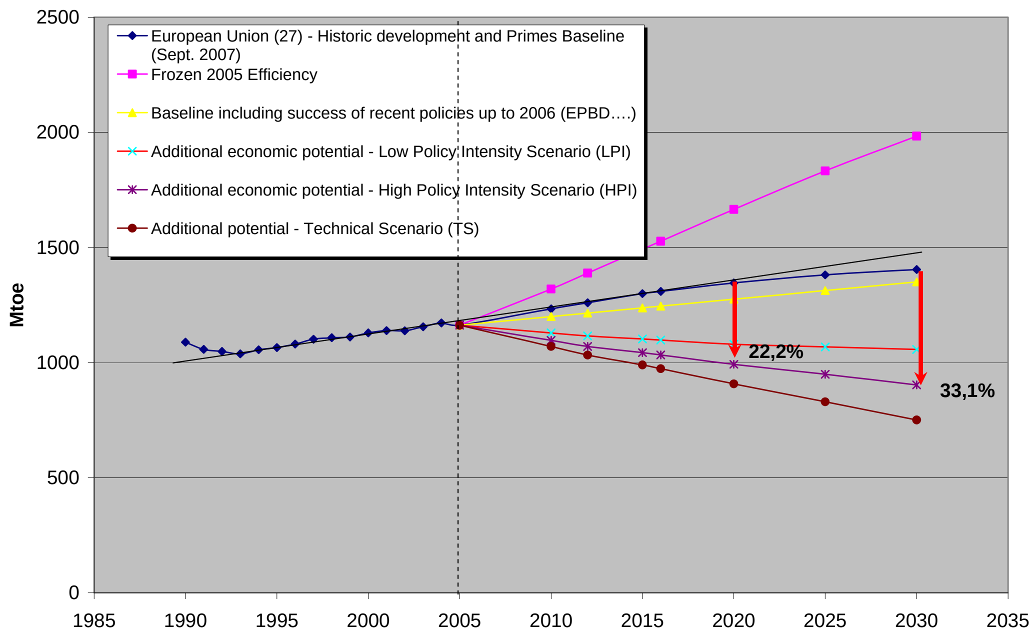


*(calculated from the Odyssee Indicators by excluding EU ETS Industry on a sectoral basis and averaging 2001-2005)

Comparison with 20% target in 2020

- The 20% target is a primary energy target hence includes also the conversion sector and renewables. For this reason it can not be really compared here to the potentials calculated here, which are pure demand side potentials.
- Nevertheless, the comparison of the potentials with the baseline in percentage points shows that even the HPI reaches 22% in 2020 that is the 20 % reduction target is rather demanding if it is to be reached by demand side measures only. Possibly additional measures on the primary energy side and renewable, or measures which are currently more expensive (and which are in the technical scenario) need to be taken on board.

Comparison of the potentials (including EU ETS industries) with the 20% target for energy of the EU Commission



PART I

Methodology and Overview of Results

1 Background and Objectives of the Study

1.1 Introduction

During the last years fundamental changes have occurred that conveys to energy efficiency improvements and energy conservation an even larger importance than it already had in view of mitigating climate change:

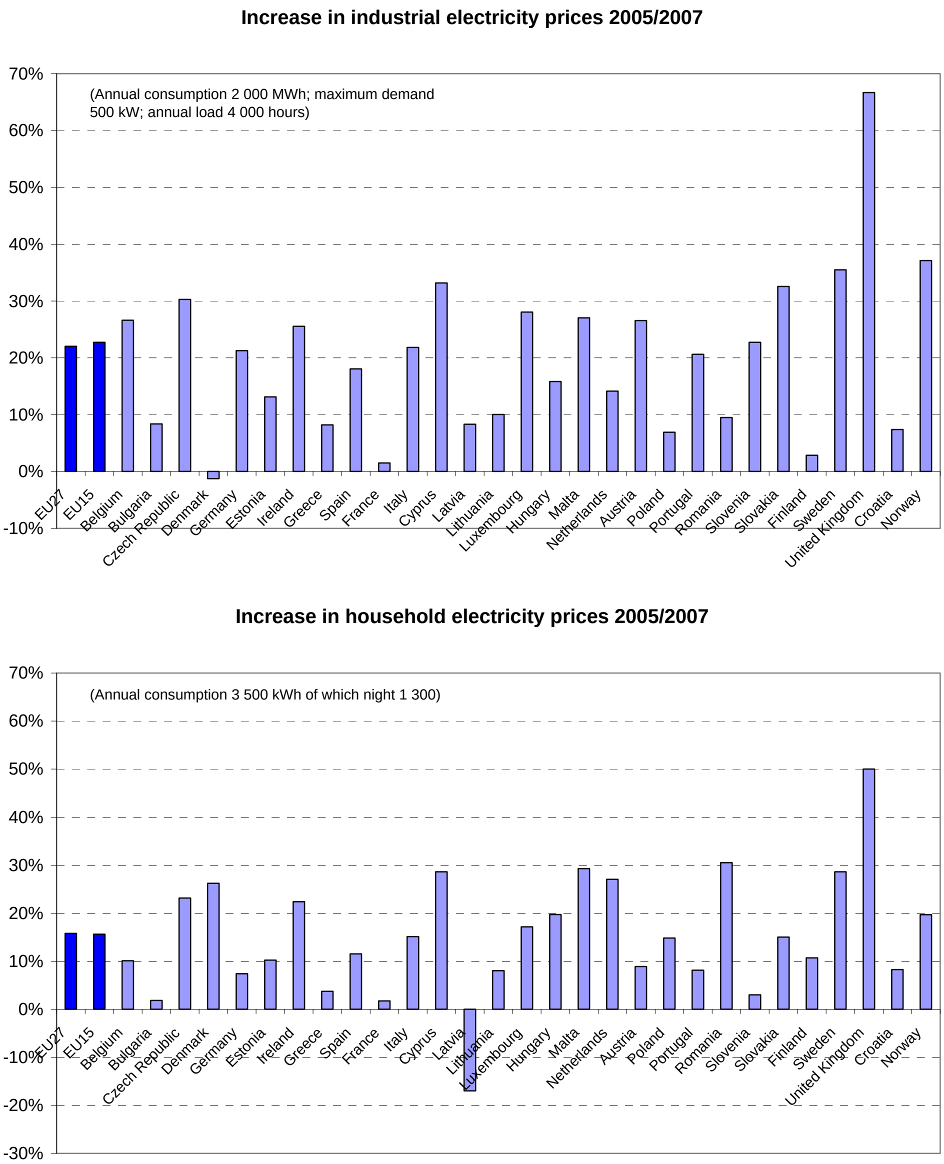
- The *oil price* has reached during some period levels of up to 147 US$ per barrel which a few years ago very few people believed possible. At the same time the prices for other energy carriers such as natural gas (but also for renewables such as wood pellets) have risen considerably. This development is due to various short and long-term factors and, although recent events such as the financial crises and the threat of an economic recession have driven the oil price down again to less than half that level (Figure 1-1), it is clear that the extended period of cheap energy during the late eighties and the nineties is definitely revolved. The extreme price volatility shows that there is shortage of energy supply and as soon as the world economy turns well, the shortness of fossil fuel carriers translates to higher energy prices.

Figure 1-1: Crude oil spot price North Sea Brent

Source: WTRG (October 2008), http://www.wtrg.com/daily/cbspot.gif

- At the same time prices for input fuels to electricity generation have also risen considerably, including coal prices. In addition, the *European Emission Trading Scheme (EU ETS)* has induced an increase in the electricity prices due to the fact that energy suppliers tend to integrate the price of allowances into their electricity prices. Electricity prices for both industrial and household consumers have risen considerably since 2005 (Figure 1-2), making electricity saving more attractive. It can be expected that with the announced drop in the prices of input fuels, electricity prices are going to recede once again but this may also not last for a long period and it can further be expected that with the continuation of the emission trading scheme after 2012 the pressure on prices will be increased if combating climate change is considered seriously.

Figure 1-2: Increase in electricity prices from 2005 to 2007

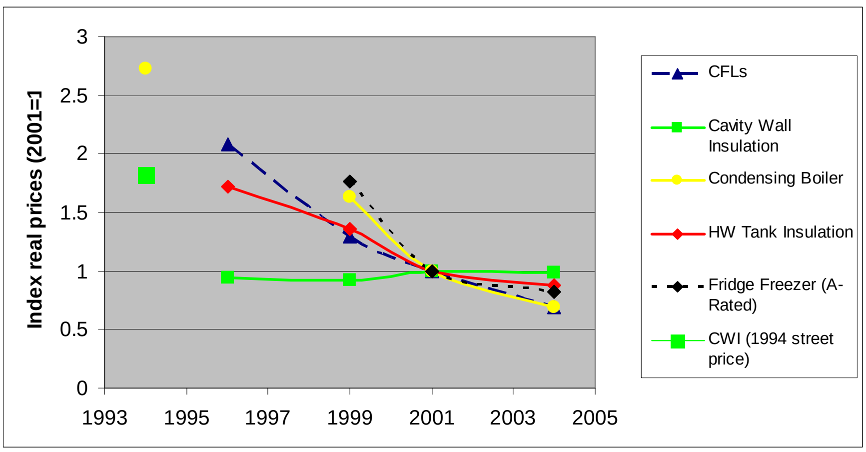


Source: Eurostat (October 2008)

- On the policy side, the most important event was, however that the *Directive 2006/32/ec of the European Parliament and of the Council of 5 April 2006 on Energy End-use Efficiency and Energy Services* (ESD) was published on 27 April 2006 (Official Journal EU L114, p64-85) and entered into force on 17 May. This Directive creates an institutional frame for energy efficiency improvements in all sectors and for energy services at the European level. In the follow-up of the Directive the European Commission intends to bring forward a European action plan for energy efficiency. In this frame, the EU Member States are required to realise through national Energy Efficiency Action Plans (NEEAPs) the economic potentials for the improvement of energy efficiency. The first of these NEEAPs were submitted in 2007 and early 2008. First assessments of the Member State Action Plans have been done by the European Commission.

The technical potentials for energy efficiency are enormous in all sectors: cars could reduce energy consumption by half without any change in comfort levels. Buildings, through the integration of renewables, could even become small "power houses" that produce net more energy than they consume. Much more important is, however, a realistic estimate at which costs these potentials can be realised beyond those potentials that are realised in an autonomous way anyhow. The current high energy prices can strongly enhance the uptake of energy efficient technologies and procedures. In addition, it is also important to describe the **innovation effects of such technologies and of the policy programmes to promote them**, as well as the scale effects that occur when energy efficiency technologies are used in a broad manner. For the Energy Efficiency Commitment and its predecessors in the UK for example it was observed that technologies such as condensing boilers, high-efficiency lamps, A-class refrigerators etc. underwent a cost reduction by up to a factor of 2-3 (Lees, 2006, see Figure 1-3).

Figure 1-3: Price development (real prices) of energy saving technologies during various energy efficiency programmes in the UK



Source: Lees (2006)

1.2 Objectives of the study

In this context a comprehensive analysis of the technical and the economic potentials appeared as necessary as without the realisation of these potentials the targets of the Energy Efficiency Directive cannot be reached. The analyses of the energy savings potentials may help to support the implementation of the ESD. In particular the results of such an analysis will help to assess the energy efficiency improvement measures drawn up in the national NEEAPs considering the national technical and cost effective (economic) energy savings potential. The potentials may also be used to justify additional measures for energy efficiency on the European level and the priority for such measures. **Nevertheless, the main focus of this report is to prepare the analytic basis for an in-depth discussion of economic energy efficiency potentials in the different energy-end uses**.

This study therefore aimed to achieve the following main objectives:

- To estimate in a harmonised manner (technical and economic) energy savings potentials for each EU27 Member State (including Romania and Bulgaria who entered the European Union in 2007), for the so far remaining candidate country Croatia, and for each European Economic Area EEA country (Norway, Iceland and Liechtenstein).
- To provide the Commission with a tool to assess national NEEAPs and to ascertain if they sufficiently take into account the existing energy savings potential within a country, and to identify the sectors where the national savings targets established under the ESD Directive can be met most cost effectively.

In order to achieve these two objectives the following main steps described in the following section have been carried out:

- to establish a common methodology for calculating energy savings potentials and its data requirements
- to identify and present the energy savings potentials in a user-friendly way

The outcome of the study was therefore, next to a harmonised and interacting energy savings potential calculation model based on the MURE simulation tool, a database[3] capable of generating and presenting present and future energy savings potentials for each of the countries involved in this study as well as for suitable groupings such as the EU27, EU25, the EU15 and EU-12 (new Member States including Bulgaria and Romania) and the EEA countries as groups.

---

[3] The database on Energy Saving Potentials (ESP Database) is currently available under restricted access at http://www.eepotential.eu/. After a broader review of the contents the EU Commission may decide on a public access to the datbase.

2 Overview of the Approach and the Report

In the frame of the project the following steps were carried out:

- Detailed specifications of the methodology chosen, definition of scenario philosophy and description of the general database structure.
- Calibration of the scenarios and parameters/data to derive the technical and economical energy savings potentials in coherence with existing official Commission projections.
- Calculation of the present and future technical and cost-effective energy savings potentials according to each scenario.
- Gathering and preparation of data in view of its intended use to communicate the analysis on energy saving potentials.
- Development and programming of a database that allows displaying potentials and related information (technology database, scenario database and output database).
- Preparation of the present report on the analysis of potentials for the EU27 and the EEA countries.

This approach and its results are described more in detail in the following sections:

- Chapter 3 gives an overview on the general methodology used in this project to evaluate the potentials by country.
- Chapter 4 discusses the data used to develop the reference scenario for the study
- Chapter 5 provides an overview on the main results
- Chapters 6 to 10 present the approach, the data used and the detailed results for the different end-use sectors (residential sector, transport, industry, and tertiary sector).
- Chapter 11 describes the ESP Database developed in the course of the project.

3 General description of the methodology for the calculation of the potentials and scenario philosophy

3.1 General structure of the methodology

The general structure of the methodology used in the study to derive energy efficiency potentials is described in Figure 3-1. It contains the following elements:

- The project and the central part of the evaluation of energy efficiency and energy savings potentials at the demand side is based on the bottom-up ***MURE simulation tool***. MURE (Mesures d'Utilisation Rationnelle de l'Énergie) has a rich technological structure for each of the four demand sectors (residential, transport, industry and services) in order to describe the impact of energy efficient technologies. Only a simulation model with sufficient technological details such as MURE is well adapted to the purpose. Macro- and General Equilibrium models do not have enough details in their sectoral representation for the required work. During the work performed we enrich the technological details of the model further to include more details on electric appliances and in particular on IT appliances and IT infrastructures such as servers, as well as on industrial cross-cutting technologies such as electric motors. The MURE simulation model and its link to the MURE database on Energy Efficiency Measures, which is available on the Internet (www.mure2.com) are briefly described in the following **Box 3-1**. For more details see Annex 1. The structure described in a technological manner in MURE comprises modules for:
    - Residential Sector Buildings
    - Residential Electric Appliances
    - Transport Sector
    - Industrial Sector: Processes
    - Industrial Sector: Electric Cross-cutting Technologies (pumps, ventilators, compressed air…)
    - Industrial Sector: Electric Cross-cutting Technologies (pumps, ventilators, compressed air…)
    - Service Sector Buildings
    - Service Sector Electric Appliances
    - IT Appliances (all sectors)
    - Demand-side CHP (all sectors)
- We also determined the potentials for decentral renewables such as solar thermal collectors and decentral PV. We used for this purpose the **Green-X**

model run by TU Vienna in cooperation with Fraunhofer ISI. This model was used extensively to determine renewables potentials in the past. This model is briefly described in the following **Box 3-2**. For more details see Annex 2. It must be emphasised, however, that the main focus of the work has been on the final demand sectors, given that they are the focus of the EU Directive for Energy Efficiency and Energy Services. Biofuels used for the transport sector where not taken into account although they may potentially reduce green-house gas emissions.

- We developed a ***flexible and user-friendly database*** which (i) gathers the data inputs (scenario data and technology data) ***for communication with the MURE simulation model*** and (ii) ***allows for a suitable presentation and structuring of the main model inputs and results concerning the analysis of energy saving potentials for external communication purposes***. This database is developed newly based on the current input/output structures of the MURE demand simulation model.

- We developed further an interface that allows ***feeding data to the two input databases and the output database***. Again it is important to distinguish whether the data fed to the database are for communication with the models and the potential analysis or for external communication purposes. For the latter, data were prepared in a more aggregate manner allowing to present results in a user-friendly way. Concerning the technology database behind the potentials this relies mainly on updated information in the MURE simulation tool, on further national sources and on the Odyssee database, supported by additional information from auxiliary sectoral models such as the residential model run by the Wuppertal Institute or an industrial model run by Fraunhofer ISI. Concerning the scenario inputs we made use of the official projections and statistical data available at both the EU and the national levels although adaptations needed to be considered. However, we limited these adaptations to data not available in the PRIMES model used for the official EU projections in order to remain compatible, despite the fact that one or the other figure in the official projections could give rise to substantial debate (such as for example the future development of transport mobility which, in our view, appears largely overestimated. The Odyssee database was used as an essential tool to calibrate future scenario data as well as social drivers such as increased comfort factors, general rebound effects etc.

Box 3-1: Main features of MURE (Mesures d'Utilisation Rationnelle de l'Énergie)

The MURE tool used for the analysis of energy efficiency and energy saving potentials on the demand side in the EU27 and has three main components:

- A **qualitative database** of energy efficiency measures set up for the EU Member States and the EU as a central entity to promote energy conservation in 4 end-use sectors: Households, Transport, Industry and Service Sector) and for cross-cutting measures. Measures may be legislative, normative, fiscal and financial, but also information campaigns, energy audits, negotiated agreements etc.
- A **quantitative database** of energy related statistics covering the EU Countries, disegregated by end-use sector.
- A **simulation tool** to carry out calculations of energy savings and emissions reduction potentials in each of the four final demand sectors and a supply module.

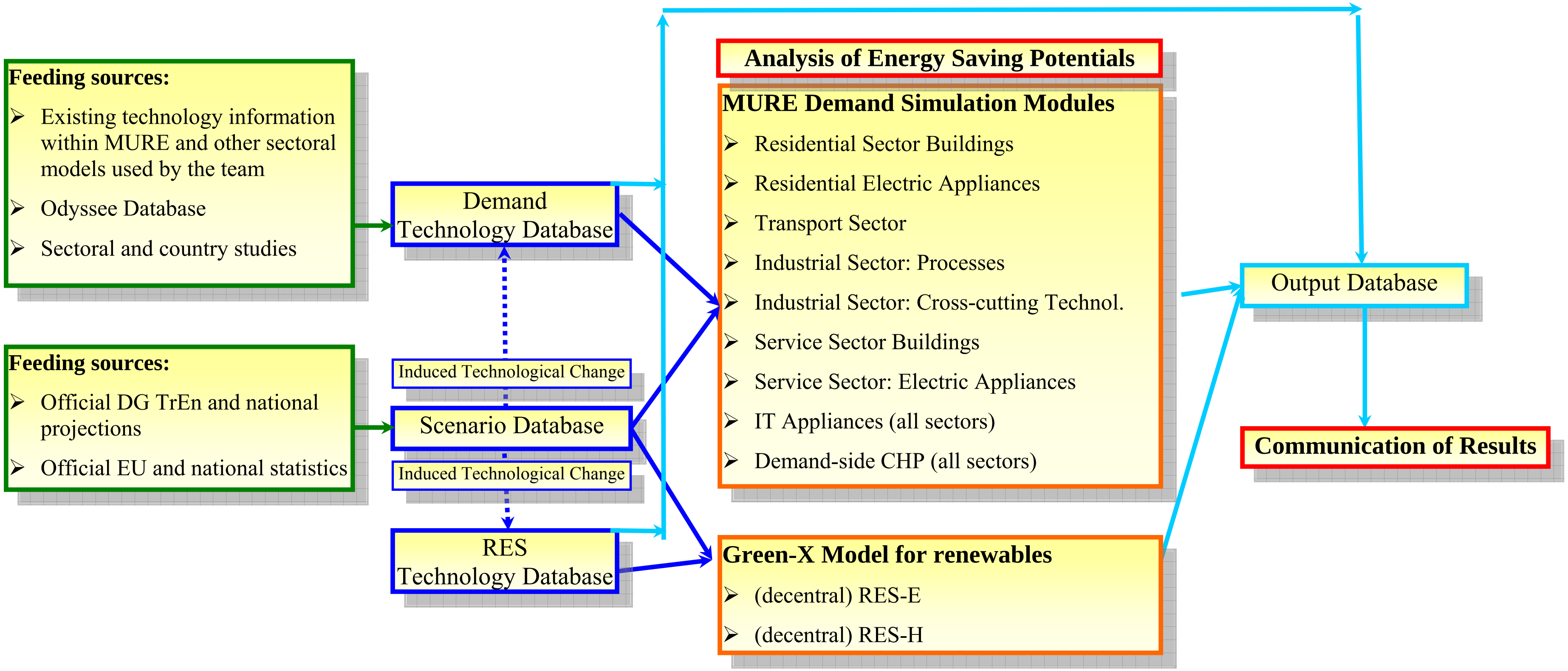
The database of measures currently includes some 1200 items, consistently described and classified according to specific keywords, thus allowing carrying out queries based on such descriptors as, e.g. the nature of the measure, the targeted audience, the technologies involved, etc.

MURE has given substantial inputs to the development of the Directive on the Energy Performance of Buildings (2002/91/EC). It has also been used in the establishment of the *Action Plan to improve Energy Efficiency in the European Community* (COM (2000) 247).

Box 3-2: Main features of Green-X

The Green-X model provides back-up for the analysis of renewable energy (RES) potentials. It covers EU27 as well as Croatia. It enables a comparative and quantitative analysis of the future deployment of RES in all energy sectors (i.e. electricity - grid-connected and non-grid, heat and transport) based on applied energy policy strategies in a dynamic context. In this context, the impact of conventional generation within each sector is described by exogenous forecasts of reference energy prices on country level. Within the model Green-X, the most important RES-E, RES-H technologies and RES-T options are described for each investigated country by means of dynamic cost-resource curves. Dynamic cost curves are characterised by the fact that the costs as well as the potential for electricity generation / demand reduction can change each year. The magnitude of these changes is given endogenously in the model, i.e. the difference in the values compared to the previous year depends on the outcome of this year and the (policy) framework conditions set for the simulation year. Green-X has given substantial inputs to the evaluation and further development of renewables promotion schemes in the frame of the projects FORRES 2020, OPTRES and was the bases of the EU Communication on renewables.

Figure 3-1: Scheme for the evaluation of energy efficiency potentials and for the communication of results



3.2 Classification of energy efficiency potentials

It is first necessary to clarify language and to set up a definition of energy efficiency potentials. Table 3-1 shows a possible classification of the potentials to be calculated. This classification distinguishes in a matrix approach the dependence of the potentials on drivers and policies to enhance technology diffusion on one hand and technological/economic restrictions on the energy savings potentials on the other hand. Generally spoken, energy savings potentials will be smallest in the right part of the matrix and largest in the left part of the matrix (the dependence of the size of the potential on the vertical classification is more complex, depending on the way how different drivers might develop and impact on energy saving potentials).

Table 3-1: Classifying energy saving potentials according to restrictions on the potentials and the dependence on drivers and policies

		Restrictions on the energy saving potentials		
		Best available technologies and practices *	Cost-effectiveness for the whole country	Cost-effectiveness for the consumer with usual market conditions
		1	2	3
Dependence on drivers, technology innovation and policies to enhance technology diffusion	static	(X)	X	X
	Dynamic (autonomous) (autonomous + recent policies)	- -	- -	X X
	Dynamic (additional): (1) high barriers / high transaction costs (energy price or policy induced)	X	X	X
	Dynamic (additional): (2) low barriers / low transaction costs (energy price or policy induced)	X	X	X

* Note: One could also work with less ambitious benchmarking technologies to derive potentials (for example the average efficiency of the current market). However, this would not show the full scope of the potential open to policies. Also it can be alternatively reflected in lower diffusion rates of the best available technologies.

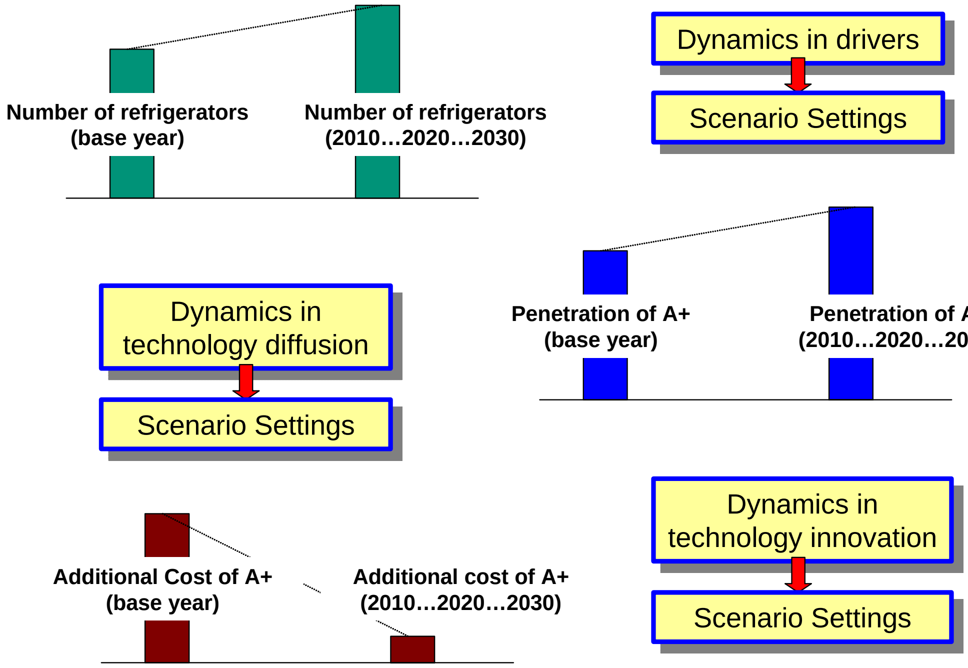
The **technological/economic restrictions on the energy savings potentials** can be distinguished as follows:

- *No restrictions, maximum technical potentials*: what can be achieved with the best available technologies available whatever the costs and prices.
- *Cost-effectiveness for the whole country*: what can be achieved with the best available technologies available, which are economic on a country-wide basis (typically a discount rate of 4 % could be used for energy saving investments for this case). Also barriers would be largely removed in such a context.
- *Cost-effectiveness for the consumer with usual market conditions*: what can be achieved with the best available technologies, which are economic for the consumer with the usual market conditions today and reflecting consumer preferences and barriers (typically a discount rate of 8-15 % or higher could be used for energy saving investments for this case).

The vertical classification in the above matrix needs first a note on what is understood by **"dynamic"**. In fact the word "dynamic" has three dimensions (Figure 3-2):

- whether or not the energy saving potentials *depend on the future development of drivers* such as the economic or social development (e.g. the stock of existing buildings, appliances, equipment of a type may be increasing or decreasing over time etc.)
- whether or not the energy saving potentials takes into account that *technology diffusion is a process in time* which might occur autonomously during normal reinvestment cycles or could be influenced by market energy prices or energy efficiency policies
- whether or not *technological innovation* (learning by searching) and *scale effects* (learning by doing) is taken into account that leads to a decrease in the cost of energy saving technology over time.

Figure 3-2: Explanation of the notion "dynamic"



The dynamic dimensions of the potentials **lead to the necessity to define scenarios to realise the potentials**. This issue will be more discussed in detail further on.

In order to simplify the multiple dimensions opened up by these three facets, the vertical classification in the above matrix reduces them to three major distinctions:

- The *static potential does not consider any of the three dynamic dimensions* discussed above. The question behind is: How much energy would be saved, if all end-use technology, buildings etc, existing today (in the base year) would at once be replaced by the best available technology (BAT)? It is purely based on the current structures and does not consider any scenarios, e.g. for GDP or other drivers, except for possible variations in energy prices in columns 2 and 3. Especially in combination with no economic restrictions on the potentials (column 1) this leads to enormous potentials (e.g. more than 100 % with the buildings if one would combine low-energy houses with decentral energy generation from renewables), which is not very useful in the frame of the project.
- The *dynamic potential (autonomous)* in the second line takes the three dynamic dependences into account but considers that *technology diffusion in time is only driven in an autonomous way*. The question behind is: How much MORE energy would be saved by the year 20## (compared to frozen efficiency), if during renovation cycles or in new installations each year between now and 20## a certain part of investments in end-use technology,

buildings etc. would be in BAT. These investments would occur in an autonomous way; it can therefore be assumed that they are in any case cost-effective for the consumer with usual market conditions, and relate to the baseline scenario. Columns 1 and 2 are therefore empty. It should be noted that this potential also includes in principle the impacts of policies previous to a recent cut-off year. This may, however, be problematic in cases where ambitious policies have been implemented recently, for example with the CO_2 standards for cars or the Energy Performance Directive for Buildings. The (supposed) success of these policies would then be included in the reference development and given for granted. The remaining potentials may then appear as reduced. However, the success of these policies still needs a lot of efforts. It was therefore decided to introduce an additional scenario (autonomous progress + recent policies) which includes the impacts if the policies succeed. In this report, the potentials were, however, systematically calculated with respect to the Autonomous Progress Scenario without the still uncertain outcome of these policies. Only in cases where the policies had been implemented years ago and have already shown their success as in the case of labelling policies for electric appliances, their future impacts were included in the reference development (i. e. due to the labelling policies of the past there is still some future trend towards A+/A++ refrigerators etc.)

- The third line, too, takes the three dynamic parameters into account but considers *additional technology diffusion of BAT only to a realistic level driven by increases in market energy prices and energy efficiency policy measures*[4]. The question here is: During renovation cycles or in new installations each year between now and 20##, WHICH ADDITIONAL SHARE of investments in end-use technology, buildings etc, can be moved to BAT (and at which cost) compared to the autonomous development. And how much MORE energy would thus be saved by the year 20##? The drivers would be further EU and/or national policies and/or changes in energy market prices.

- The fourth line takes also the three dynamic parameters into account and considers *additional technology diffusion of BAT to the maximum possible*. The maximum, here, is only limited either by technical limits (e.g., the availability of natural gas); or economic limits from either the whole country or the consumer perspective. The question here is: How much MORE energy could hypothetically be saved by the year 20## compared to the autonomous development, if ALL investments in end-use technology, buildings etc, were moved to BAT (and at which cost) during renovation cycles or in new installations each year between now and 20##? This is a maxi-

4 Note: including the impacts of energy prices in this line might be a subject of debate. However, it appears as useful to separate price-induced changes in the diffusion of technologies from autonomous change given the large variation observed in energy prices over time)

mum that in practice may not be fully reached unless most barriers are removed by instruments; but it is good to know how large the “space” for policy could be at all.

3.3 Operational definition of energy efficiency potentials

Nevertheless, despite the already reduced complexity in the definition of the potentials in the previous section it was necessary to reduce the number of potential definitions in order to present a clear picture of the potentials (see Table 3.2). This reduction in the number of potentials will be justified in this section.

- The **Static Potential** all in all does not appear as very meaningful, even considering the economics of the energy saving measures. The technical static potentials anyhow lead to rather large figures as said above. Static potentials by definition do not consider drivers or technology learning and may therefore be rather far away from any realistic potential. It is also quite difficult to add such static potentials up. For these reasons, none of the static potentials of the first row have been considered further.
- Considering the **Dynamic Autonomous Potential** for energy savings appears as necessary, especially in the light of the Directive for Energy Efficiency and Energy Services, which tends to make a distinction between autonomous savings and policy-induced savings, although this distinction may lead to some subjective choices. Methodologies used to find out about autonomous developments are in particular interviews with technology experts in the field or econometric analysis. For the dynamic autonomous potential only the third column is relevant because the autonomous consumer choices are determined by individual investment criteria. The dynamic autonomous potential may also be titled in a short-hand way as the **Baseline**. As already mentioned previously the baseline excludes very recent policies where the success is not yet given for granted. In order to show the impacts of these policies, a variant was defined which adds the supposed impacts of the policies to the Autonomous Potential.
- In the third line of dynamic parameters in Table 3-2 the most adequate choice is a potential which is characterised by a **low policy intensity**, i.e. by considering an **additional technology diffusion of BAT beyond autonomous diffusion only to a realistic level driven by increases in market energy prices and comparatively low level energy efficiency policy measures** as in the past in many EU countries. In this case it is rather likely that consumer decisions will be motivated by cost-effectiveness criteria based on usual market conditions. Barriers to energy efficiency will persist.
- From the last line there are two types of potentials which are important in the selection: They describe the **additional technology diffusion of best energy saving technologies (BAT) to the maximum possible, either tech-**

nically or economically. In the case of maximum economic potentials the most suitable choice of the economic criteria is to consider cost effectiveness from a country perspective, given the fact that one can assume in such a case a **high policy intensity** which reduces transaction costs for the consumer by suitable measures. Barriers to energy efficiency are mostly removed.

Table 3-2: Final selection of energy saving potentials

		Restrictions on the energy saving potentials		
		Best available technologies and practices *	Cost-effectiveness for the whole country	Cost-effectiveness for the consumer with usual market conditions
		1	2	3
Dependence on drivers, technology innovation and policies to enhance technology diffusion	static	(X)	X	X
	Dynamic			
	(autonomous)	-	-	X
	(autonomous + recent policies)	-	-	X
	Dynamic (additional): (1) high barriers / high transaction costs (energy price or policy induced)	X	X	X
	Dynamic (additional): (2) low barriers / low transaction costs (energy price or policy induced)	X	X	X

Baseline (1) - Autonomous Progress + Older policies (APS)

Autonomous Progress + Recent Policies (APS+RP)

Technical Potential (4) (TP)

Economic Potential - High Policy Intensity (3) (HPI)

Economic potential - Low Policy Intensity (2) (LPI)

3.4 Three steps for the calculation of potentials

In the previous section, the following choice of four types of potentials was motivated:

- Potential 1: Baseline (autonomous development, high discount). Variant: autonomous potential + impact of recent policies
- Potential 2: Economic potential - low policy intensity (low additional penetration / high discount)
- Potential 3: Economic potential - high policy intensity (high additional penetration / low discount)
- Potential 4: Technical potential

For the calculation of these potentials the following three steps were carried out for each energy use:

- **Step 1: Set up saving options.** For this step it was necessary to define first possible saving options and then describe their technical performance as well as their possible penetration in the future, see the example of washing machines in Figure 3-3). There are different possibilities to define the future developments. For example in Figure 3-3 the possible target values may reach from the average on the market in 2004 (column "1"), to the performance of an A-class appliance (column "2), of a possible A+-class appliance (column "3"; officially such an A+-class does not exist for washing machines but only for refrigerators but unofficially such a class is used by the manufacturers because most washing machines are now A-class) or of the best appliance on the market (column "4"). The saving potential of each option may be measured against the base year value of the stock (**frozen efficiency**) or may also evolve dynamically over time. In fact, the average evolution of the market (column "1) may be the yard stick for the other technology options.
- **Step 2: Describe cost development**. For each of the technology options identified in the previous step it is necessary to describe the investment costs and maintenance costs of each option (example in Figure 3 4). These cost categories are described in general as differential costs compared to a standard technology or standard development, unless there is an acceleration of the investment cycle beyond the usual values. In such cases the full costs, or a larger cost may be applied to the options scaled to the acceleration of the penetration of the energy efficient technologies. In addition it is also necessary to consider that the differential costs will evolve dynamically over time. Over the past decade an important body of empirical evidence has been gathered on energy efficient demand technologies which shows this important effect (see the different examples presented in Figure 3-6 to Figure 3-12. This leads in general, at least for mass produced energy efficient products, to the development de-

scribed in Figure 3-13, which indicates that after some time for example after 10 years in the case of energy efficient A-class devices), the price differential will have been diminished considerably or even be reduced to zero.

Figure 3-3: Step 1: Define individual saving options (Example "Electric appliances – washing machines")

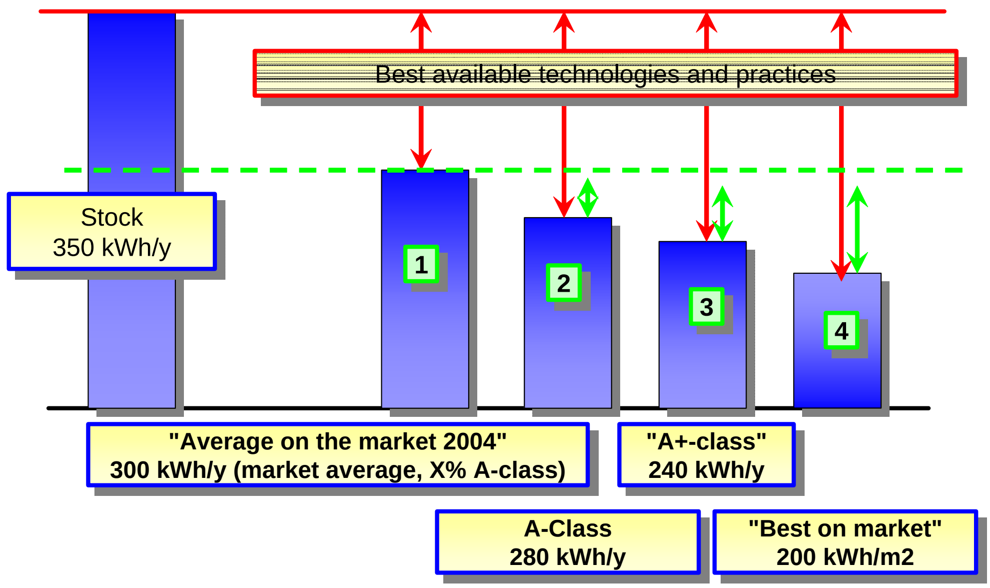
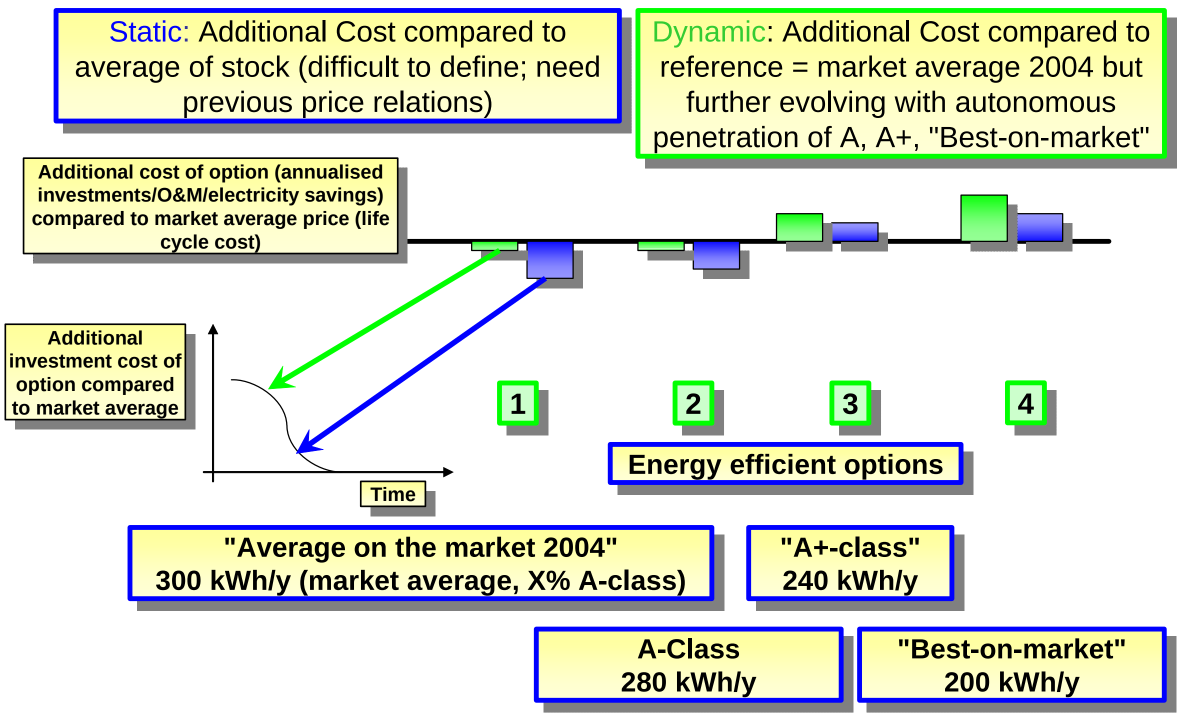


Figure 3-4: Step 2: Define the costs of the saving options (Example "Electric appliances – washing machines")



➢ **Step 3: Set up the scenario mix.** The different options defined in Step 1 may generally be realised altogether in a certain mix up to a given time horizon. It is therefore necessary to describe different scenarios of how they mix, depending on the potential considered, as described in the previous sections, see the example in Figure 3-5, where packages are defined for existing buildings or for new buildings and then mixed together in a certain share of the market.

Figure 3-5: Step 3: Set up the scenario mix (Example "Existing Single Family Houses")

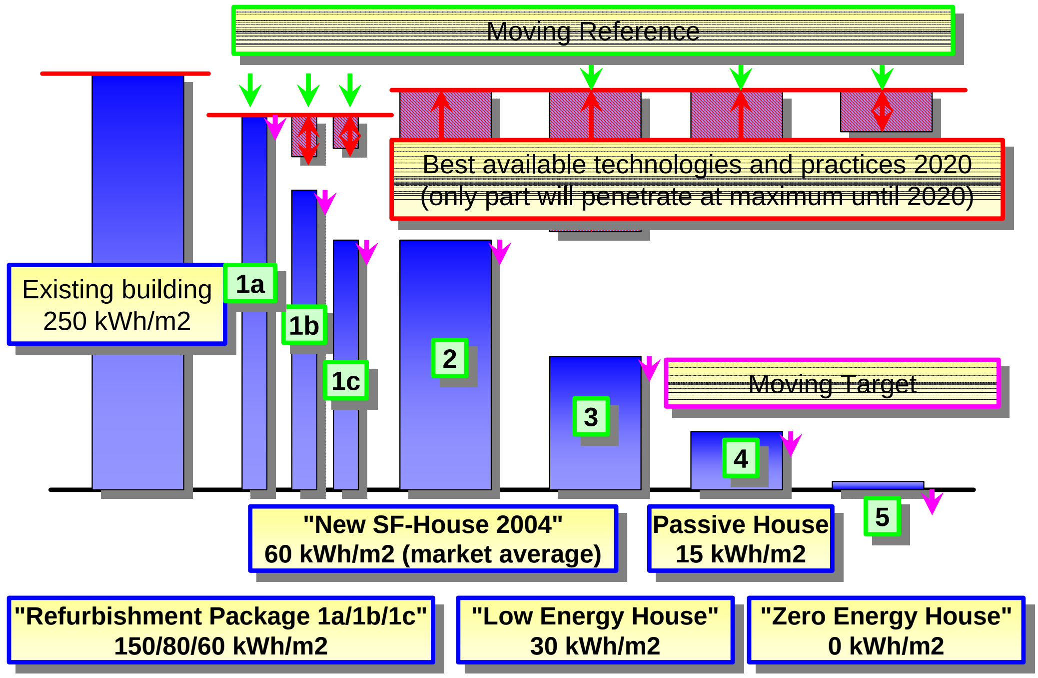
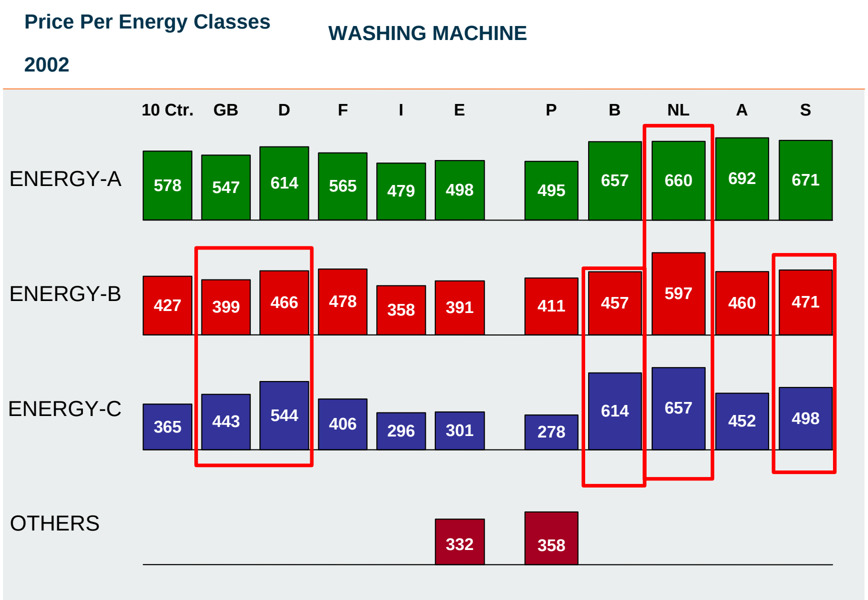
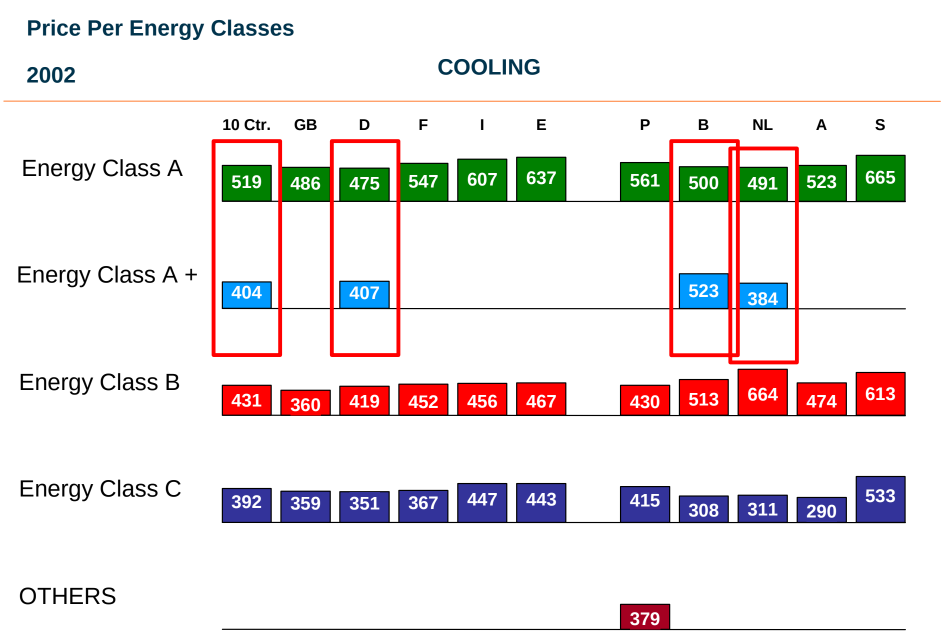


Figure 3-6: Do energy efficient washing machines really cost more?



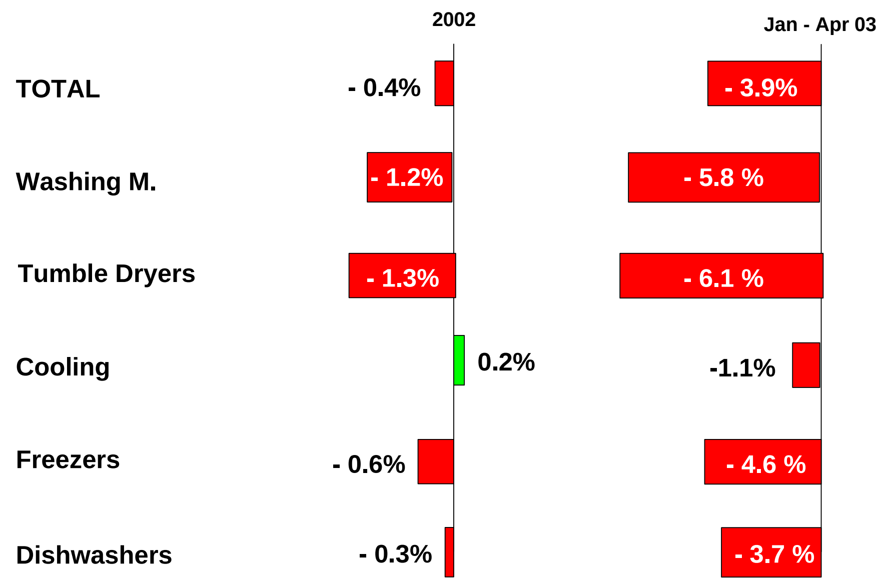
Source: GfK (2005)

Figure 3-7: Do energy efficient cooling appliances really cost more?



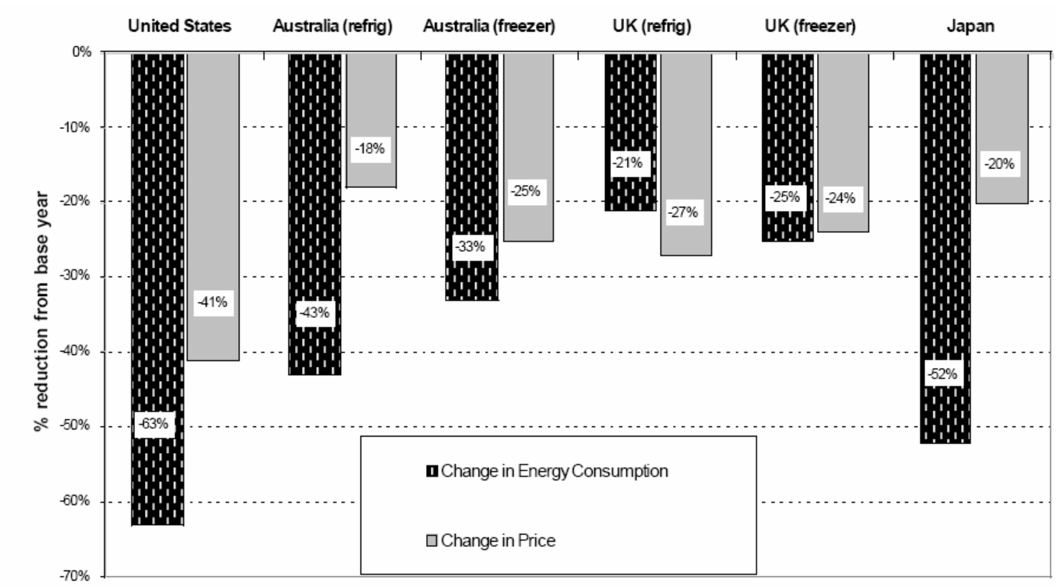
Source: GfK (2005)

Figure 3-8: Changes in the average price for electric appliances are not really linked to the penetration of labelling classes…



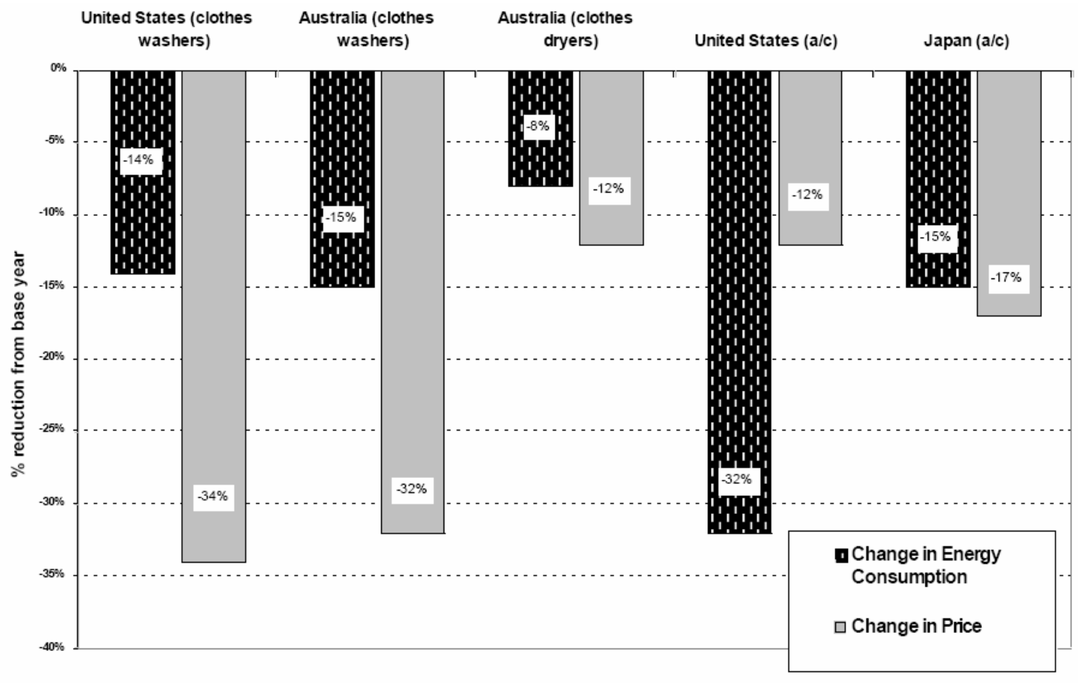
Source: GfK (2005)

Figure 3-9: Efficiency and real price trends for cold appliances (varying time scales)



Source: M. Ellis et al. (2007)

Figure 3-10: Efficiency and real price trends for clothes washers, clothes dryers and air conditioners (varying time scales)



Source: M. Ellis et al. (2007)

Figure 3-11: Do energy efficient windows really cost more?

Table 4 Cost of window manufacturing in 1970 and in 2000, nominal and real (*U*-value 1970 approx. 2.5–3.0 W/m^{2}K; 2000 approx. 1.3 W/m^{2}K), expressed in CHF/m^2 standard window

	Glass	*Material, coating*	*Window manufacturing*	*Assembly incl. transport*	*Calculated contribution margin*	*Total*
1970						
nominal	150	70	120	60	80	480
real[1]	202[2]	94[2]	135[3]	80[2]	90[3]	601
2000	100	100	80	80	90	450

[1]Real 2000 prices;

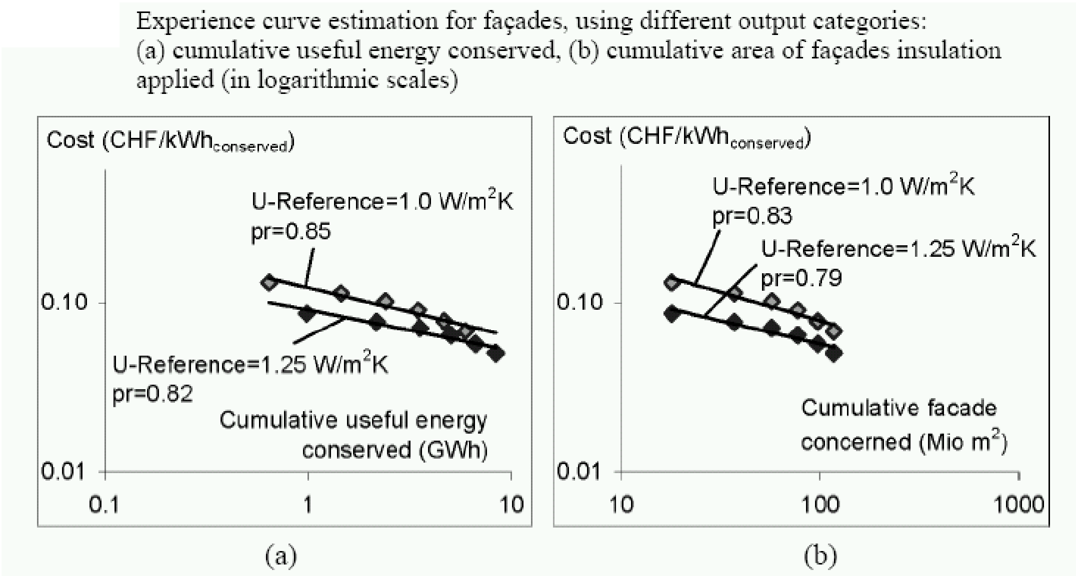
[2]Adjusted with the Swiss producer price index for the manufacturing industry;

[3]Adjusted with the average price index for the construction of residential buildings.

Source: [3], data obtained from an interview with a representative of SZFF (Schweizerische Zentralstelle für Fenster- und Fassadenbau), Dietikon/ZH.

Source: M. Jakob (2004)

Figure 3-12: Experience curves for facades

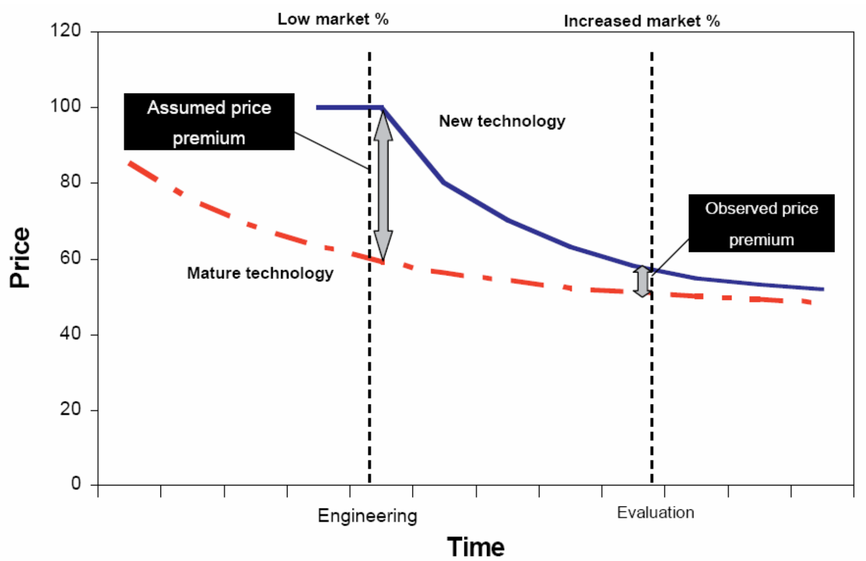


Progress ratio: cost decrease in case of doubling of cumulative output

$$pr = c \cdot (2Y_{\text{cum}})^b / c \cdot Y_{\text{cum}}^b = 2^b$$

Source: M. Jakob (2004)

Figure 3-13: Price impact of market growth for energy efficient technology



Source: M. Ellis et al. (2007)

4 Data for the reference scenario

As stated in the previous chapter the calculation of dynamic energy efficiency potentials depends in three different ways on scenario settings: (1) on exogenous drivers such as the number of appliances (if the number of appliances has doubled, the saving potential is in principle also twice as large); (2) on technological innovation which in turn influences the evolvement of the different saving options and their mix chosen in a given potential scenario; (3) on the impact of policies.

For the first issue, there are also in general a variety of scenarios possible. However, in order to reduce complexity, it was decided to rely for this exercise on the choice of the baseline scenario calculated with the PRIMES model in the DG TrEn projections. From these projections drivers such as the number buildings, energy prices, the development of value added of industry etc was chosen in order to be consistent with these projections. However, the future development of unit consumptions, intensities etc. was allowed to evolve according to the knowledge implemented in the MURE model because otherwise it would have been difficult to maintain consistency in the figures. Hence it cannot be expected that the overall energy consumption evolves totally in the same way as in the PRIMES projections.

The version of the PRIMES projections used was European energy and transport: Trends to 2030 – Update 2007 [5]. The new baseline takes into account policy developments up to the end of 2006 and is based on higher energy import prices compared to the 2005 edition of the baseline (Table 4.1).

Table 4-1: Prices for EU imports of fossil fuels in $ / boe in US$2005

	2005	2010	2015	2020	2025	2030
Oil	54.5	54.5	57.9	61.1	62.3	62.8
Gas	34.6	41.5	43.4	46.0	47.2	47.6
Coal	14.8	13.7	14.3	14.7	14.8	14.9

Source: European Commission (2008)

These are border prices. For tax rates applying to the border prices, the modellers have taken the existing tax rates in 2006 in real terms unless there was better knowledge on future increases of rates to adapt to EU minimum rates at the end of the respective transition periods - mostly for the New EU Member Countries[6].

[5] European Commission (2008): European energy and transport: Trends to 2030 – Update 2007. Luxembourg: Office for Official Publications of the European Communities, 2008. http://ec.europa.eu/dgs/energy_transport/figures/trends_2030_update_2007/index_en.htm

[6] Tax rates can be found through the following link: http://ec.europa.eu/taxation_customs/taxation/excise_duties/energy_products/rates/index_en.htm

The CO_2 prices in the ETS sectors increase from 20 €(2005)/t CO2 in 2010 to 22 €/t CO_2 in 2020 and 24 €/t CO_2 in 2030 reflecting current levels and preserving the baseline approach of assuming a continuation of current policies – but taking into account that CDM/JI credits may become more expensive over time.

The 2007 Baseline scenario includes policies and measures implemented in the Member-States up to the end of 2006. Differences with the present work may arise from the fact that the PRIMES baseline includes impacts from the building directive, while our baseline excludes the impacts from the Directive only the Autonomous Progress Scenario + Recent Policies does include this. On the other hand, in difference to previous PRIMES projections no success was assumed any more for the CO_2 agreement for cars, although some further progress was assumed.

Assumptions on discount rates in the PRIMES model are as follows: In industry, services and agriculture the discount rate amounts to 12% for the whole projection period. Households have an even higher discount rate of 17.5%. For transport, the discount rate depends on the type of operator. Private passenger transport investments (e.g. for cars) are based on a discount rate of 17.5%, while for trucks and inland navigation the rate is 12%. Public transport energy investment is simulated with an assumed discount rate of 8% reflecting the acceptance of longer pay-back periods than those required in industry or private households. All these rates are in real terms, i.e. after deducting inflation. For comparison, the discount rates used in this study are reported in Table 4-1.

Table 4-2: Discount rates used in PRIMES and the present study

		Present study	
	PRIMES	LPI	HPI
industry	12%	30%	8%
services and agriculture	12%	8%	6%
Households	17.5%	8%	4%
Private passenger transport	17.5%	8%	4%
trucks and inland navigation	12%	8%	6%
Public transport energy investment	8%	8%	4%

Source: EU Commission (2008) for the PRIMES column

Some important macroeconomic driver of the PRIMES scenario are shown in Table 4-3.

Table 4-3: Macroeconomic and other drivers for EU27 energy demand in PRIMES, 1990-2030

	1990	1995	2000	2005	2010	2015	2020	2025	2030	Annual Growth 1990-2000	2000-2010	2010-203
GDP of EU-27 (in 000 M€ '05)	8109	8712	10046	10949	12430	14059	15687	17266	18687	2.17	2.15	2.06
Value Added at Factor Prices (in 000 M€ '05)												
Energy Intensive Industry	353	375	416	448	503	566	628	685	734	1.67	1.91	1.91
Non Energy Intensive Industry	1227	1232	1426	1500	1692	1911	2133	2345	2527	1.52	1.72	2.03
Services Sector	4806	5274	6176	6857	7844	8925	10003	11050	12001	2.54	2.42	2.15
Agriculture Sector	241	245	269	272	289	311	332	350	367	1.08	0.72	1.21
Consumer Expenditure (€/capita)	10057	10634	12208	13230	14748	16452	18202	19955	21622	1.96	1.91	1.93
Population (million)	470	476	481	489	493	495	496	496	495	0.21	0.26	0.02
Passenger transport activity (Gpkm)	4785	5222	5820	6245	6784	7350	7897	8413	8861	1.98	1.54	1.34
Freight transport activity (Gtkm)	1879	1929	2175	2464	2770	3061	3321	3546	3717	1.47	2.45	1.48

Source: EU Commission (2008)

5 Overview of the results for the EU27

Scenarios (Figure 5-1**)**

- 4 scenarios have been considered:
  - **Autonomous Progress Scenario APS** (which comprises autonomous progress and earlier policies such as the labelling Directives for electric appliances but excluding the success of important recent EU policies which are not yet fully implemented such as the EU Performance Directive for Buildings and the CO2 standards for cars and light duty commercial vehicles).
  - A **variant of the Autonomous Progress Scenario** which includes the success of these recent policies (**APS+RP**)
  - **Low Policy Intensity Scenario LPI** (which implies continued high barriers to energy efficiency, a low policy effort to overcome the barriers and high discount rates for investments in energy efficiency)
  - **High Policy Intensity Scenario HPI** (which implies removing barriers to energy efficiency, a high policy effort to overcome the barriers and low discount rates for investments in energy efficiency, options are economic on a life cycle basis).
  - **Technical Scenario** (includes also more expensive but still fairly realistic options; no exotic technologies).
- Energy price assumptions are conservative (Table 4-1), for crude oil as the leading energy around 61$2005 in 2020 (real prices), 63$2005 in 2030 (real prices). The 61$ in 2020 implies a price of 83$ in nominal terms in 2020 (assuming an inflation rate of 2 % annually), while the 63 $ in 2030 correspond to 105 $ nominally in 2030.
- Final energy consumption is still on the rise in the APS+RP scenario. It stabilises in the LPI Scenario, while the HPI and the Technical Scenarios curb the final energy demand by 2020 as compared to the baseline (APS) which still is on the rise.

Potentials (Figure 5-2 and Figure 5-3**)**

- In 2020 the LPI potentials may reach 158 Mtoe for the EU27 (15 % compared to APS); in 2030 244 Mtoe (22 % compared to APS) are achievable in economic terms.

- In 2020 the HPI potentials may reach 248 Mtoe for the EU27 (22 % compared to APS); in 2030 405 Mtoe (33 % compared to APS) are achievable in economic terms.
- In 2020 the Technical Potentials may reach 336 Mtoe for the EU27 (29 % compared to APS); in 2030 565 Mtoe (44 % compared to APS) are achievable.
- Potentials from the (still supposed) success of recent policies (EPBD, CO2 standards for cars and light duty commercial vehicles) reach 44 Mtoe in 2020 and 63 Mtoe in 2030.

Sectoral contributions (Figure 5-2 and Figure 5-3**)**

- At the shorter term (2010) transport, non-EU ETS sectors (in particular cross-cutting technologies such as electric motor applications) and electric applications in the residential and tertiary sectors may have the largest potentials.
- At medium term (2020) the contribution from the building sector (residential and tertiary) to the potentials grows larger.
- The contribution of the buildings to the potentials is largest in the HPI and Technical Potential scenarios and for the longer term up to 2030. However, this also would imply an early mobilisation of these potentials through measures due to the longer lead times.

Comparison with ESD Targets in 2016 (Figure 5-6**)**

- For the comparison with the 9 % target of the ESD, the target was calculated as average for the period 2001-2005 from Odyssee data, excluding EU ETS industries. It should be noted that the ESD target is calculated on a historic 5-years period while the potentials calculated here are calculated with respect to the Autonomous Progress Scenario.
- Potentials for this comparison are also without EU ETS industries. Potentials in non EU ETS sectors are considerably larger than for the EU ETS sector, especially for electricity
- If all proposed measures in the National Energy Efficiency Action Plans (NEEAPs) will be new measures than they represent an effort broadly in the range of the LPI scenario.

- Early action measures undertaken 1995 to 2007 are admitted under the ESD. They are not included in the potentials as calculated here. In fact, they are part of our baseline. If Early Actions represent 30 % which is rather realistic when looking at the NEEAPs then the new effort represents less than the LPI potentials. Some countries have even 50 % Early Action. This implies that between the new action and the HPI potentials there is still some gap open for further action in future NEEAPs. If there is in addition autonomous progress included in the actions than the effort is even less.

Comparison with 20% target in 2020 (Figure 5-7**)**

- The 20% target is a primary energy target hence includes also the conversion sector and renewables. For this reason it can not be really compared here to the potentials calculated here, which are pure demand side potentials.
- Nevertheless, the comparison of the potentials with the baseline in percentage points shows that even the HPI reaches 22% in 2020 that is the 20 % reduction target is rather demanding if it is to be reached by demand side measures only. Possibly additional measures on the primary energy side and renewable, or measures which are currently more expensive (and which are in the technical scenario) need to be taken on board.

In the following sections the different settings for the three different steps for the potential calculations mentioned in Chapter 3.4 are described in detail sector by sector:

- residential electric appliances and lighting (chapter 6),
- IT appliances (chapter 6.2),
- residential buildings (chapter 7),
- technical and non-technical options in the transport sector (chapter 8),
- cross-cutting technologies and process specific technologies in the industrial sector (chapter 9),
- electric uses and buildings in the tertiary sector (chapter 10).

Figure 5-1: Scenario development for the four scenarios and comparison with the PRIMES baseline (EU Commission 2008)

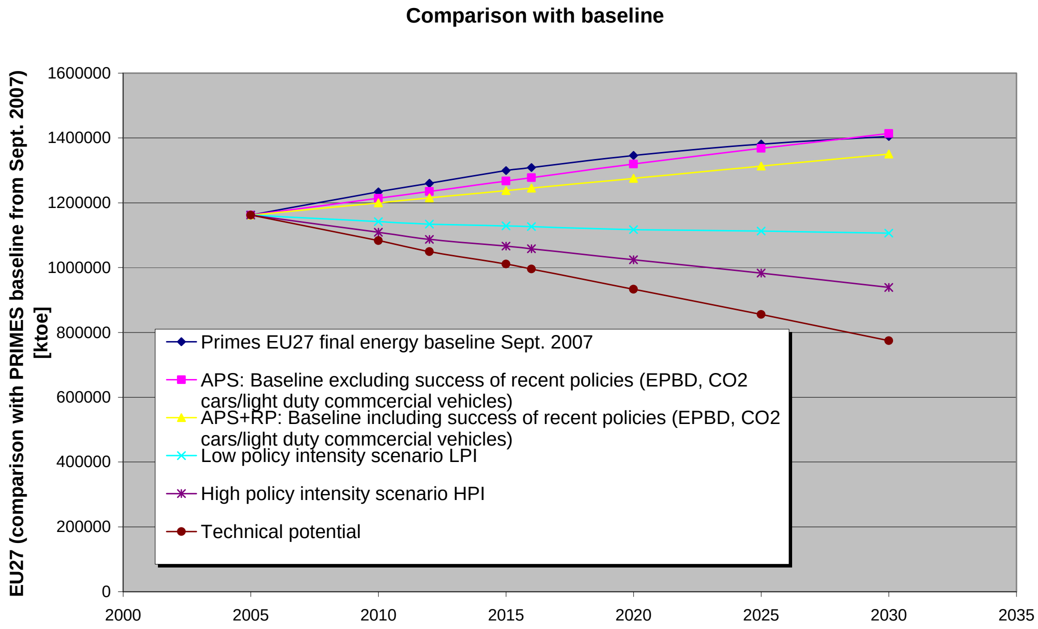


Figure 5-2: Overview of energy efficiency potentials in the different scenarios (ktoe, compared to APS)

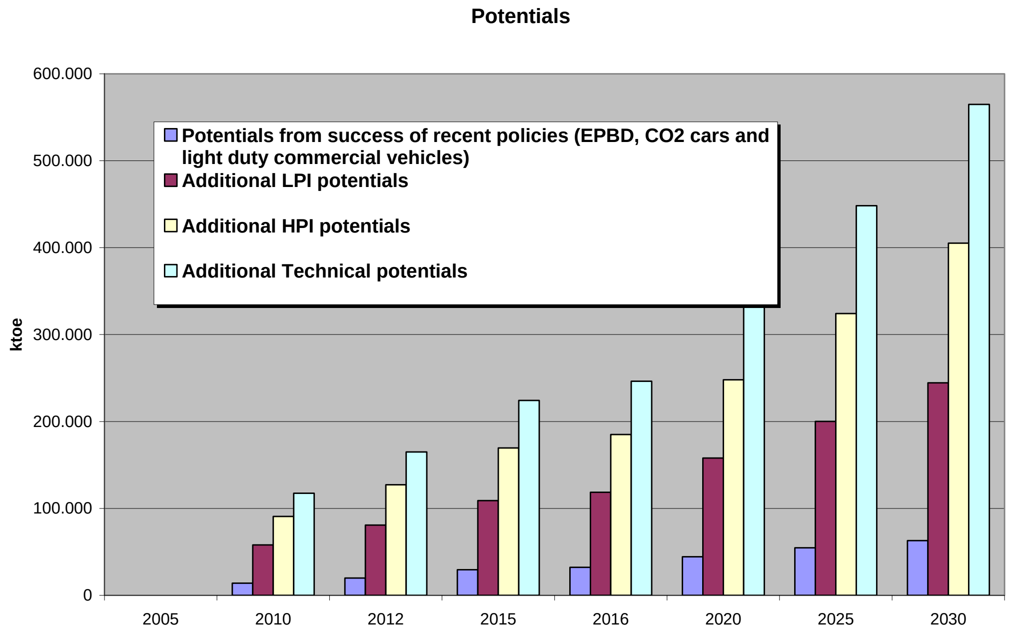


Figure 5-3: Overview of energy efficiency potentials in the different scenarios (% compared to APS)

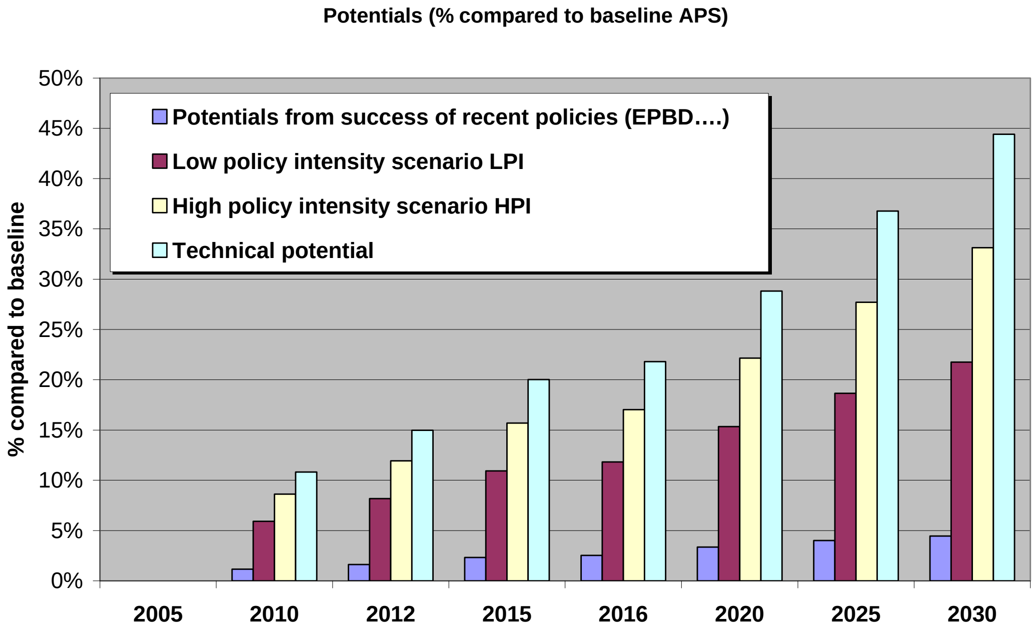


Figure 5-4: Sectoral contributions to the potentials over time in relative terms

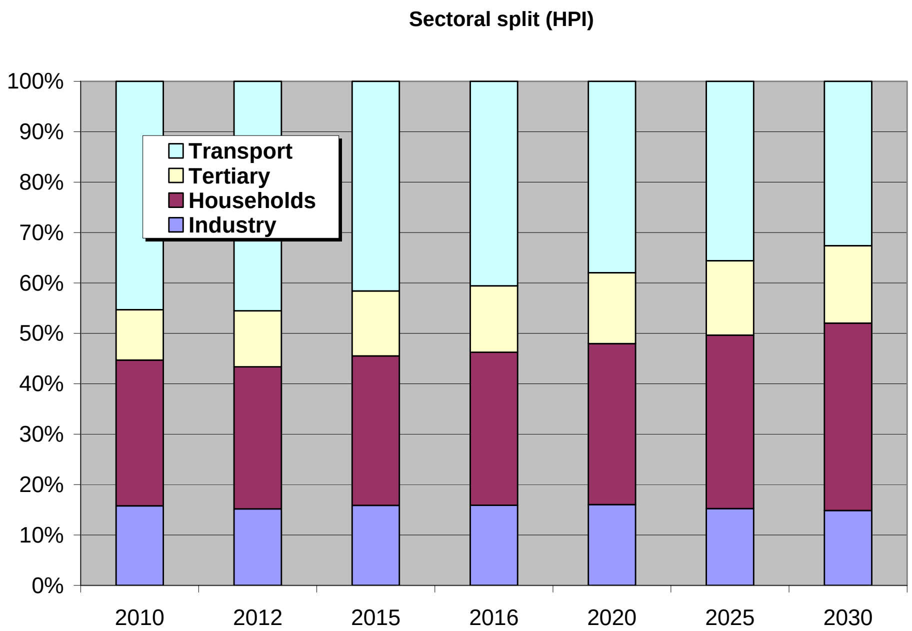


Figure 5-5: Sectoral potentials over time compared to the APS in percent

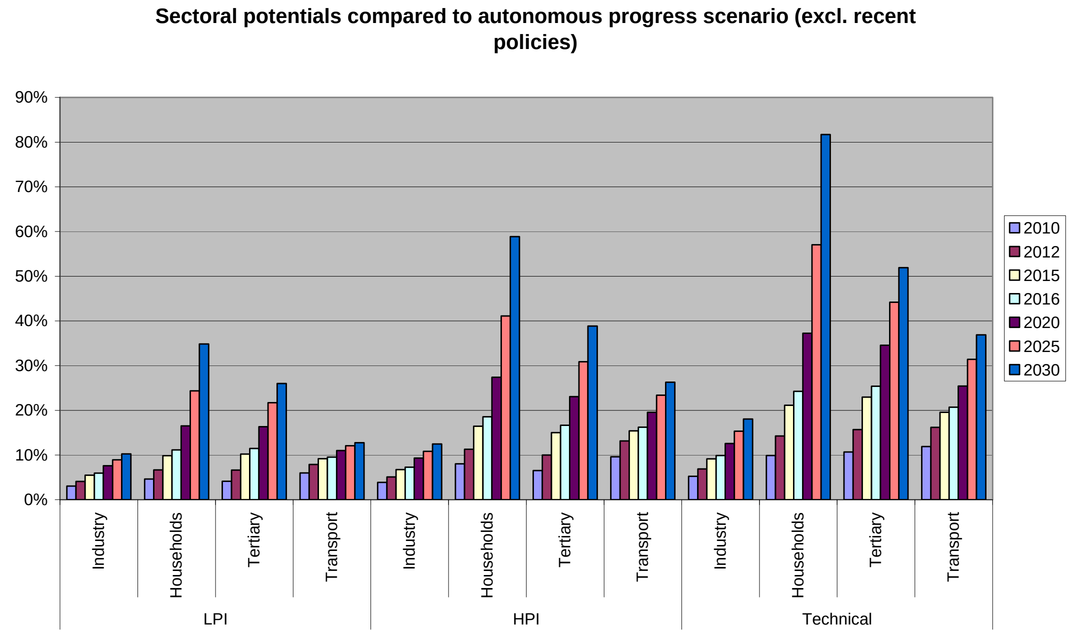
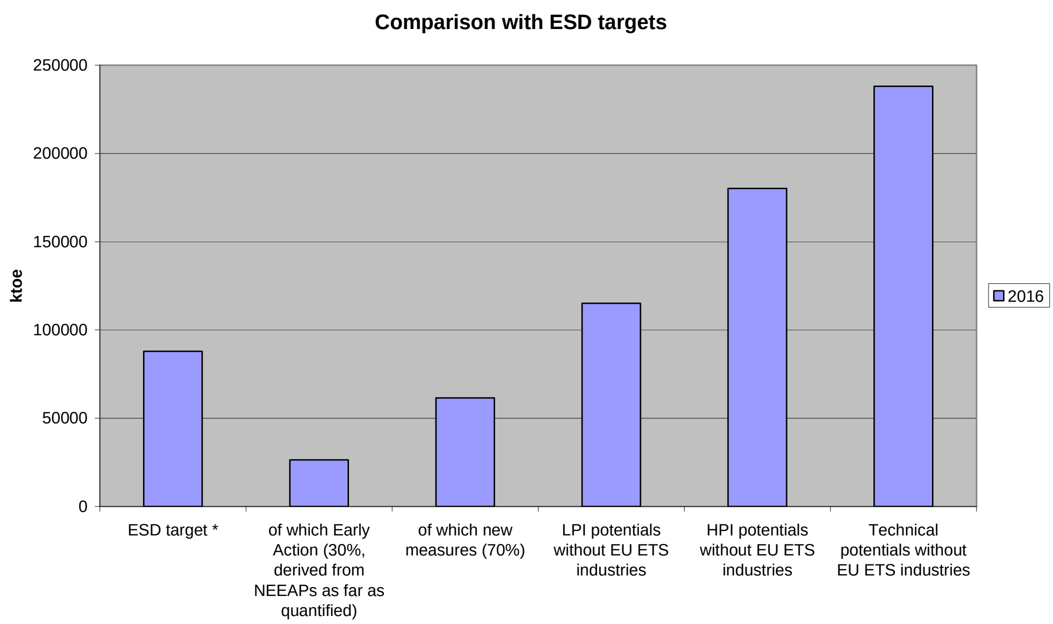
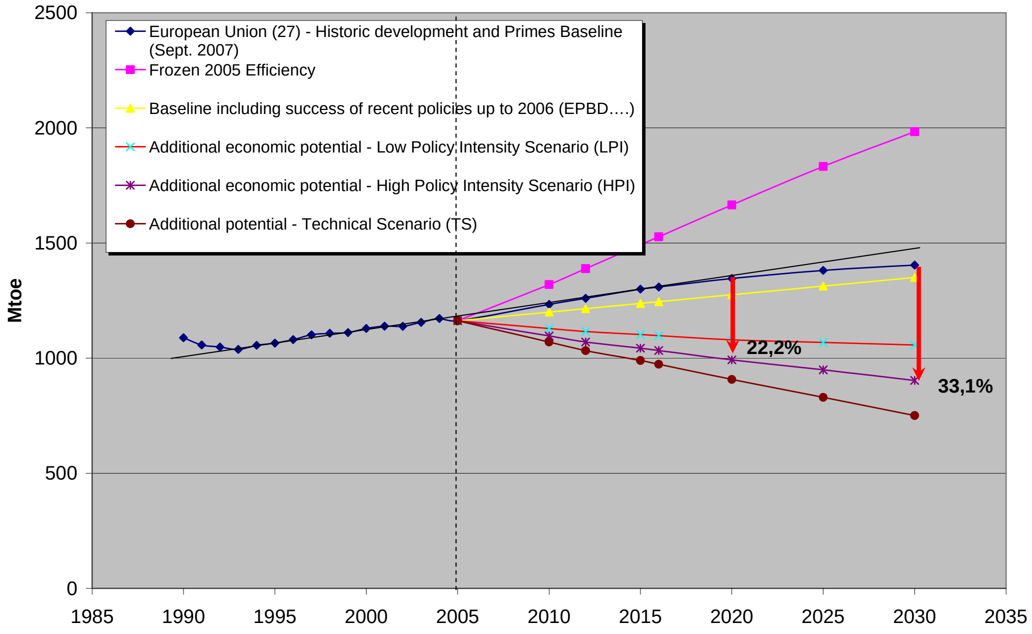


Figure 5-6: Comparison of the potentials (excluding EU ETS industries) with the targets of the Energy Service Directive in 2016



*(calculated from the Odyssee Indicators by excluding EU ETS Industry on a sectoral basis and averaging 2001-2005)

Figure 5-7: Comparison of the potentials (including EU ETS industries) with the 20% target for energy of the EU Commission



PART II

Sectoral Potentials for Energy Efficiency

6 Residential electric appliances (incl. IT appliances) and lighting

6.1 Residential electric appliances

6.1.1 Description of the sector/end-use

The electric appliances taken into account in this study are the following:

- Refrigerators (categories 1 to 7 of the cold appliances)
- Freezers (categories 8 and 9 of the cold appliances)
- Washing machines, mainly represented by the 5-kg-load machines
- Dishwashers, mainly represented by the 9 and 12-place settings
- Driers
- TV sets
- IT appliances (for more details see 6.2)

6.1.2 Sector-specific / use-specific data sources and modelling issues

6.1.2.1 The MURE stock model

The stock and energy consumption data for the appliances mentioned above are provided by the MURE stock model (a component of the MURE household model which has been enhanced and further developed for the purpose of this project). Figure 6-1 shows the simplified layout for such a model.

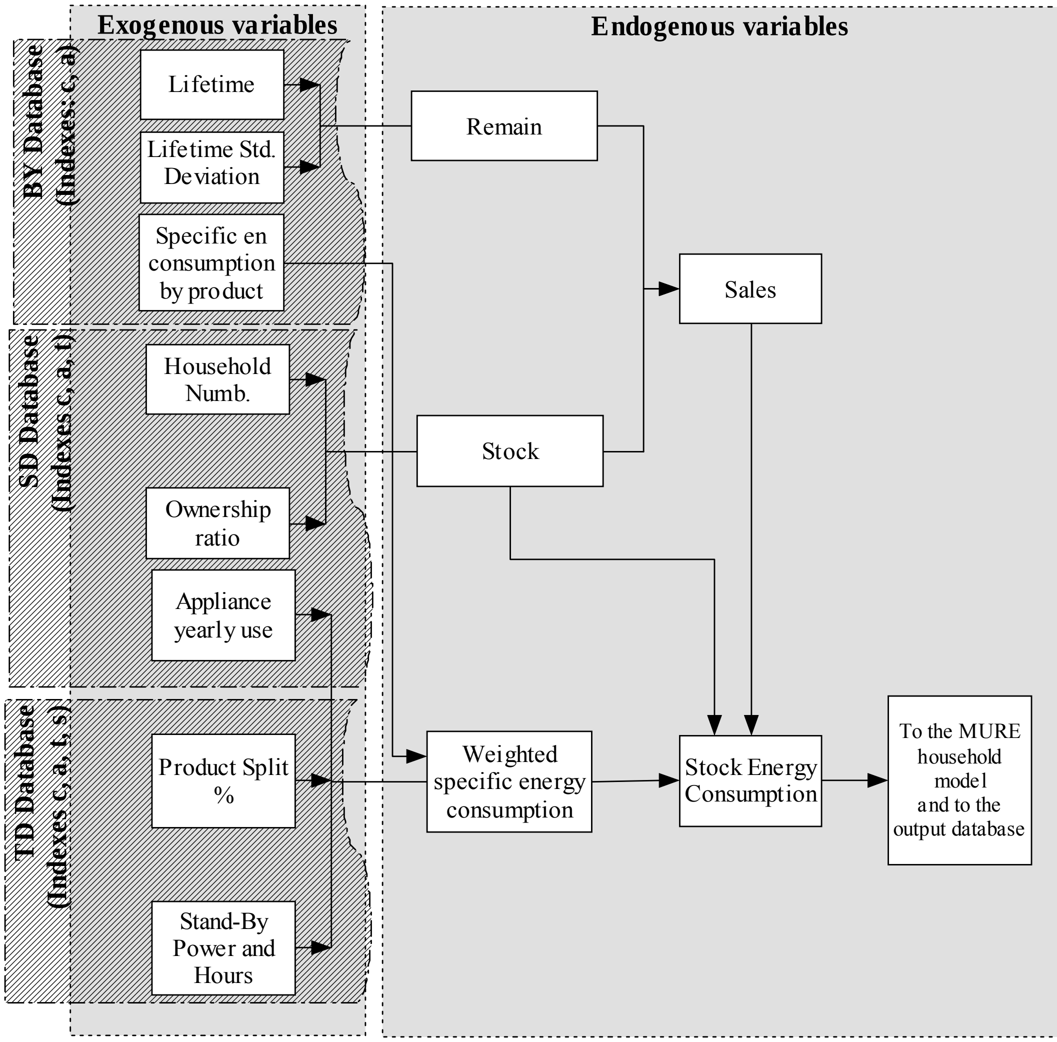
The main exogenous (input) and endogenous (output) variables are clearly shown. The exogenous variables are divided into three groups according to the origin of data sources. The meaning of the indices is explained in the exogenous variables section. The model provides different stock energy consumption figures in accordance with the values assumed for each energy efficiency potential scenario for the two sets of variables listed within the Technology Driver (TD)[7] database: Product split% and the Stand-by variables. The energy efficiency potentials are provided as the difference between the value of the stock energy consumption calculated for the Autonomous Progress Scenario and the values assumed by these variables in, re-

---

[7] For the structure of the database see Chapter 11

spectively, the Low Policy Intensity (LPI) Scenario, the High Policy Intensity (HPI) Scenario and the Technical Scenario.

Figure 6-1: Appliance stock model layout in MURE



Abbreviations: BY = Base Year, SD = Scenario Driver, TD = Technology Driver

6.1.2.2 *Exogenous variables*

Indices

The indices specify the data set on which the variables depend on. We have defined five classes of indices: a = type of appliance, p = technologies (products) or labelling categories, s = scenarios, c = countries and t = time. The meaning of the index categories is the following; it shows at the same time the structure of the stock model:

Index a (Appliance)	*Index p (Technology/Label category)*
a1 = Refrigerators (categories 1 to 7 of the cold appliances)	p1 = NewTech[8] p2 = A++ p3 = A+ p4 = A p5 = B p6 = C p7 = D p8 = E p9 = F p10= G
a2 = Freezers (categories 8 and 9 of the cold appliances)	
a3 = Washing machines	
a4 = Dishwashers	
a5 = Driers	
a6 = Air conditioners	
a7 = TV sets	p1 = CRT screens p2 = LCD screens p3 = Plasma screens p4 = OLED screens p5 = FED screens
a8 = Set-top boxes	
a8 = PCs	p1= desk top computers p2 = lap top computers
a9 = Computer Screens	p1 = CRT screens p2 = LCD screens p3 = OLED screens p4 = FED screens
a10 = Modem/Routers	
a11 = Servers (tertiary sector and industrial sector only)	

8 In order to avoid confusion with non-existing labelling classes such as A+++, we preferred in this study the expression "NewTech" to characterise technologies that might still arise at the medium and long term.

Index s (Scenarios)	*Index c (countries)*					
s1 = autonomous progress	c1	AT	c12	FI	c23	NL
s2 = LPI scenario	c2	BE	c13	FR	c24	NO
s3 = HPI scenario	c3	BG	c14	HU	c25	PL
s4 = technical scenario	c4	CR	c15	IE	c26	PT
	c5	CY	c16	IS	c27	RO
	c6	CZ	c17	IT	c28	SE
	c7	DE	c18	LI	c29	SI
	c8	DK	c19	LT	c30	SK
	c9	EE	c20	LU	c31	UK
	c10	EL	c21	LV		
	c11	ES	c22	MT		

Input Variables

The exogenous variables, the related indices according to which the variable is differentiated and the database where the data are stored, are the following:

Exogenous variable	Indices	Database
Appliance lifetime	a	BY
Lifetime standard deviation (Generally, this variable will be that same for all the appliances taken into account)	a	BY
Appliances use: This variable provides the annual number of washing (and drying) cycles for washing machines, dishwashers and tumble driers. For all other appliances this variable is equal to 1.	a,c,t	SD
Number of households	c,t	SD
Appliance ownership rate	a,c,t	SD
Percentage split of the products (or technologies	a,c,t,p,s	TD
Specific energy consumption of the products p[9]	a,p	BY
Stand-by power and Stand by hours. Variables to calculate the energy consumption when the appliances are left on stand-by	a,c,p,t,s	TD

Abbreviations: BY = Base Year, SD = Scenario Driver, TD = Technology Driver

For example the variable Split% (a7, DE, 2010, p1, s1) provides the percentage of CRT TV screens in Germany for the year 2010 and for the autonomous progress scenario.

9 For the appliances having the labelling system, this variable provides the energy consumption of the energy efficiency class “p”

6.1.2.3 Data sources

The data sources for the variables are the following:

Table 6-1: Data sources for the variables in the MURE stock model for appliances

Source ☞ Input variables ☟	Wuppertal data-bases. Cold and Washing Appliances Driers Air conditioning[10] TV sets	ISIS (GfK data and CECED databases – Eco-design studies) Contribution to the Cold and Washing Appliances	Fraunhofer Institute (Eco-design studies, other) IT appliances
Lifetime	X		
Lifetime standard deviation		X	
Ownership rate	X	X	X
Percentage product split	X	X	X
Product specific energy consumption	X	X	X
Stand-by figures		X	X

The number of households as the main exogenous driver is provided by the PRIMES database.

6.1.3 Step 1 – Definition of energy saving options

For the larger appliances, the energy saving options are described in technical terms, in particular the labelling classes. The saving options for the IT appliances will be described separately in section 6.2. The main variable for the calculation of the achievable savings of the large appliances briefly described in paragraph 6.1.1 is the unitary average energy consumption of their annual sales. This variable (called "weighted specific energy consumption" in the stock model layout scheme described in Figure 6-1) is a function of the appliances' specific consumption per energy labelling category and the share of these categories in the annual sales. The first variable is kept constant in the different scenarios while the second one varies

[10] The database for the air conditioners is still weak and needs to be further improved if additional data becomes available.

in accordance with the different scenario hypotheses. This means that the energy saving options of this category of products are determined by the appliance sales dynamic, that is, the entrance in the market of the more efficient products and the phase out of the less efficient ones.

It is worth adding that in this study we refer to the standard specific energy consumption of the energy labelling categories, that is:

- to the specific energy consumption calculated on the basis of the data provided by the manufacturers databases (i.e. kWh per year, per unitary washing load or washing cycle, etc);
- and to the average parameter values concerning the appliance use (e g. the number of yearly washing cycles) accepted at EU level.

These last values may vary considerably in accordance with user habits and behaviour but, according to the assumption made here, are not generally the target (at least so far) of energy policies. In the future we might expect that, for instance, under the pressure of informative campaigns, the washing machines will be mostly used at full load but it is very is difficult to foresee the possible impact of these type of policies, in particular because there are no reliable data on the current habits of use. In conclusion, in this study, the behavioural aspects concerning the appliance use have not been taken into consideration [].

A final note concerns the cold appliances. The specific standard energy consumption per energy labelling category of these appliances depends on the volume of the appliance itself (or – to be more precise - on the equivalent volume that takes into consideration the ratio of the different freezing and chilling compartments inside the appliance). The value we provide is calculated considering the weighted average of the equivalent volumes per energy labelling category (Source: CECED databases) but this value is valid for a given year and might change over time. We are nevertheless convinced, and the data on the sales of the recent years support our conviction, that in the near future, the net volume of the refrigerators is saturating and so the average specific consumption per energy labelling category is not expected to change anymore in an appreciable way.

6.1.4 Step 2 – Technology costs

For the main large appliances types (the cold and wash appliances), the technology costs are provided by the technological analysis carried out within the Lots 13 (cold appliances)[11] and 14 (wash appliances)[12] of the EuP-Ecodesign studies set[13]. This technological analysis has worked out two levels of investment costs:

---

[11] http://www.ecocolddomestic.org/

[12] http://www.ecowetdomestic.org/

- The Least Life Cycle Cost (LLCC) corresponds to the minimum of the energy consumption/investment + running cost curve and represents a consumer perspective;
- The Best Available Technology (BAT) cost, corresponding to the investment costs of the appliance (an average product) in which the best available technologies set has been applied. This point corresponds to the maximum of the above mentioned curve.

In our case, for the cold appliances, the LLCC point corresponds to an A+ appliance (Energy Efficiency Index EEI around 44) and the BAT to an A++ appliance (EEI around 30).

For the dishwashers the LLCC point, having an EEI of around 0.62, correspond to a good A model, and the BAT, with an EEI around 0.52, to the upper limit of the A class models (as already outlined, we can rate these BAT models as A+ class, even if this category does not exist in the CECED databases).

For washing machines the LLCC point, having an efficiency index of 0.168, represents appliances that are rated A+, while the energy efficiency value for the BAT is 0.158, corresponding to the upper limit of the A+ class.

In both cases for the wash appliances the BAT models represent the technological limits for these products and, with the current technology, no further improvements are in sight.

Table 6-2 shows the investment costs of the LLCC and BAT case compared to the base case models. The base model costs correspond to the average purchase costs of the most representative models produced in 2005. These models correspond to the A class for the refrigerators (mainly category 1) and fridge-freezers (category 7), the A/B classes of the upright and chest freezers, the A class and 5/6 kg models for the washing machines and the A class and 12/14 settings models for the dishwashers.

Table 6-2: Investment costs (in Euro) for the large White Appliances

	Base models	LLCC models	BAT models
Refrigerators	456	543	807
Freezers	328	428	646
Dishwashers	576	586	796
Washing Machines	443	470	590

Source: EuP-Ecodesign studies, Lots 13 and 14

13 For a full overview of the issues studied under the EuP (Energy Using Product) Directive see: http://ec.europa.eu/energy/demand/legislation/doc/issues_to_be_studied.pdf

The above costs (estimated for the year 2006) can be further processed to evaluate the average future investment cost corresponding to the scenario hypotheses as described below. A first hypothesis to evaluate the future cost investments is to establish that the cost decrease corresponding to a possible learning curve is at least equal to the inflation rate. This hypothesis is applicable in the case that the productivity increment of the manufacturing sector balances the increment of the cost of the money (and of the production factors). This balancing mechanism has been largely applied in past (actually the prices trend of the sector has been lower than the inflation rate) and it is likely to be applied in the future, especially in the presence of new and strong energy policies.

To evaluate the HPI scenario hypothesis it is finally necessary to estimate the investment cost of the new technology for the cold appliances. This new technology mainly consists in the application of high-performance insulation systems, high-efficiency heat exchangers with small air-to-refrigerant temperature differences and highly efficient compressors. It could lead to a final Energy Efficiency Index of 19-20 with an investment cost estimable at around 1.000/1.200 euro or more. Actually this type of appliance does not exist in the market and the investment costs are a rough estimate provided by some manufacturer on the basis of the possible costs of these new technologies but are not based on a robust production cost evaluation.

6.1.5 Step 3 – Definition of the four scenarios

6.1.5.1 Definition of the Autonomous Progress Scenario

The definition of the autonomous progress scenario for the large appliances is not an easy task. It is in fact worth remembering that the notable technological progress and the very high energy efficiency gains achieved by the appliance manufacturers during the last 15 years is entirely due to the strong policies enacted in the same period by the European Commission and the Members States. This does not mean that, without these policies, the sector would have not upgraded the energy efficiency of its products, but there is no evidence to which extent this could have been achieved, that is, there is no evidence of what could have been the autonomous technological progress. Actually there were significant improvements of the energy efficiency during the eighties and the beginning of the nineties (see for example Table 6-3 that shows the unitary energy consumption for the cold appliances) but at that time the technical energy efficiency potentials were very high and the efficiency improvements relatively easy to obtain. Now, each further efficiency improvement is more difficult to achieve for the appliance industry and must be justified by the market demand, although for some appliances such as cold appliances there is still scope for improvement.

Table 6-3: Unitary energy consumption of cold appliances

Year	1950-	1980-	1985-	1990-	1995	1996	1997	1998
Unitary Energy Consumption (kWh/year)	839	586	526	482	425	437	432	411

Year	1999	2000	2001	2002	2003	2004	2005
Unitary Energy Consumption (kWh/year)	382	363	334	328	317	308	292

Source: CECED

All this leads to the assumption that, without further policy measures (the last measure concerning the manufacturer voluntary agreement on the cold appliances ends in the year 2008), we could expect relatively little or even no additional energy efficiency increment for these appliances. What could probably happen is that:

- due to the market transformation induced by the earlier labelling policies, the consumers will continue asking for the class A appliances Today the prices of these products set the average prices in the EU markets.
- the manufacturers will hardly decrease the prices of the A+ or the A++ appliances and these last, especially the A++ ones, will remain a niche product.

These basic hypotheses are translated into the following scenario assumption (at EU level): These assumptions have been discussed with appliance experts:

- For refrigerators A, A+ and A++ classes will cover the total market up to 2010 but the A class will represent 70 % of the market, the A+ class 25 % and the A++ the residual 5 %. This situation will slowly change till the year 2030 where one can envisage a penetration of a further 10 % for the A+ appliances and of somewhat more than 5 % for the A++ ones.
- The starting situation for the freezers is different. Actually in 2005 there was still a strong presence of the B and C classes that together represented more than 50 % of the market, and a notable penetration of the A+ class (25 %). In 2005 the A class freezers represented one third of the market. It is proposed that up to the year 2020 a gradual phase out of the class B, and a slow and steady penetration of the classes A+ and A++ will occur in the autonomous scenario. The different A-type classes will thus achieve 100 % of the market after the year 2020.

➢ For the washing machines and the dishwashers it is possible to envisage a market saturation of the A class up to the year 2010, without any other change of the market in the period after this year.

Figure 6-2 to Figure 6-5 show the market transformation trends for these 4 appliances in accordance with the above outlined hypothesis.

Figure 6-2: Market transformation for refrigerators (autonomous progress)

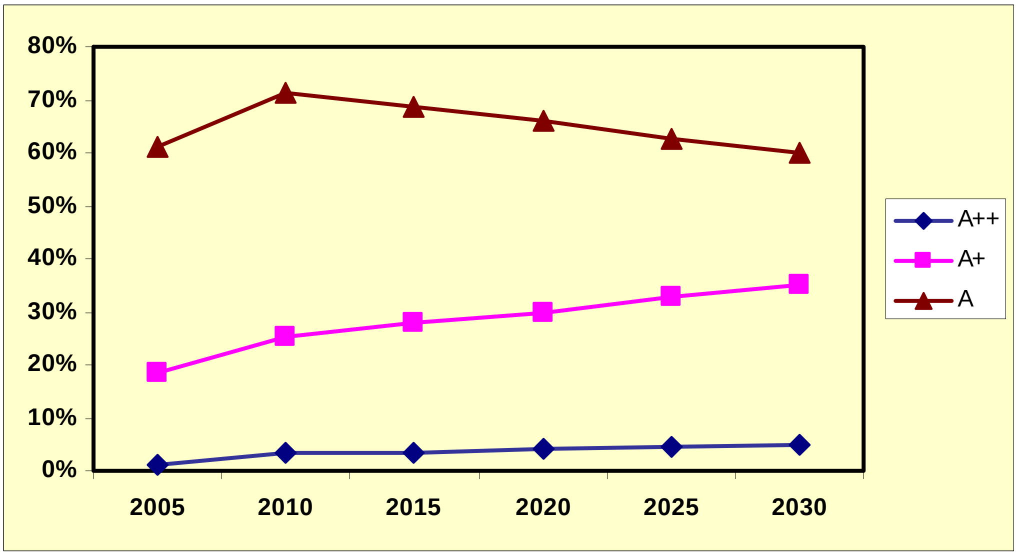


Figure 6-3: Market transformation for freezers (autonomous progress)

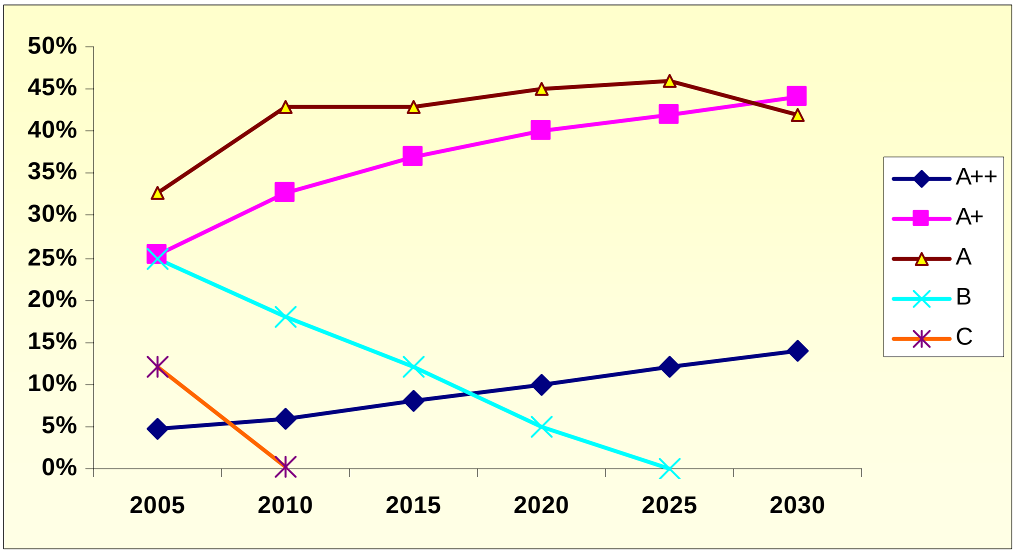


Figure 6-4: Market transformation for washing machines (autonomous progress)

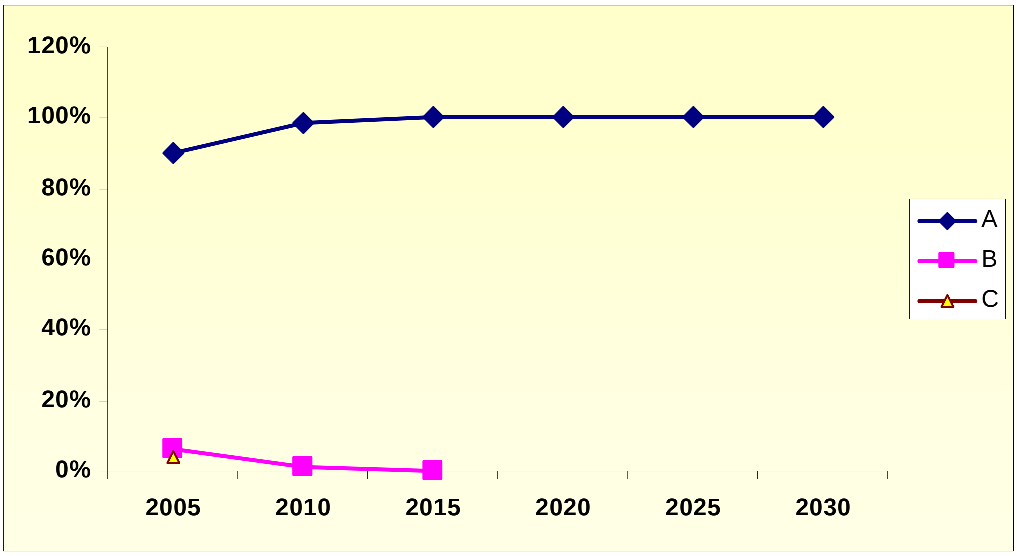
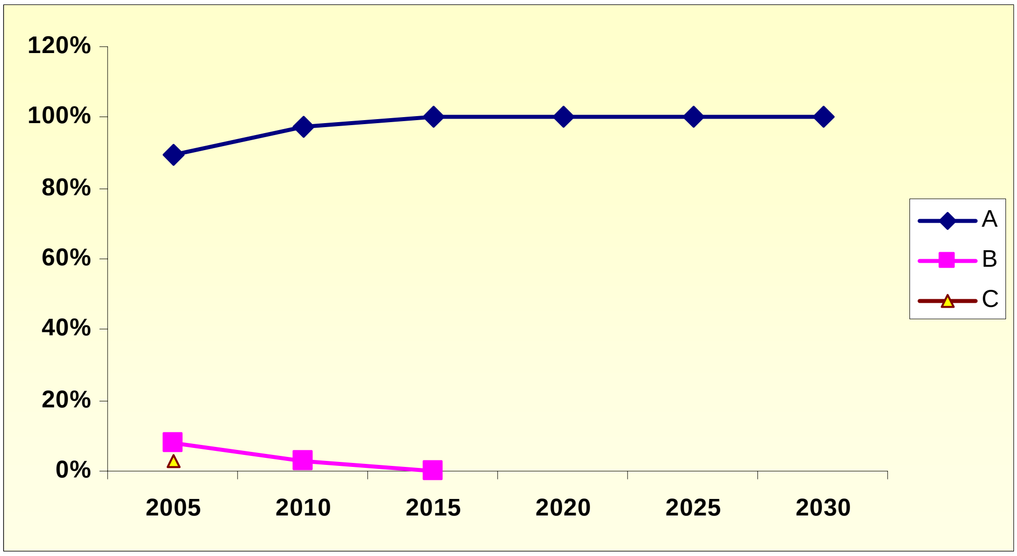


Figure 6-5: Market transformation for dishwashers (autonomous progress)



A similar trend has been also devised for the driers. The data regarding these appliances are less reliable than those concerning the other large appliances. We relay on data drawn from the databases of the Wuppertal Institute and the first information coming from the Ecodesign study on driers (recently started). According to these inputs, the prevailing energy labelling category in the reference year is that corresponding to C level (60 – 70 % market share) while the A class (heat pump technology) is practically not existing. In this situation we foresee a slow but steady improvement of the starting situation in order to halve the C category share by the year 2020 and correspondingly increase the B and A classes.

6.1.5.2 Definition of the LPI Scenario

Within this scenario the introduction of new policies is envisaged and thus the market will continue transforming with the same dynamics observed during the past 10 years. For all appliances the main type is represented by the A+ category. For the cold appliances the A class behaves as residual while the A++ steadily acquires incremental market portions. At 2030 only the classes A++ and A+ will be sold in the market.

For the wash appliances the A+ class practically represents the top of the achievable efficiency and the introduction of an A++ class is not envisaged in the LPI. This means that by 2030 the sales will be composed by class A+ only. It is worth adding here that the A+ class does not exist for dishwashers. In our case this class corresponds to the upper band of the A class composed by the models using the BAT technologies (see also the next paragraph).

Figure 6-6 to Figure 6-9 show the market transformation hypothesis for the four appliances in the case of the LPI scenario.

Figure 6-6: Market transformation for refrigerators (LPI Scenario)

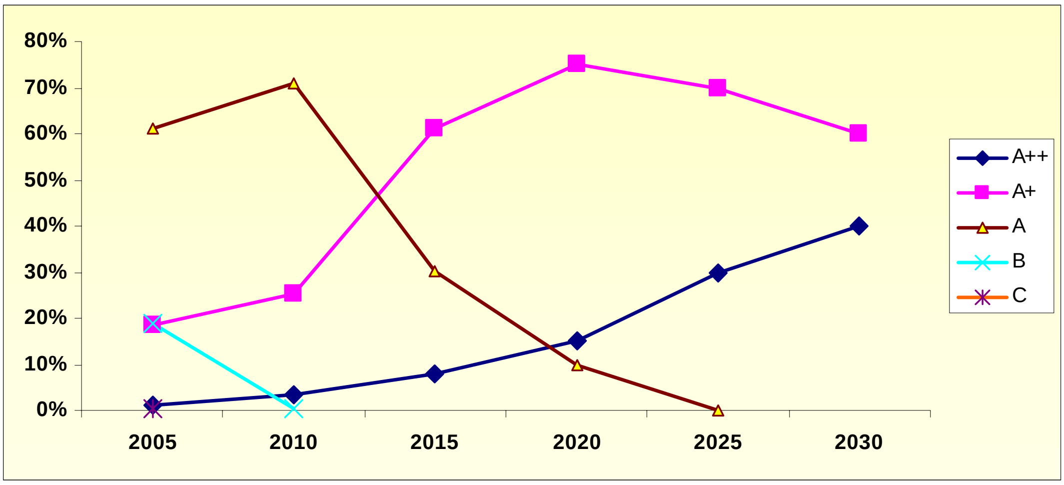


Figure 6-7: Market transformation for freezers (LPI Scenario)

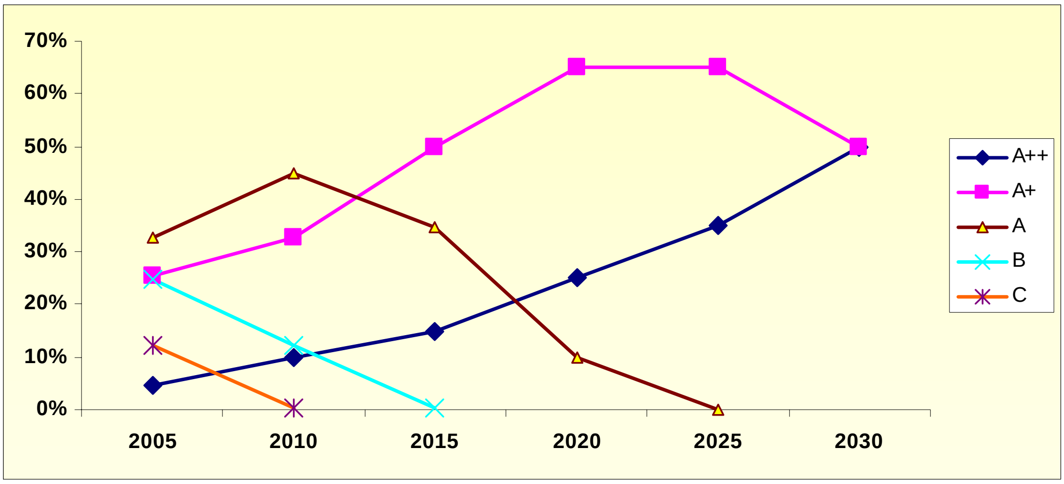


Figure 6-8: Market transformation for washing machines (LPI Scenario)

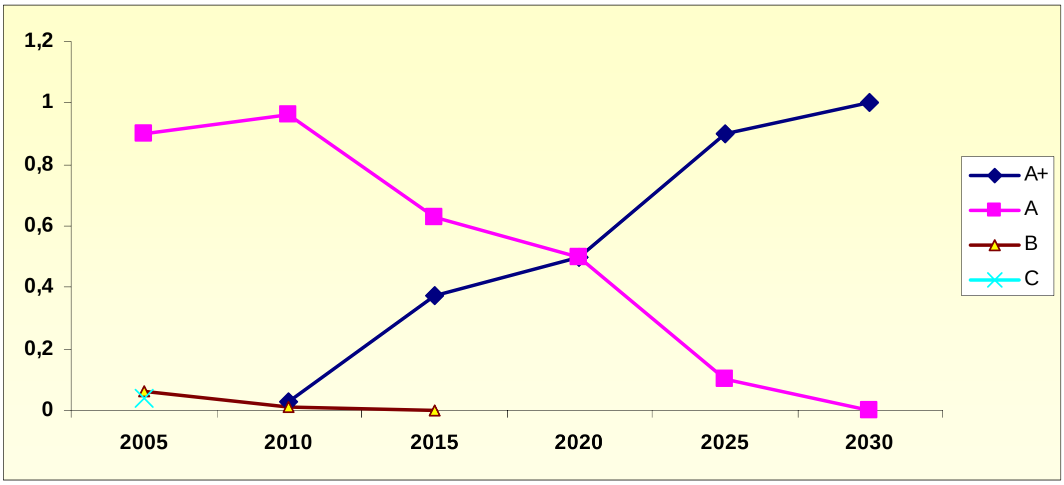
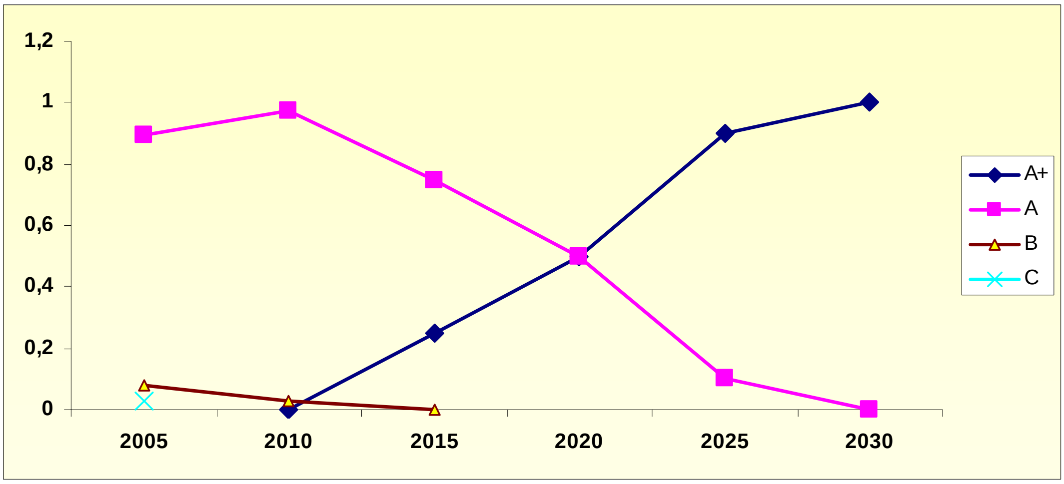


Figure 6-9: Market transformation for the dishwashers, LPI scenario



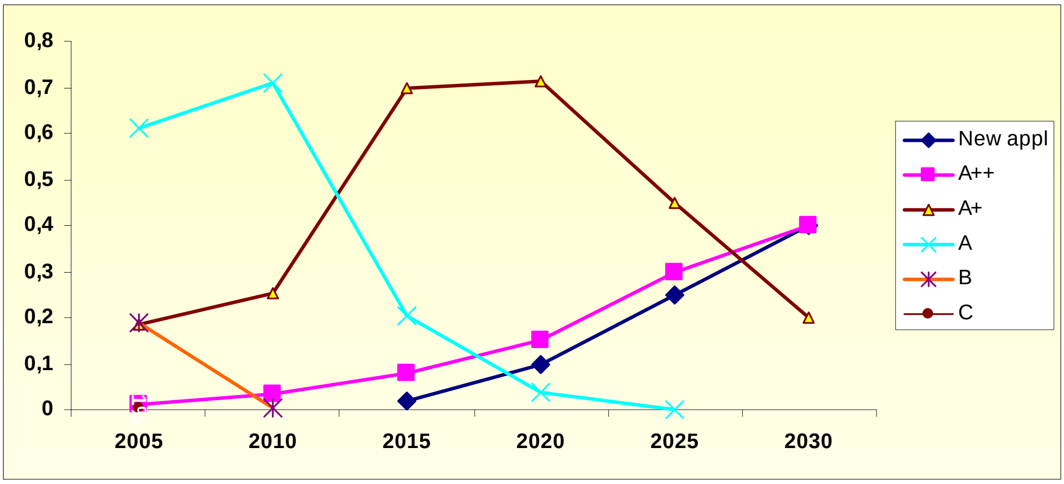
For the driers a strong penetration of the A and B categories is envisaged as well as the phase out of the C category by the year 2020.

6.1.5.3 Definition of the HPI Scenario

In the HPI scenario the introduction of strong support policies is envisaged which allow the penetration of new very highly efficient technologies (see footnote 8). Actually, as outlined in the section before, this is only possible for the cold appliances because, with the introduction of the A+ class, there are practically no more margins for further improvements to the energy efficiency of the wash appliances (at least with the current technology). At medium to long term further efficiency improvements could be reached by integrating the wash appliances in the household heating system (but only for natural gas heating systems) and/or by connecting the appliances to solar panels. A completely new technology line such as dry cleaning might also reduce further the energy consumption. Another possible efficiency improvement might come from a change in the consumers' washing behaviour by using, as far as possible at full load, high load charge (7-9 kg) but flexible washing machines. In this type of washing machines the detergent and washing water quantity is proportional to the clothes load and the maximum efficiency is in any case reached at full load. This issue is promising but presents several cons and uncertainties linked to the behaviour, and it is currently under discussion. So, for the moment, for this type of appliances the only possible scenario is the LPI one and the HPI Scenario will be not simulated.

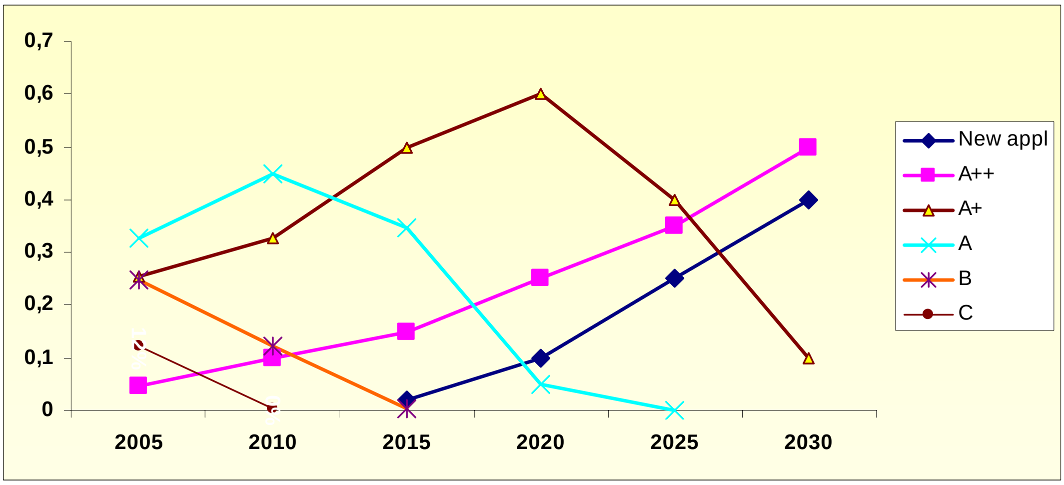
Figure 6-10 and Figure 6-11 show the transformation of refrigerator and freezer markets in the case of the HPI Scenario.

Figure 6-10: Market transformation for refrigerators (HPI Scenario)



New appliance: see footnote 8

Figure 6-11: Market transformation for freezers (HPI Scenario)



New appliance: see footnote 8

For the driers we envisage, starting from the year 2020, the introduction in the market of a new technology, the phase out in the same year of the category C as in the LPI scenario and the phase out of the B category in the year 2025.

6.1.5.4 Definition of the Technical Scenario

For all the appliances considered in this study the Technical Scenario has been designed to rapidly saturate the energy labelling mix with the BAT categories in order to let them arrive at 100 % around the year 2015/2020 for cold appliances and 2010/2015 for wash appliances and driers. In this way it is possible to compare the energy efficiency trend achieved by the Autonomous Progress Scenario in these years with the maximum energy efficiency achievable today.

6.2 Residential information/communication (IT) appliances

6.2.1 Description of the sector/end-use

The IT appliances are part of the MURE stock model for electrical household appliances (see Chapter 6.1). Therefore, both the data requirements and the definition of the scenarios are similar to the residential appliances. IT appliances in households comprise a wide range of appliances: audio-visual devices such as compact systems, TVs, set-top-boxes, DVD player or video game consoles, computers and peripherals (screens, printers, scanners etc.), telephones and the whole communications infrastructure. In the MURE stock model, not all IT appliances are included, but only the most important ones with regard to energy consumption or appliances with an increasing consumption trend. The following IT appliances have been examined in detail:

- Televisions (highest share in consumption, big saving potential)
- Set-top boxes (strongly increasing energy demand due to digital TV etc.)
- Computers (increasing consumption trend in normal mode)
- Screens (technological change, increasing screen size)
- Routers/modems (increasing energy demand in households)

6.2.2 Sector-specific / use-specific data sources and modelling issues

The general structure of the MURE stock model for electric appliances is described in Chapter 6.1.2.1. For IT appliances, the following variables are required by the model:

- Household growth rate
- Appliance ownership rate
- Appliance life time (for IT appliances: relatively short)
- Sales shares by appliance technology (for TVs and screens)
- Time of use, distinguishing between "active mode" and "standby mode"
- Specific energy consumption by appliance type, distinguishing between "active mode" and "standby mode"

The main data sources for the collection of the input variables are shown in Table 6-3. Whereas the assumptions on the number of households, the appliance ownership rate and lifetime as well as the time of use remain the same in all scenarios, the assumptions on the sales shares by technology and on specific consumption are technology drivers and therefore depending on the scenario.

Table 6-4: Main data sources for the variables required by the MURE stock model for IT appliances

Variable	Main data sources
Number of households	PRIMES
Appliance ownership rate	ODYSSEE (TVs), Statistical Offices/Eurostat, EuP case studies (Lot 3 [14] and Lot 5 [15])
Appliance lifetime	EuP case studies (Lot 3 and Lot 5)
Time of use	EuP case studies, Fraunhofer ISI 2005
Sales by appliance technology	GfK sales data from the Gfk retail panel (available for most of the MS)
Specific energy consumption	ODYSSEE (TVs), model assumptions based on measurements and studies (not country-specific): esp. EuP case studies; Roth et al. 2007; Fraunhofer ISI 2005

The following basic assumptions on the scenario-independent input variables have been made:

Appliance ownership rate:

- For the base year 2004 country-specific ownership rates, mainly based on the Eurostat ICT statistics, have been collected.[16]
- For TVs, the ownership rates should include secondary appliances. These data are, however, not available from the Eurostat statistics by country. Therefore, the assumptions were taken from the EuP Preparatory Study "Televisions" (Lot 5) without differentiation by country (2004: 1.4 TVs/hh).
- Until 2030, it has been assumed that the ownership rates for ICTs will be the same within the EU, mainly based on the assumptions in the EuP studies "Televisions" (Lot 5) and "Computers" (Lot 3) and own estimates (see Figure 6-12).

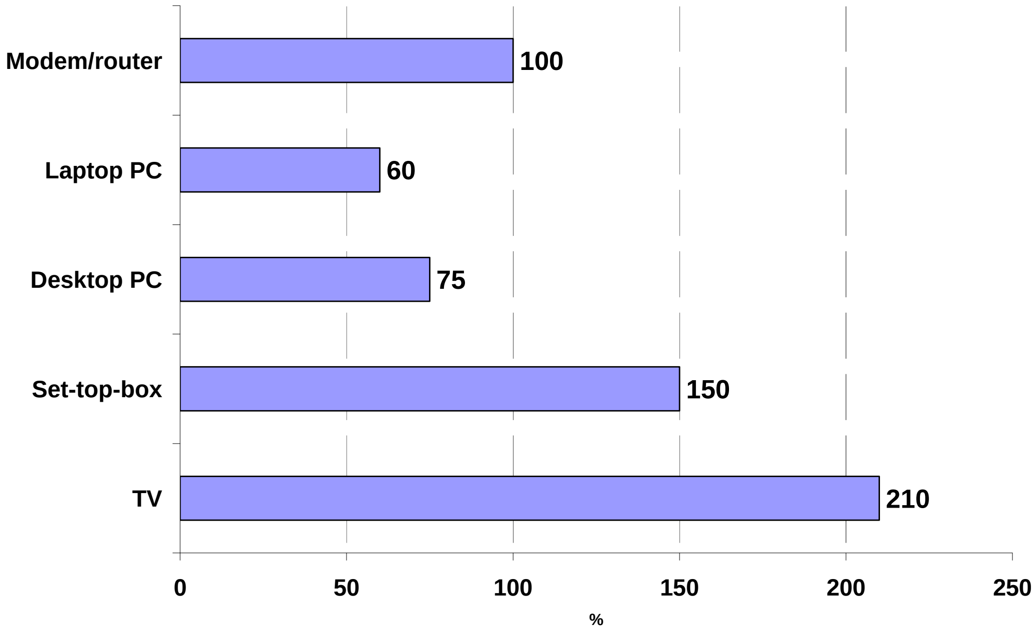
---

14 http://www.ecocomputer.org/

15 http://www.ecotelevision.org/

16 http://epp.eurostat.ec.europa.eu/portal/page?_pageid=2973,64549069,2973_64554066&_dad=portal&_schema=PORTAL

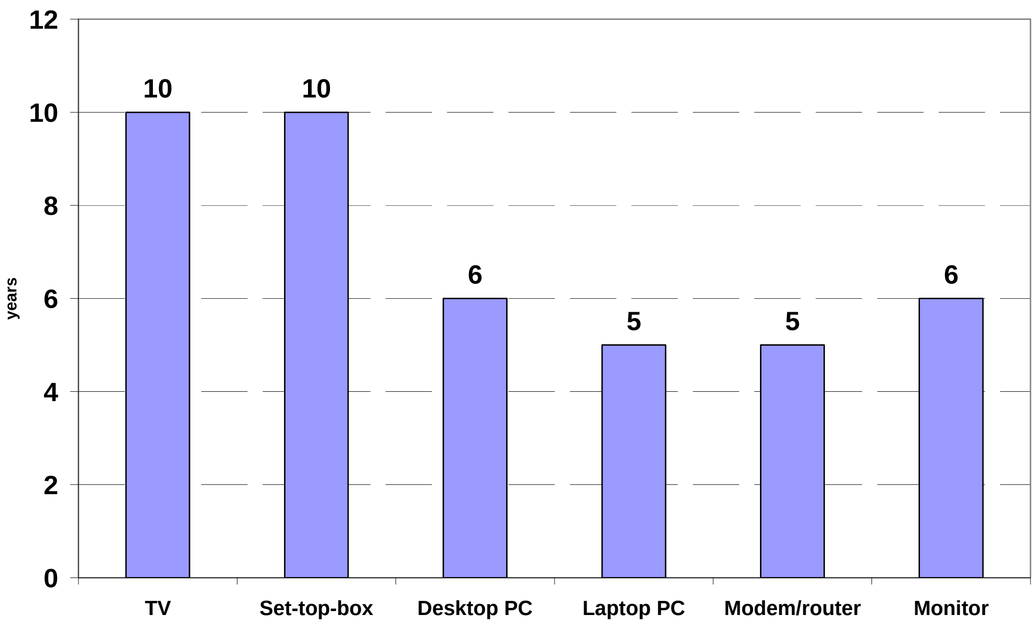
Figure 6-12: Assumed IT appliance ownership rates for the year 2030 (all countries)



Appliance lifetime:

- The assumptions on the appliance life time have been taken from the EuP case studies (see Figure 6-13).

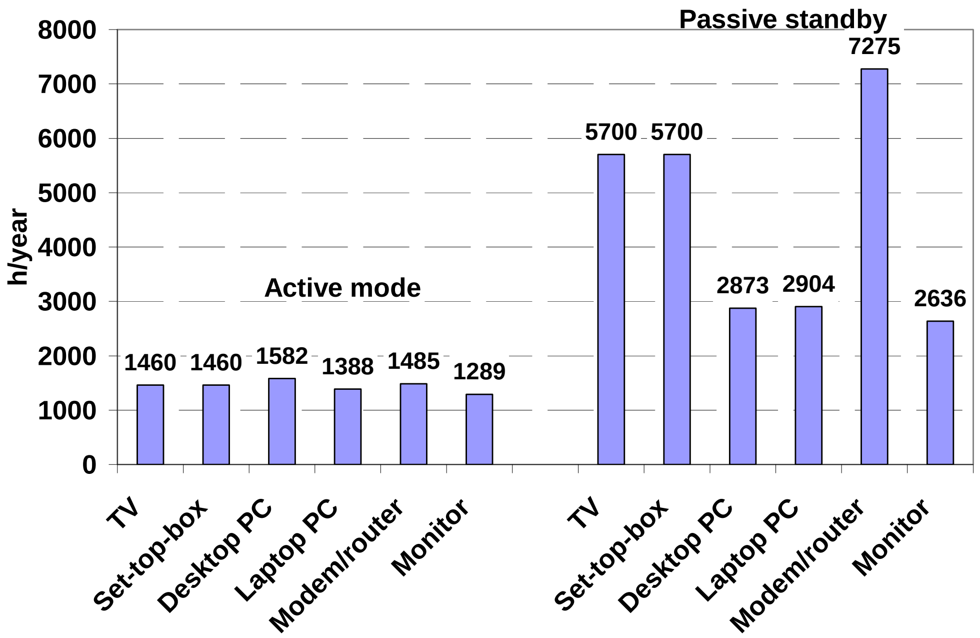
Figure 6-13: Appliance lifetime of IT appliances



Time of use:

- ➢ The assumptions on the time of use have been taken from the EuP case studies and from a study by Fraunhofer ISI (2005).
- ➢ Since there are only a few data available at the level of individual countries, the assumptions are the same for all countries (see Figure 6-14).

Figure 6-14: Assumptions on the time of use of IT appliances



6.2.3 Step 1 – Definition of energy saving options

For IT appliances, the saving options in the active mode (normal operation) and in the standby mode have to be considered separately, since the saving technologies are different. Two different saving options have to be taken into account within normal operation. On one hand, energy savings can be achieved by a technology switch from less efficient to more efficient technologies (e.g. from the CRT to the LCD or FED technology in the case of TVs and screens or from desktop to notebook technology in the case of computers). It is, however, a matter of debate, how much of this switch is triggered by energy efficiency considerations – probably not very much. On the other hand, technical improvements are also possible for single appliances or appliance technologies. In addition to that, savings can also occur through the penetration of appliances with lower stand-by consumption.

This means that the following three types of energy saving options have been taken into account in the case of TVs and IT appliances.

(1) Technology switch from CRT technology to LCD/FED/OLED technology (in case of TVs and screens) and from desktop to notebook technology.

(2) Improvement of single technologies in normal operation (e.g. technical improvement of LCD screens).

(3) Technical and behavioural options to reduce stand-by consumption (TVs and all IT appliances).

6.2.4 Step 2 – Technology costs

The current heavily competitive market conditions in conjunction with an unpredictable dynamic technology development make it difficult to estimate realistic cost for the saving options. But the considerable drop in product prices during the past years suggests that at least best available technology (BAT) saving options which are the main basis for the economic saving potential in this study should not result in appreciable additional costs. According to the EuP case studies, the costs of the BAT options are assumed to be neutral, even if the competitive market situation is not taken into account. This assumption is taken over for this study, too. For the technical potential, which also considers BNAT (best not available technology) saving options, technology costs cannot be considered due to the high degree of uncertainty.

6.2.5 Step 3 – Definition of the four scenarios

For IT appliances, the four scenarios are defined as follows:

(1) Autonomous Progress Scenario (APS): an **autonomous scenario** which is realised by the baseline.

(2) Low Policy Intensity Scenario (LPI-S): an **economic scenario** with a high discount rate reflecting a low policy intensity and high barriers; in this scenario, the additional technology diffusion of best available technologies (BAT) beyond autonomous diffusion is restricted to a moderate level.

(3) High Policy Intensity Scenario (HPI-S): an e**conomic scenario** with a low discount rate reflecting a high policy intensity (**HPI**) and low barriers; in the case of IT appliances, however, scenario 3 is identical with scenario 2, since for IT appliances no additional technology costs are assumed for BAT saving options (see Chapter 6.2.4).

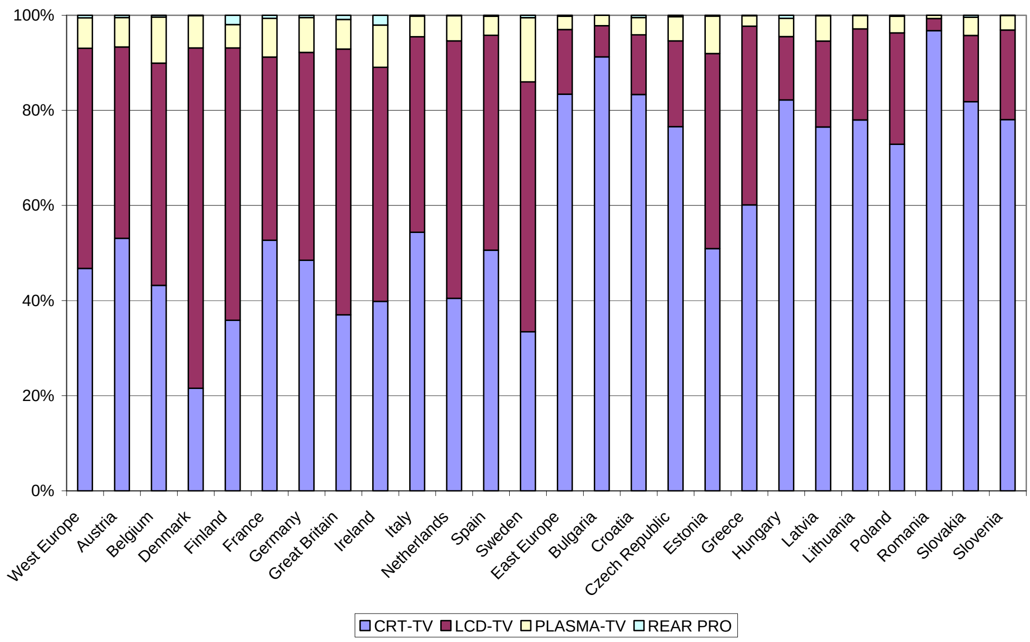
(4) Technical Scenario (TS): a **technical scenario**, in which BAT saving options are realised to a large scale and also some BNAT saving options get into the market.

For IT appliances, these scenarios are on the one hand defined by different sales shares of appliance technologies (for TVs and screens), with the highest shares of the most efficient technologies (FED, OLED) in the Technical Scenario (s4). Additionally, the scenarios are defined by a different level of specific energy consumption for each appliance/appliance technology, with the lowest specific consumption in the technical scenario. A distinction is also made between active mode and standby mode. The following scenario assumptions for these technology drivers have been made:

Sales shares by appliance technology (TVs, monitors):

- For TVs, country-specific sales data by TV technology have been available for the base year 2004 and for 2006 from GfK (2007) for most of the countries, distinguishing between the following technologies: CRT, LCD, Plasma and Rear-Pro (see Figure 6-15).

Figure 6-15: Shares of TV sales by technology and country in the year 2006



Source: GfK 2007

- From 2020, the same structure of TV technologies has been assumed for all EU-countries with a phase-out of the CRT technology until 2020.
- In the autonomous and economic scenarios, LCD TVs are the dominating technology (65 %), with moderate shares of Plasma TVs (25 %) and Rear Pro TVs (10 %). In the technical scenario, a slow penetration of a "new technology" (FED, OLED) is assumed (see Figure 6-16).
- For monitors, country-specific sales data by technology (CRT, LCD) have not been available for the base year. Therefore, the same structure has been

estimated for all EU-countries, based on the EuP study on computers (for 2004: CRT 25 %, LCD 75 %).

- In the Autonomous Progress Scenario, the monitor market is dominated by the LCD technology, whereas in the economic scenario and even more in the technical scenario a "new technology" (FED, OLED) gets into the market, too (see Figure 6-17).

Figure 6-16: Assumed shares of TV sales by technology in 2030, all countries

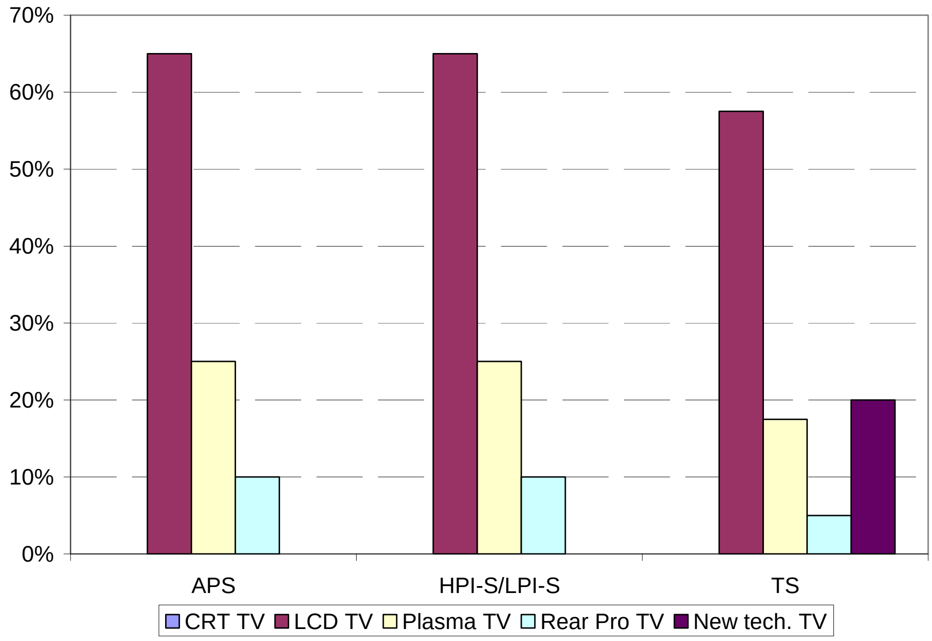
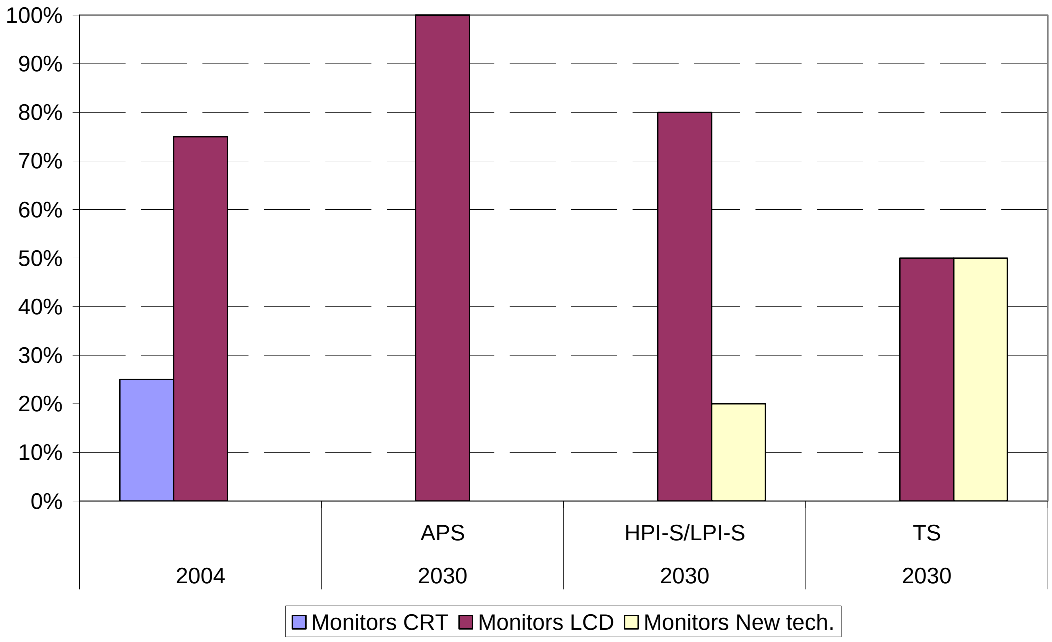


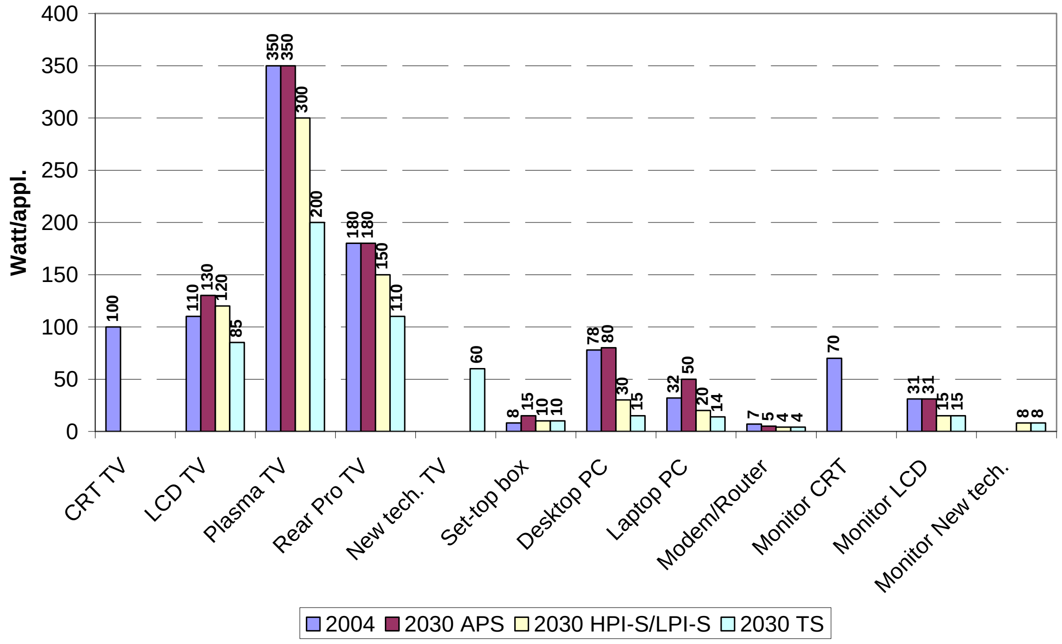
Figure 6-17: Assumed shares of monitor sales by technology, all countries



Specific energy consumption by appliance and technology, active mode:

- The assumptions on the specific energy consumption by appliance type and technology are not differentiated by country, since the appliances sold are almost the same all over Europe.
- The specific consumption of TVs in active mode is strongly influenced by the screen size, which compensates or even over-compensates energy efficiency improvements especially in the autonomous scenario, but also in the economic scenario (Figure 6-18).
- For most of the other IT appliances, a moderate increase in specific consumption is expected in the autonomous scenario, which is mainly due to bigger screens or displays and increased (use) performance and additional functions. In the economic and technical scenario, however, the influence of technical BAT options to reduce the power demand is dominating (Figure 6-18).

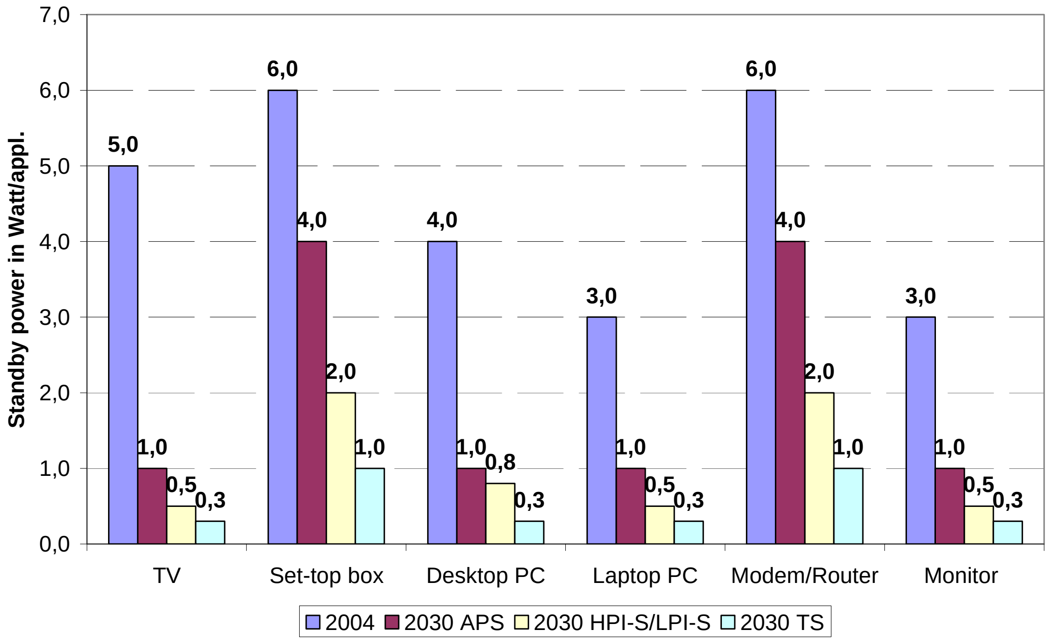
Figure 6-18: Assumptions on specific energy consumption by appliance and technology in active mode



Specific energy consumption by appliance, standby mode:

- For standby consumption, a considerable decrease is already expected for the autonomous scenario, so that the additional decrease in the other scenarios is moderate (Figure 6-19).

Figure 6-19: Assumptions on specific energy consumption for IT appliance in standby mode



6.3 Residential lighting

6.3.1 Description of the sector/end-use

The residential lighting end use takes into account the lighting demand trends of the European countries. For the sake of simulation for the potentials, the current lighting situation has been described through two types of lighting systems:

- The incandescent (and halogen) lamps, having an average efficiency of 13.8 Lumen/W
- The high efficiency lamps (CFL), having an average efficiency of 60 Lumen/W

For the future another lighting technology has been added:

- The LED technology, having an average efficiency of 120 Lumen/W

To transform the above specific lighting efficiency in the lighting household luminous intensity per square meter, we have assumed the average technical figure of 200 Lumen/m^2.

6.3.2 Sector-specific / use-specific data sources and modelling issues

The energy consumption trends and the achievable savings of residential lighting end use have been simulated through a lighting sub model of the MURE household model. The main data source has been Bertoldi and Atanasiu (2006).

The input variables used in this sub model have been:

Household number	(PRIMES)
Total electricity consumption	(PRIMES)
Lighting energy consumption (2004)	(Bertoldi/Atanasiu)
Lighting points per household (2004)	(Bertoldi/Atanasiu)
% of CFL lighting points per household in the year 2004	(Bertoldi/Atanasiu)
Forecast for penetration rates of the lighting technologies	(ISIS)
Efficiency of the incandescent lamps	(technical literature)
Efficiency of the CFL lamps	(technical literature)
LED efficiency	(technical literature)

The sub model calculates the lighting unit consumption per lighting point for each of the three lighting technologies mentioned above. This lighting unit consumption has been determined on the following basis:

- The weighted sum of the unit consumptions of the three lighting technologies is equal to the total unitary lighting consumption; which is a known figure.
- There is a linear relationship among the unit consumptions of each technology, the number of the corresponding lighting points and the corresponding efficiency expressed in Lumen/watt

In this way the sub model calculates the total lighting energy consumption trend through the following equation (1):

$$Light\_en\_cons_{c,s,t} = \begin{pmatrix} unit\_cons\_LED_{c,s,t} \times LED\_point_{c,s,t} + \\ + unit\_cons\_CFL_{c,s,t} \times CFL\_point_{c,s,t} + \\ + unit\_cons\_Inc_{c,s,t} \times Inc\_point_{c,s,t} \end{pmatrix} \times household\_number_{c,t}$$

Where “unit_cons_*technology* is the unit consumption per lighting point, *technology*_point are the lighting points per technology and “household_number” is the number of household. As for the indexes, c = country, s = EE scenario, t = scenario steps.

The lighting points are in turn provided by equation (2):

$$CFL\_points_{c,t,s} = Light\_points_{c} \times \left(light\_split\%_{c,s,l=1,t} - light\_split\%_{c,s,l=2,t}\right)$$

$$LED\_points_{c,t,s} = Light\_points_{c} \times light\_split\%_{c,s,l=2,t}$$

$$Inc\_points_{c,t,s} = Light\_points_{c} - \left(CFL\_points_{c,t,s} + LED\_points_{c,t,s}\right)$$

Where the variable "Light_points" provides the total household lighting points and the variables "light_split" the penetration rates of the energy efficiency technologies being l=1 the CFL lamps and l=2 the LED technology. These settings imply that the penetration of the LED technology as well as of the sum of the more efficient lighting types CFL and LEDs is set, while the number of lighting points for incandescent light is set.

6.3.3 Step 1 – Definition of energy saving options

For the residential lighting uses the energy saving option are driven by the penetration of the most efficient technologies in the household stock (see equation (1)) with the following settings:

- The CFL lamps substitute the incandescent (and halogen) lamps
- The LED technology substitutes the CFL lamps.

6.3.4 Step 2 – Technology costs

Assumption on technology costs for lighting are based on a cost degression hypothesis of ten years.

6.3.5 Step 3 – Definition of the four scenarios

Also for the lighting uses, the scenarios have been laid out in accordance with the general project definitions:

- An Autonomous Progress Scenario which is realised by the baseline. In our case the following criteria have been applied:
  - Slow but steady introduction of the CFL lamps up to the point where 25 % of the lighting points are represented by CFL lamps
  - No introduction of the LED technology
- An LPI Scenario with high discount rates reflecting cost-effectiveness for the consumer with usual market conditions. This is generally reflected in the following targets:

- o A rather strong penetration of the CFL lamps up to a level of 50 % of the lighting points (25% additional CFL lighting points with respect the Autonomous Progress Scenario)
- o A very slow introduction of the LED technology (that partially substitutes the already introduced CFL lamps)

➢ An HPI Scenario which is derived from maximum technical potential, but only including options with net negative costs (net cost savings; but with low discount rates or subsidies). In this case the targets are:

- o A strong penetration of the CFL lamps that arrive to substitute 80 % of the incandescent stock.
- o A rather high penetration of the LED technology that substitutes 15-16 % of the already installed CFL stock.
- o Apart from the economic constraints, we consider that for style or architectural constraints there will still remain a stock of around 20 % of incandescent-like lamps such as the halogen lamp.

➢ A maximum technical scenario which includes all saving options, also those with net positive costs. This is made by the penetration of the 60% of the CFL lamps and 40% of LED technology.

6.4 Results appliances (incl. IT appliances) and lighting

6.4.1 Overall results

Figure 6-20 shows the total energy consumption trends by scenario due to the EU27 electric uses described in this chapter (large appliances, lighting and IT devices). In accordance to the outputs provided by the MURE model the energy consumption due to these uses starts from 24,670 ktoe in 2004 and rises in the Autonomous Progress Scenario to over 39,000 ktoe in 2030. The energy consumption growth is due to both the growth of the household numbers, the increase of the ownership rates of some appliances (ITs and dishwashers and driers, especially in the eastern countries) and the increase of the use of some ITs. The EE interventions envisaged in the two policy scenarios described in the previous paragraphs invert the growing trend of the Autonomous Progress Scenario but still the final energy consumption in 2030 exceeds the consumption of the starting year: + 25 % for the LPI Scenario and + 13 % for the HPI Scenario. The energy consumption achieved in the technical scenario is, on the contrary, 28 % lower in 2030 then in 2004. According to these results it is technically but not economically feasible to counterbalance the pressure of the demographic and socio-economic drivers.

Table 6-5 and Table 6-6 as well as Figure 6-21 and Figure 6-22 show in detail the overall savings achievable in the EU27 countries from these electric uses in ktoe and percentage savings. At the beginning, the savings are limited to some percentage points but increase rapidly along the scenario steps due to the substitution of the less efficient technologies with the new ones.

Finally Table 6-7 and Table 6-8 as well as Figure 6-20 show the contribution of these final electric uses to the total savings by the year 2030. It is interesting to note the strong and increasing contribution provided by the lighting systems to the savings which, in order of importance, are followed by the IT appliances and the driers. The cold appliances (refrigerators + freezers) contribute with a constant share of 12 % while the contribution of the wash appliances (washing machines + dishwasher) is marginal.

The reason why these final electric uses behave in such a different way is better highlighted in the following three paragraphs that provide for each of them the trend of the EE potentials and of the corresponding unit consumption.

Figure 6-20: Energy consumption trends from electrical appliances and lighting (EU27)

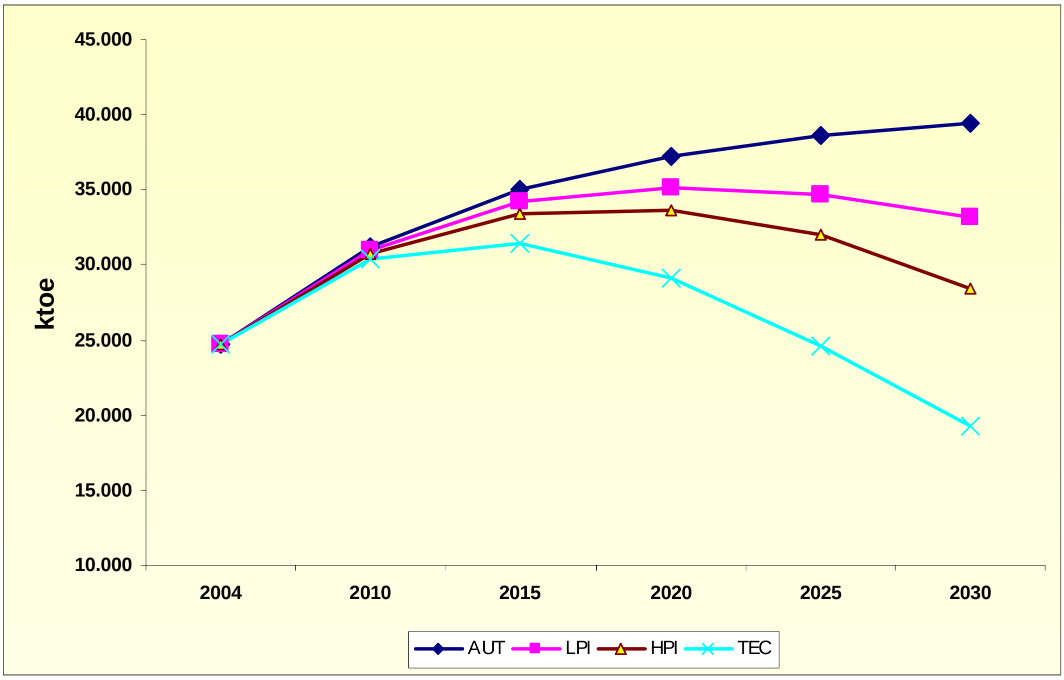


Table 6-5: **Additional savings from electrical appliances and lighting (EU27; ktoe compared to the Autonomous Progress Scenario)**

ktoe	2010	2015	2020	2025	2030
LPI-S	213	841	2.170	3.988	6.232
HPI-S	430	1.568	3.673	6.672	10.954
TS	800	3.564	8.155	14.087	20.109

Table 6-6: **Additional savings from electrical appliances and lighting (EU27; % compared to the Autonomous Progress Scenario)**

ktoe	2010	2015	2020	2025	2030
LPI-S	0.7%	2.4%	5.8%	10.3%	15.8%
HPI-S	1.4%	4.5%	9.9%	17.3%	27.8%
TS	2.6%	10.2%	21.9%	36.4%	51.0%

Figure 6-21: **Additional savings from electrical appliances and lighting (EU27; ktoe compared to the Autonomous Progress Scenario)**

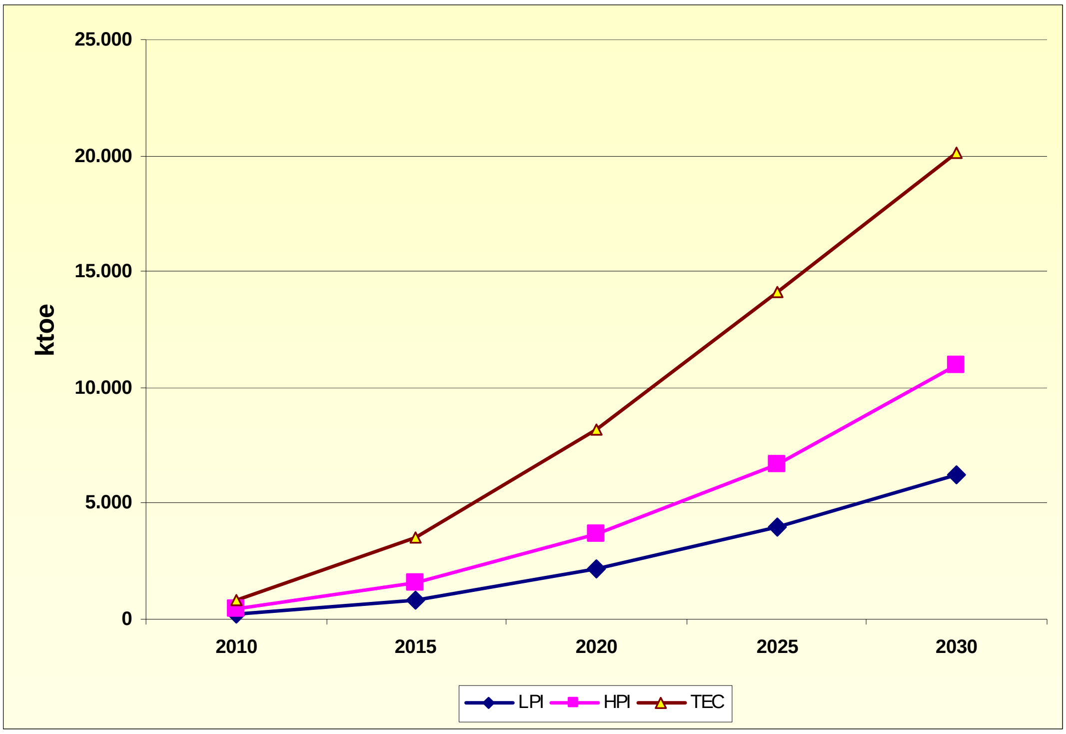


Figure 6-22: Additional savings from electrical appliances and lighting (EU27; % compared to the Autonomous Progress Scenario)

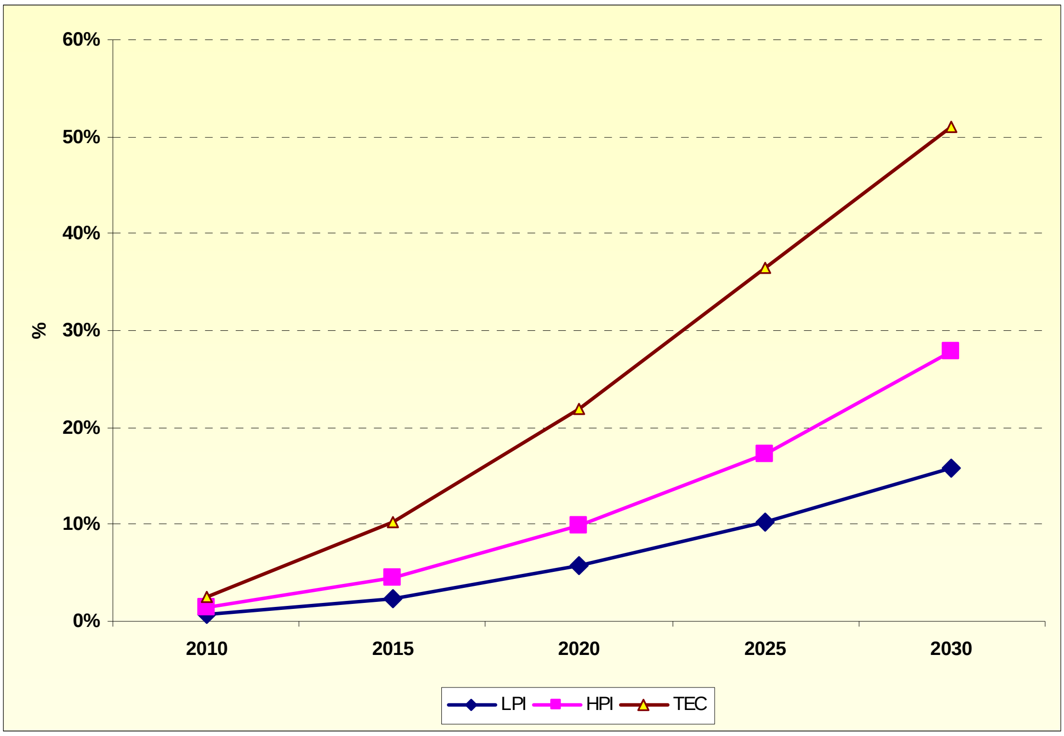


Table 6-7: Contribution of the final electric uses to the overall additional EE potentials in 2030 (ktoe, EU27)

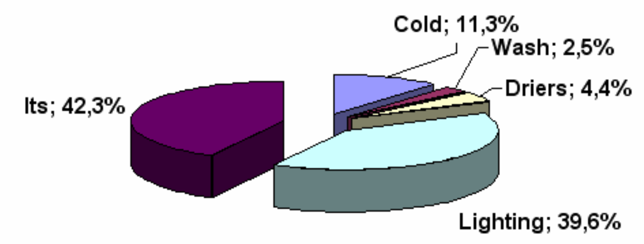
	Cold appliances	Wash appliances	Driers	Lighting	ITs	Total
LPI-S	704	153	272	2,469	2,634	***6,232***
HPI-S	1,304	184	594	6,238	2,634	***10,954***
TS	2,497	298	2,778	8,851	5,686	***20,109***

Table 6-8: Contribution of the final electric uses to the overall additional EE potentials in 2030 (%, EU27)

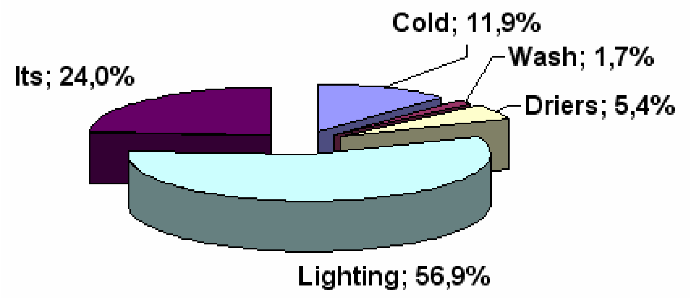
	Cold appliances	Wash appliances	Driers	Lighting	ITs	Total
LPI-S	11.3%	2.5%	4.4%	39.6%	42.3%	100.0%
HPI-S	11.9%	1.7%	5.4%	56.9%	24.0%	100.0%
TS	12.4%	1.5%	13.8%	44.0%	28.3%	100.0%

Figure 6-23: EU27, Contribution of the final electric uses to the overall EE potentials in the year 2030 (%)

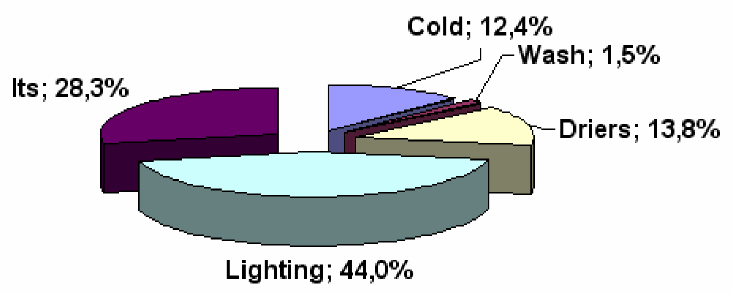
LPI Scenario



HPI Scenario



Technical Scenario



6.4.2 Results residential electric appliances

6.4.2.1 Cold and wash appliances

Table 6-9 as well as Figure 6-24 to Figure 6-27 show the additional EE potentials for each scenario (compared to the Autonomous Progress Scenario) for the cold and wash appliances while Figure 6-28 to Figure 6-31 show the EE potential trends expressed in percent for the EU-12 and EU15 countries. From both the results expressed in absolute terms and those expressed in relative terms it is possible to note that the cold appliances, and especially the refrigerators, can still achieve a good level of additional savings while the wash appliances seem to have no further margins for a substantial energy efficiency improvement. Altogether, in the year 2030 the cold appliances can save from 700 to 1300 ktoe in the LPI respectively the HPI scenario, and up to around 2500 ktoe in the Technical Scenario. Wash appliances hardly reach one seventh of the savings as compared to cold appliances: 153 ktoe for the LPI Scenario and 184 ktoe for the HPI Scenario. In the Technical Scenario wash appliances achieve with 298 ktoe proportionally lower savings than cold appliances: the EE potential increases in the Technical Scenario compared to the HPI Scenario by 38 % for the wash appliances and by 48 % for the cold appliances.

The comparison between the EU-12 and the EU15 countries indicates that the percentage savings are more or less the same for both groups of countries except for the washing machines and, partially, the freezers, for which the Eastern countries have greater EE potentials. This result depends on the fact that, in the Eastern Countries, the refrigerator stock and, to less an extent, the freezers stock, have been largely renewed during the nineties while the washing machine stock still starts from a less efficient situation (and thus the EE potential is larger).

Finally the fact that, especially for the wash appliances, the EE potentials are decreasing after the year 2025 (see Figure 6-26 and Figure 6-27) means that, for more or less all the EU countries, more energy savings are taken up in the Autonomous Progress Scenario; hence less additional potentials remain for the other scenarios.

Table 6-9: Additional EE potentials from cold and wash appliances by scenario (EU27; ktoe compared to the Autonomous Progress Scenario)

Refrigerators

ktoe	2010	2015	2020	2025	2030
LPI-S	31	192	427	591	630
HPI-S	63	382	745	966	1,012
TS	174	1,010	1,668	1,981	1,867

Freezers

ktoe	2010	2015	2020	2025	2030
LPI-S	6	38	66	79	74
HPI-S	12	75	161	242	292
TS	46	268	459	599	630

Washing Machines

ktoe	2010	2015	2020	2025	2030
LPI-S	11	62	100	115	100
HPI-S	20	91	134	143	125
TS	28	139	211	243	216

Dishwashers

ktoe	2010	2015	2020	2025	2030
LPI-S	10	51	76	75	54
HPI-S	10	53	80	80	59
TS	15	68	88	94	82

Figure 6-24: Additional EE potentials from refrigerators by scenario (EU27; ktoe compared to the Autonomous Progress Scenario)

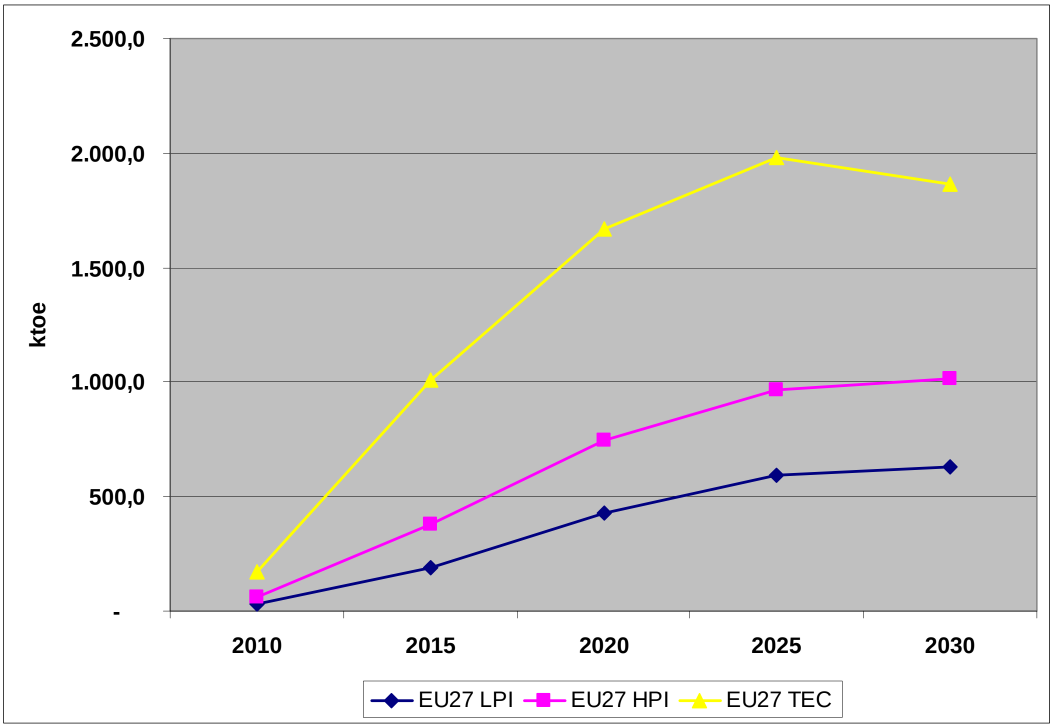


Figure 6-25: Additional EE potentials from freezers by scenario (EU27; ktoe compared to the Autonomous Progress Scenario)

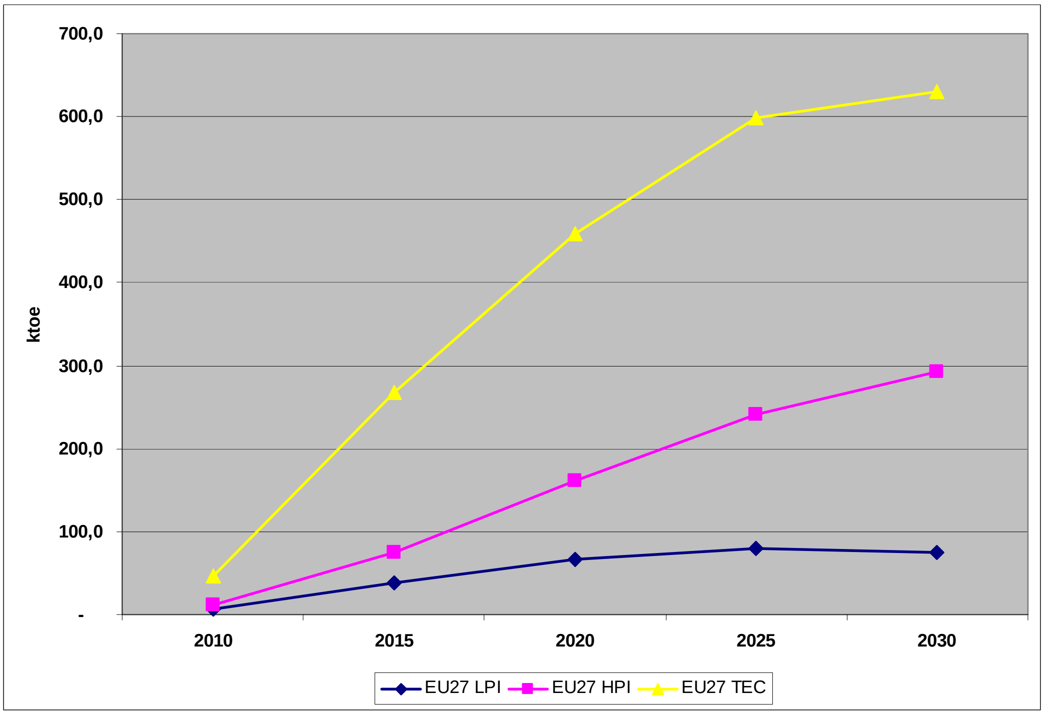


Figure 6-26: Additional EE potentials from washing machines by scenario (EU27; ktoe compared to the Autonomous Progress Scenario)

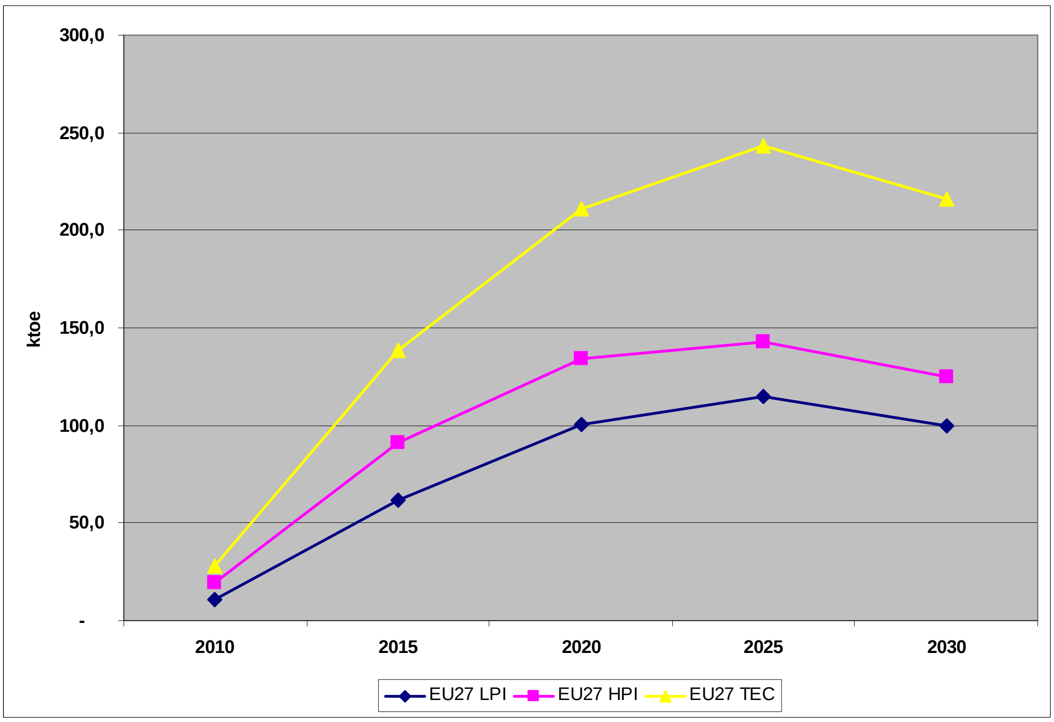


Figure 6-27: Additional EE potentials from dish washers by scenario (EU27; ktoe compared to the Autonomous Progress Scenario)

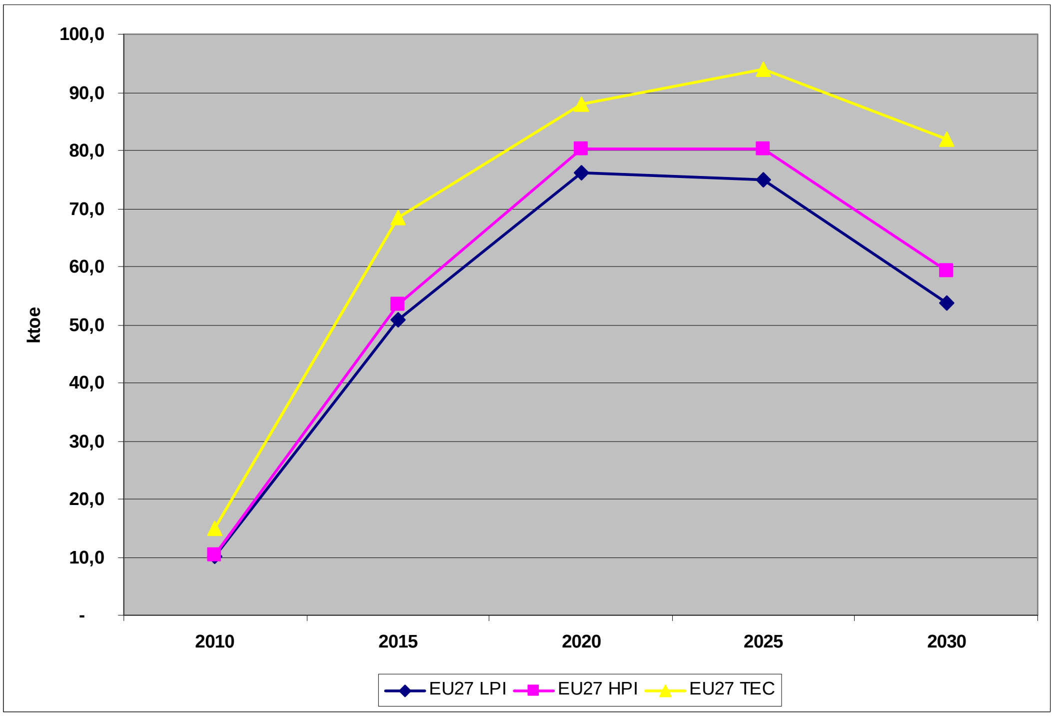


Figure 6-28: EE potentials trends in % for refrigerators (EU-12 & EU15)

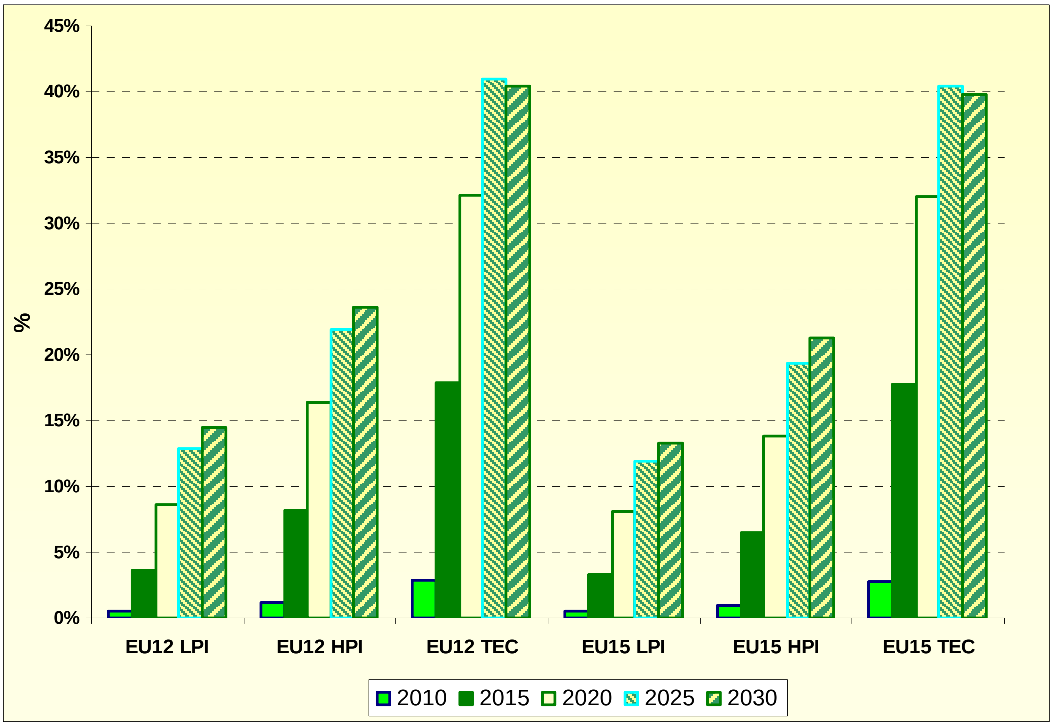


Figure 6-29: EE potentials trends in % for freezers (EU-12 & EU15)

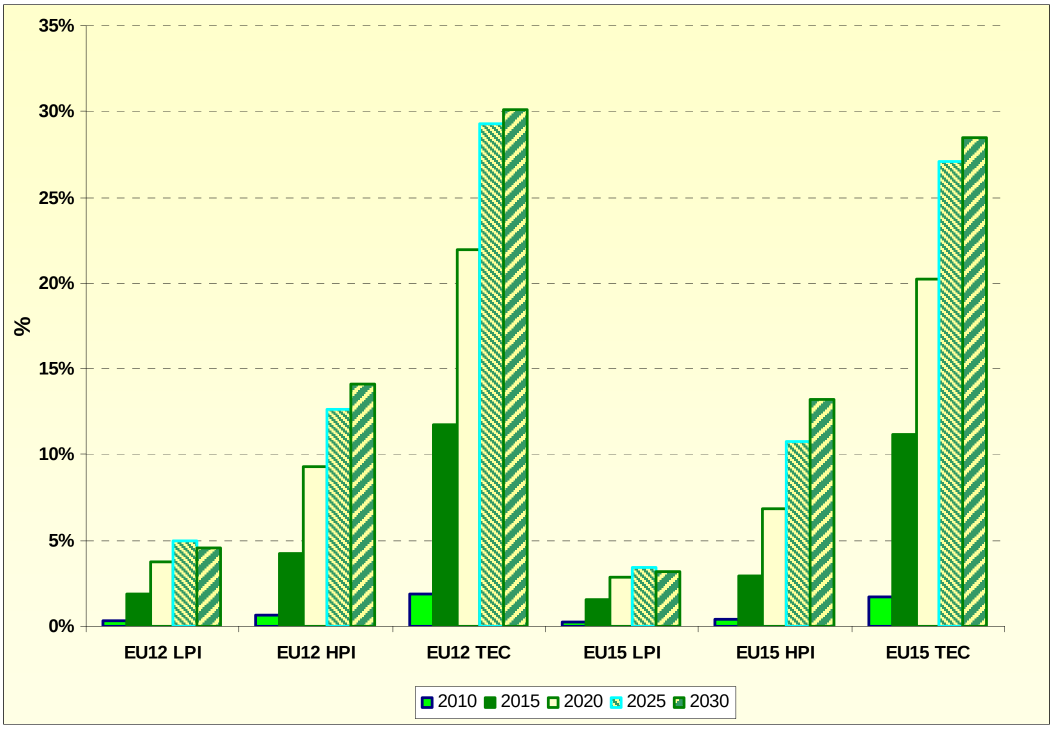


Figure 6-30: EE potentials trends in % for washing machines (EU-12 & EU15)

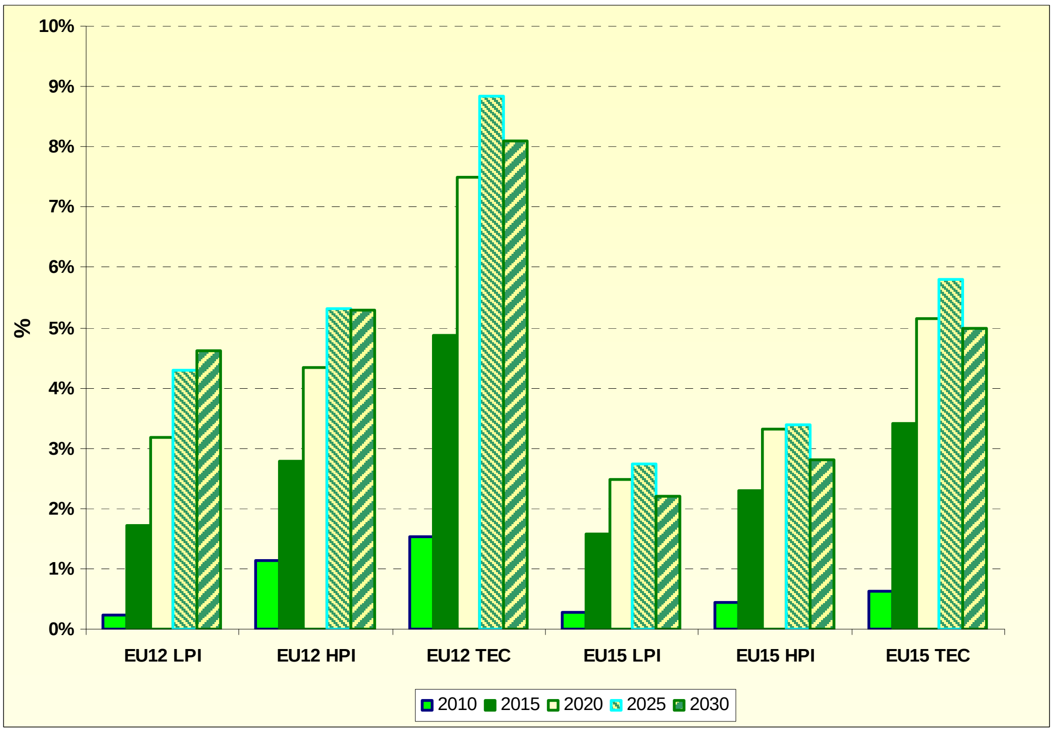
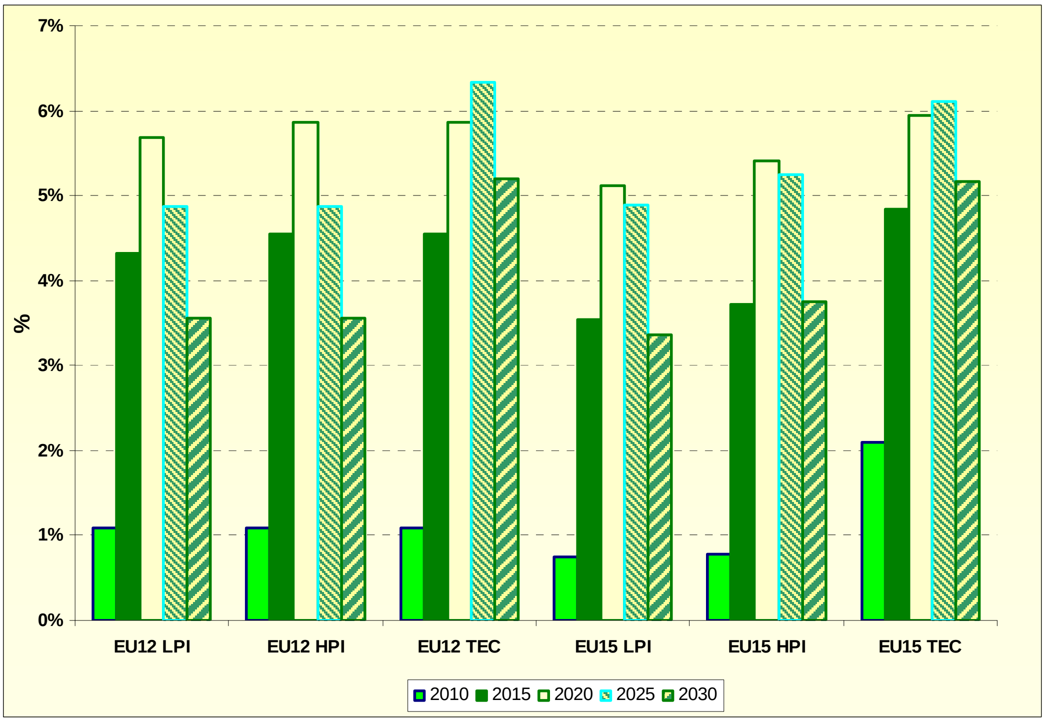


Figure 6-31: EE potentials trends in % for dishwashers (EU-12 & EU15)



The phenomenon of the progressive saturation of the stock energy efficiency is visible in Figure 6-32 to Figure 6-35 which provide the unit consumption trends expressed in kWh/appliance. In all these graphs the stock unit consumption seems to have an asymptotic trend (magnified by the trend of the technical scenario) indicating that the marginal energy efficiency potential is steadily decreasing. This trend may indicate an exhaustion of the energy efficiency potentials but it may also be the expression of the fact that the longer the time horizon the less reliable is our knowledge about new technologies or technologies not yet developed.

Figure 6-32: EU27, Refrigerators – Unit consumption trend by scenario

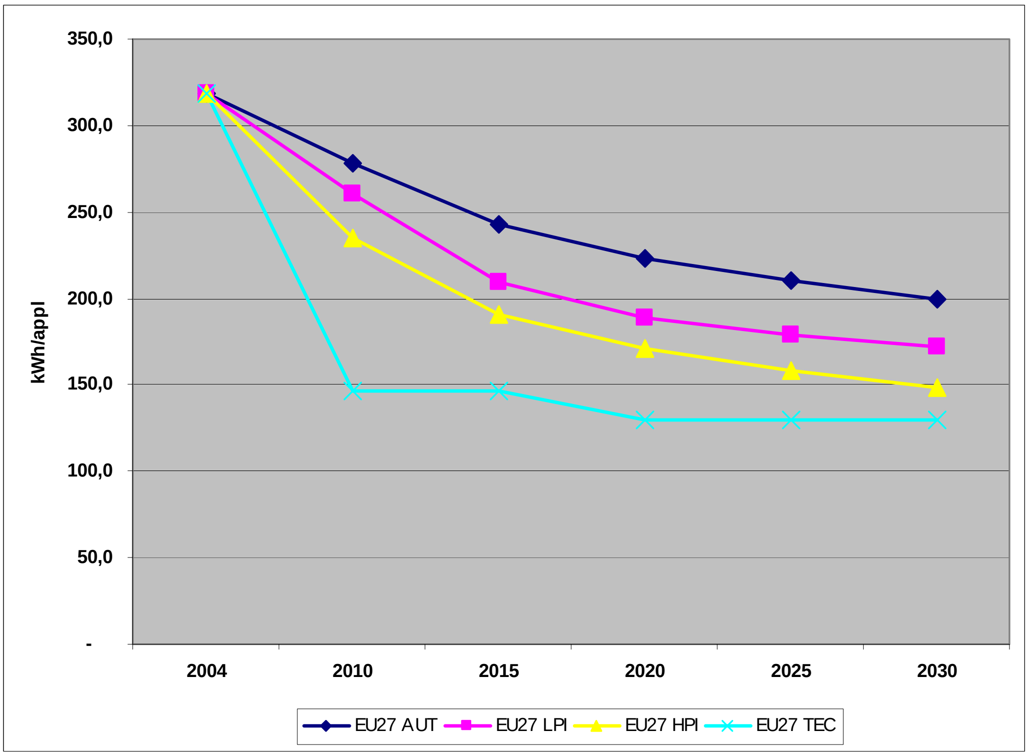


Figure 6-33: EU27, Freezers – Unit consumption trend by scenario

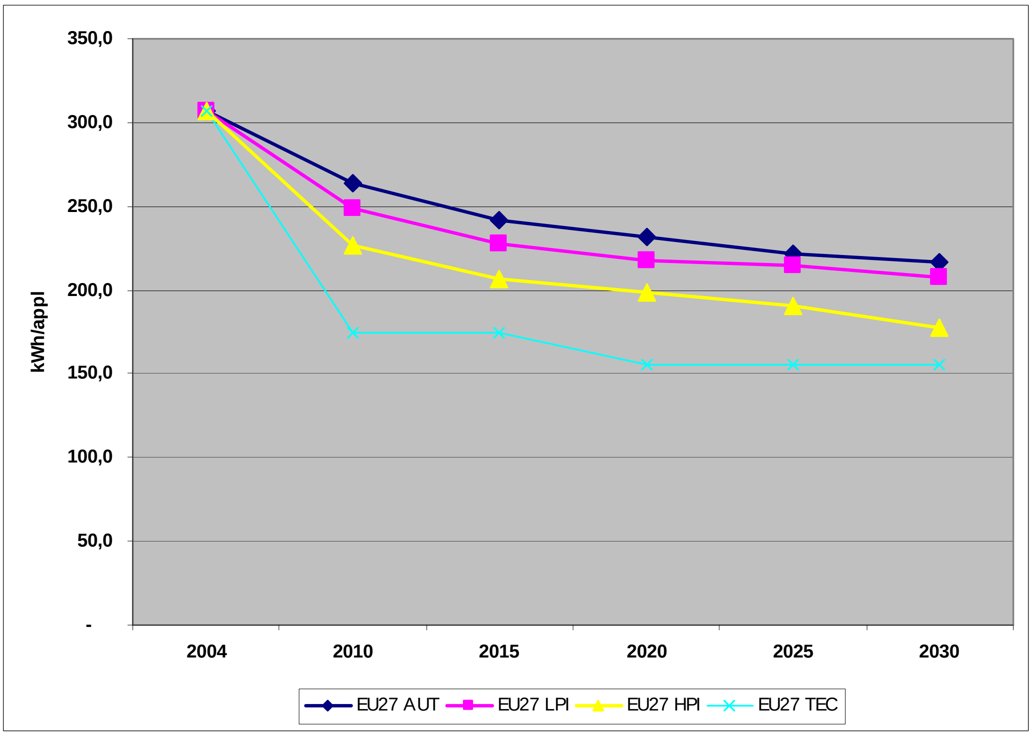


Figure 6-34: EU27, Washing Machines – Unit consumption trend by scenario

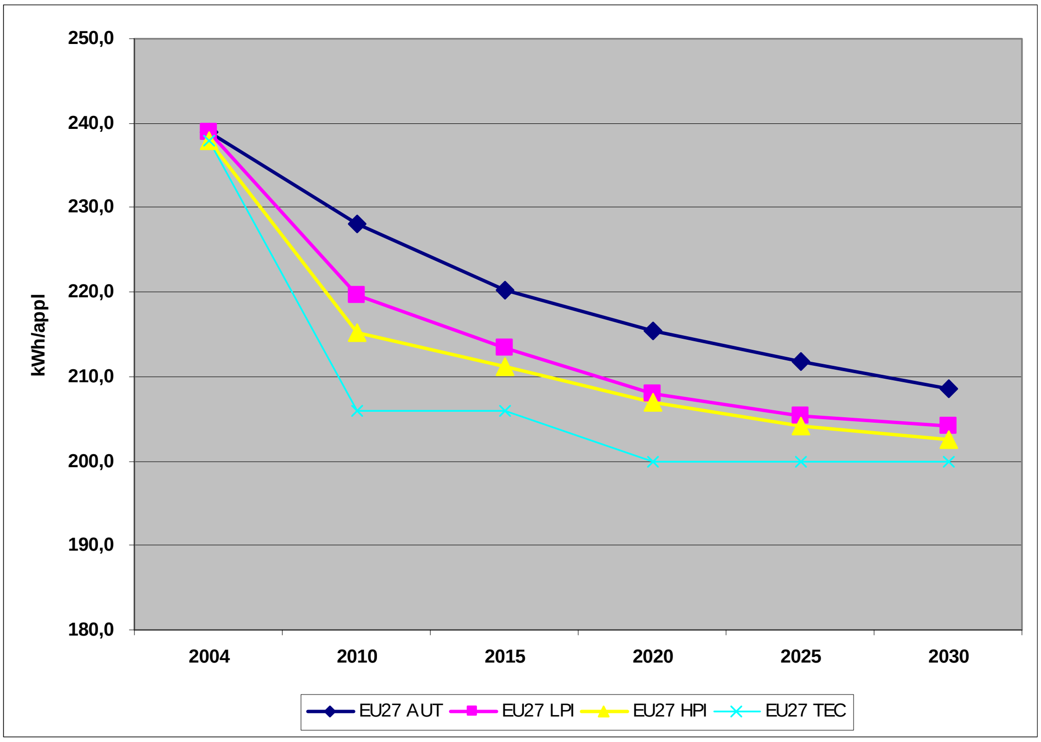
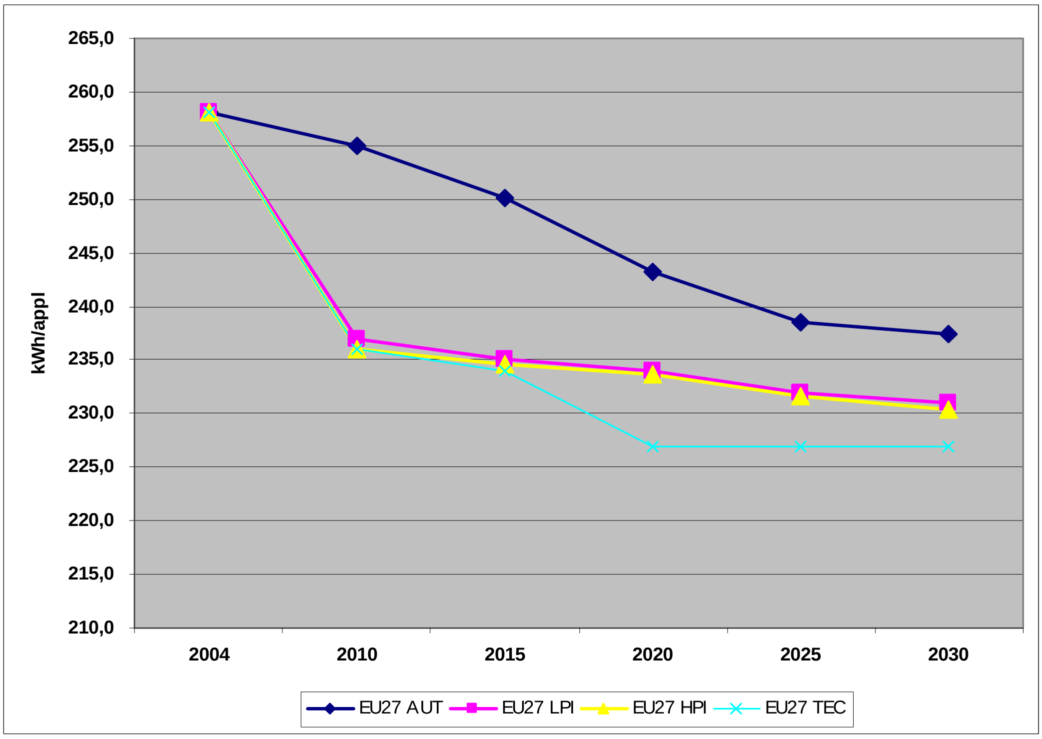


Figure 6-35: EU27, Dishwashers – Unit consumption trend by scenario



6.4.2.2 Driers

Table 6-10 and Figure 6-36 show the additional EE potentials per scenario for the driers. The starting energy efficiency of the driers is low (in the year 2004 the majority of these appliances are in class C) and, as briefly outlined in paragraph 6.1.5, the penetration of the more efficient classes is rather slow as the more efficient classes still represent a niche market. The technical potential is nevertheless very high as the slow energy efficient trend of the autonomous progress scenario is compared with a very efficient scenario in which the A labelling category which is 30 % more efficient than the C labelling category, reaches rapidly 100 % of the market and is in turn substituted (from 2020) by a new more performing technology, that is 55 % more efficient than the C class. It is also important to remember that the data for this type of appliance are less reliable than those provided for the other ones and that, for this reason, the differences of the EE potentials by country are not significant.

It is worth noting that the EE potential of this type of appliances, also shown by Figure 6-37 that provides the unit consumption trends by scenario, is low if compared with the savings achievable in the Technical Scenario but higher than the EE potential from freezers and comparable with that from refrigerators. The high potentials from driers is underlined by the fact that ownership rate of the driers is 40 % less than that of refrigerators.

Table 6-10: Additional EE potentials from driers by scenario (EU27; ktoe compared to the Autonomous Progress Scenario)

ktoe	**2010**	**2015**	**2020**	**2025**	**2030**
LPI-S	-	-	-	38	272
HPI-S	-	8	53	161	594
TS	101	640	1,279	2,199	2,778

Figure 6-36: Additional EE potentials from driers by scenario (EU27; ktoe compared to the Autonomous Progress Scenario)

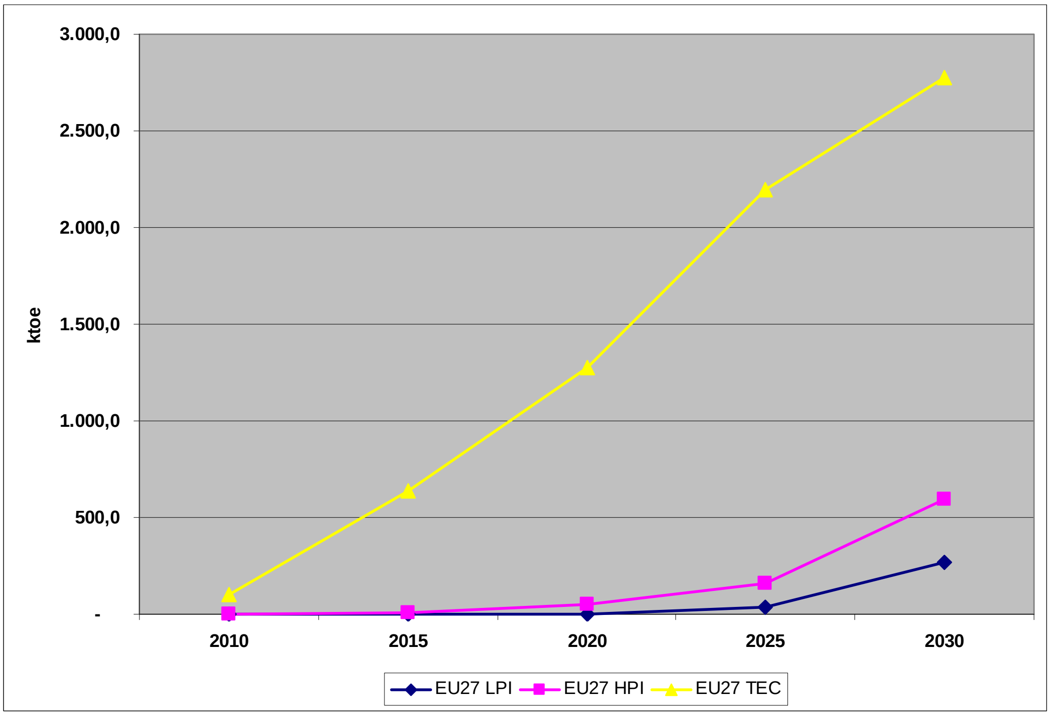
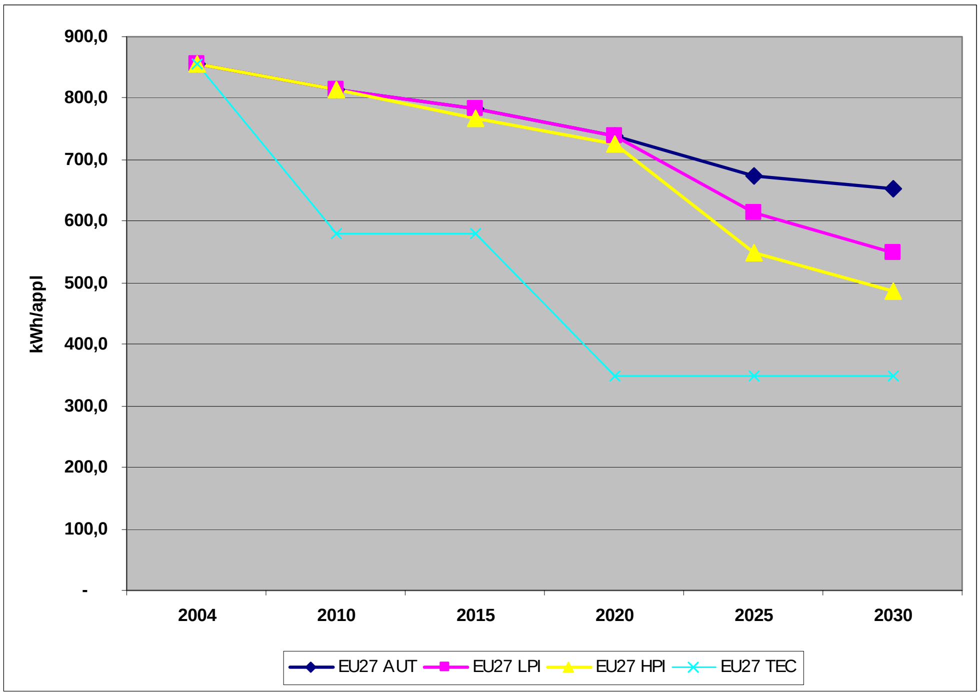


Figure 6-37: EU27, Driers – Unit consumption trend by scenario



6.4.3 Results residential information/communication (IT) appliances

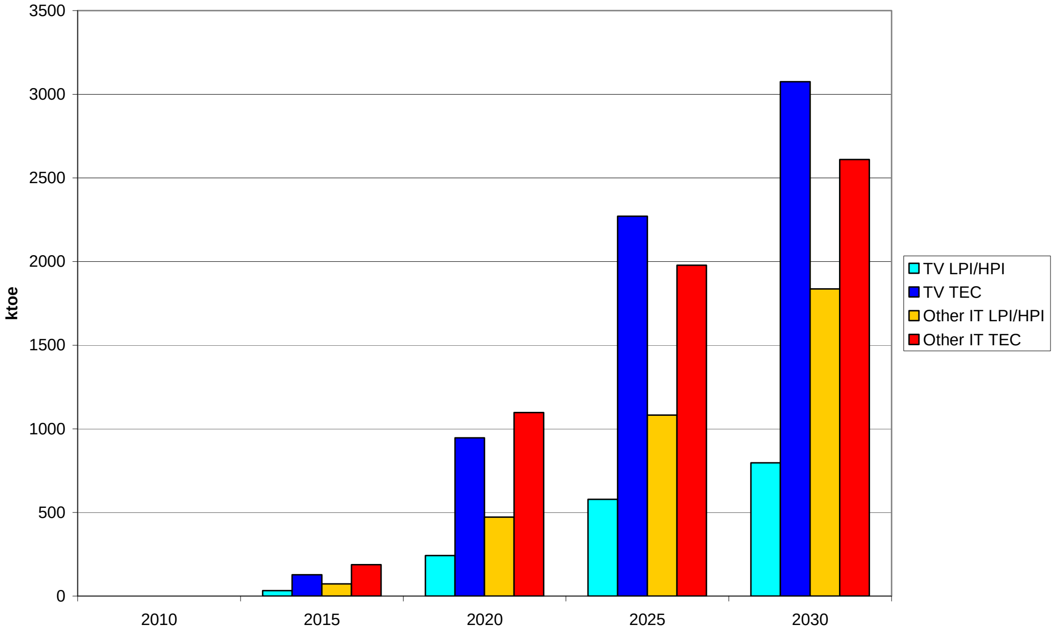
In the economic scenarios, the saving potential which can be achieved by all IT appliances (incl. TV) in EU27 amounts to about 2.6 Mtoe in 2030 (Table 6-11 and Figure 6-38). For TVs, the saving potential in the economic scenarios is relatively low, since savings due to more efficient technologies are partly compensated by the trend to bigger screens. In the technical scenario, however, the impact of technical efficiency improvements predominates. For the other IT appliances, the difference between the economic and the technical scenario is less pronounced.

Table 6-11: Additional EE potentials from IT appliances by scenario (EU27; ktoe compared to the Autonomous Progress Scenario)

Appliance type	Scenario	2010	2015	2020	2025	2030
		ktoe				
TV	**LPI-S/HPI-S**	**0**	**33**	**243**	**579**	**797**
TV	**TS**	**0**	**128**	**946**	**2,271**	**3,076**
Set-top-box	LPI-S/HPI-S	0	11	68	114	149
Set-top-box	TS	0	14	88	148	186
Desktop PC	LPI-S/HPI-S	0	18	149	487	946
Desktop PC	TS	0	75	511	1,122	1,502
Laptop PC	LPI-S/HPI-S	0	16	90	192	308
Laptop PC	TS	0	47	223	311	408
Modem/Router	LPI-S/HPI-S	0	8	36	48	78
Modem/Router	TS	0	14	60	68	101
Computer screen	LPI-S/HPI-S	0	21	129	241	355
Computer screen	TS	0	38	216	329	413
Sum other IT[1)]	**LPI-S/HPI-S**	**0**	**74**	**472**	**1,082**	**1,836**
Sum other IT[1)]	**TS**	**0**	**188**	**1,098**	**1,978**	**2,610**

1) All IT appliances (without TV)

Figure 6-38: Additional EE potentials from IT appliances by scenario (EU27; ktoe compared to the Autonomous Progress Scenario)



The corresponding saving potentials for EU27 by appliance type in % are shown in Figure 6-39 and Figure 6-40.

Figure 6-39: Additional EE potentials from IT appliances in the economic scenarios (LPI/HPI) (EU27; % compared to the Autonomous Progress Scenario)

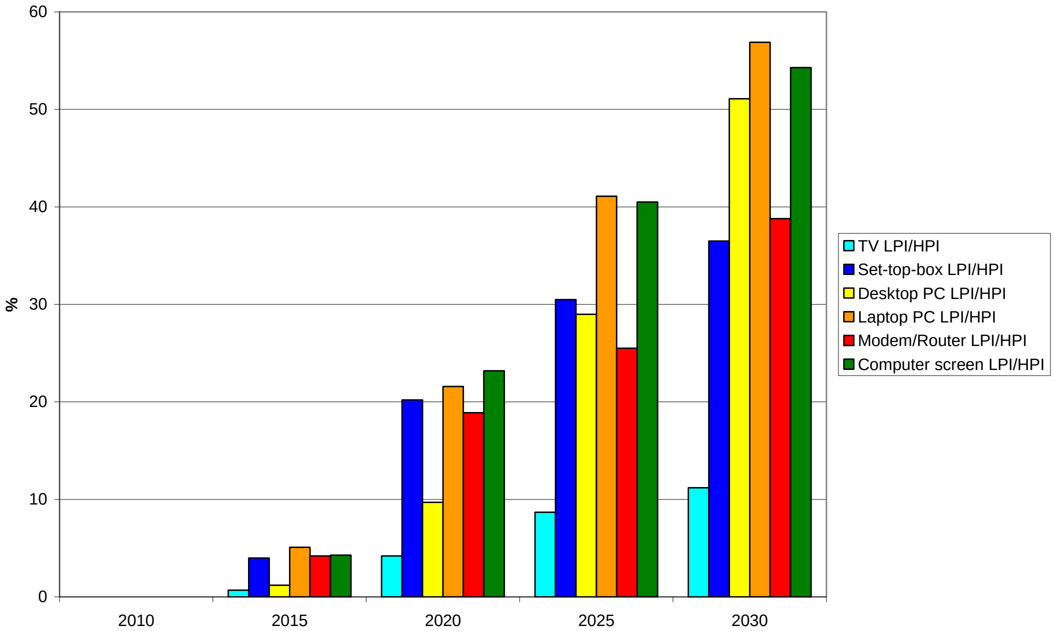
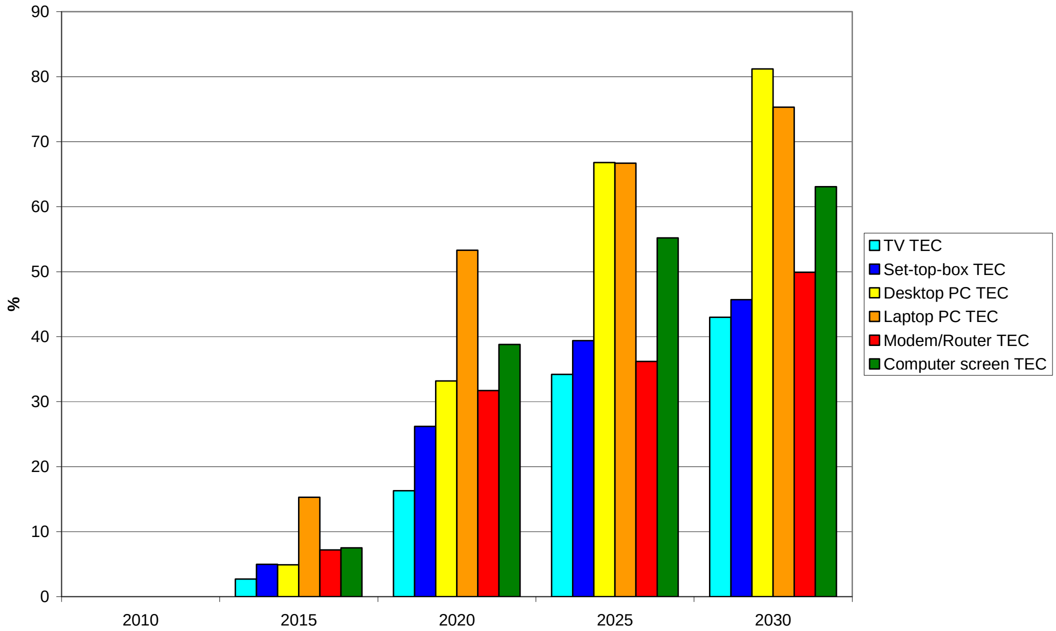


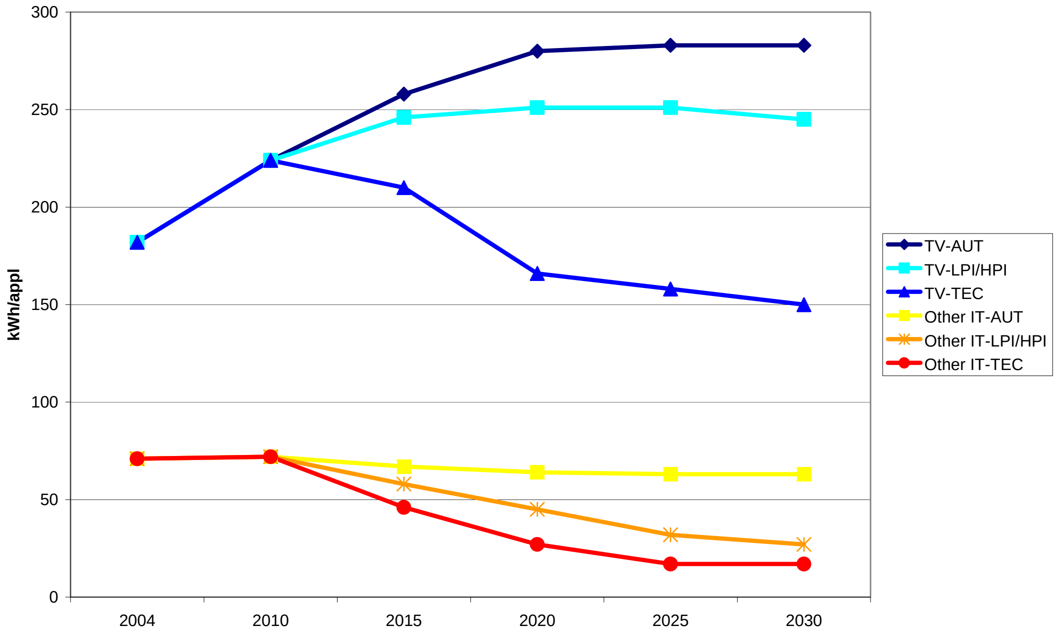
Figure 6-40: Additional EE potentials from IT appliances in the Technical Scenario (EU27; % compared to the Autonomous Progress Scenario)



In the economic scenarios (LPI/HPI), the saving potential for TVs only amounts to a little more than 10 % in 2030, whereas the other IT appliances range between 40 and 55 %. In the Technical Scenario, the differences are less pronounced. The largest potentials are achieved by PCs and computer screens.

The different development of TVs and the other IT appliances also becomes clear when regarding the development of unit electricity consumption per appliance (Figure 6-41). Whereas the unit consumption of TVs both increases in the autonomous and in the economic scenario at least until 2020, the other IT appliances show a moderate decrease even in the autonomous scenario, which is considerably more pronounced in the LPI/HPI and in the Technical Scenario.

Figure 6-41: EU27, IT Appliances – unit electricity consumption trend by scenario



6.4.4 Results residential lighting

Table 6-12 as well as Figure 6-42 show the EE potentials per scenario for the lighting technologies. As already noted in paragraph 6.4.1, not surprisingly, the lighting EE potential is important and reaches up to 50 % of the total achievable savings of the electric uses analysed in this chapter. Up to 2030, if we refer to the LPI scenario which is based on average on a doubling of the CFL lighting points estimated for the reference year, the lighting technologies alone have an EE potential comparable to that delivered by all IT appliances considered here and double the potential achievable by cold and wash appliances and the driers.

Table 6-13 and Figure 6-43 show the EE potentials trends expressed in % for the EU-12 and EU15 countries. In this case the relative potentials between these two groups of countries are different during the first scenarios steps, and slowly bigger for the EU15 countries due a more rapid lamps stock renewal, but tend after to equalise being the final targets more or less the same for all the EU countries.

Finally Figure 6-44 shows the unit consumption trend for lighting. It is worth noting that this consumption initially increases because it refers to the mix of the lighting points of the households: at the beginning the lighting points referring to the not efficient lamps increase more rapidly then those referring to the CFL lamps (or LEDs) but after, around the year 2015 for the policy scenarios, this trend invert its slope and the unit consumption starts decreasing. The lower limit of approximately 60 kWh/dwelling achieved up to the 2030 by the technical scenario shows where it could be possible to arrive if the laps stock will be composed by the 60% of CFLs and the 40% of high efficiency LED technology.

Table 6-12: Additional EE potentials from Lighting by scenario (EU27; ktoe compared to the Autonomous Progress Scenario)

	2010	2015	2020	2025	2030
LPI-S	156	393	785	1,429	2,469
HPI-S	325	852	1,785	3,420	6,238
TS	424	1,124	2,406	4,723	8,851

Figure 6-42: Additional EE potentials from Lighting by scenario (EU27; ktoe compared to the Autonomous Progress Scenario)

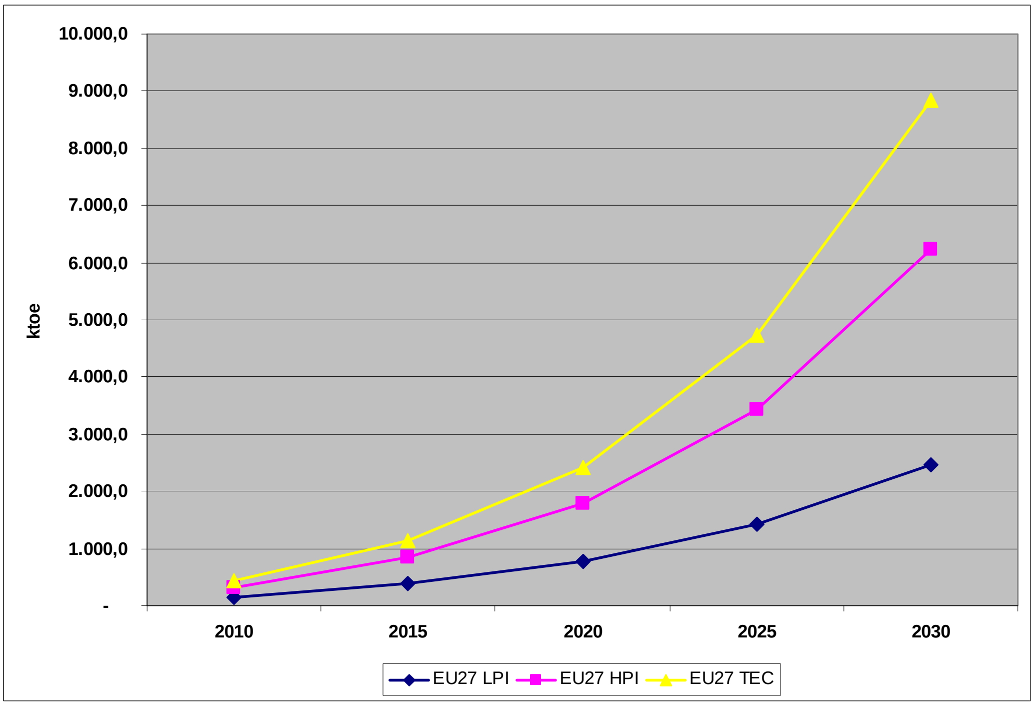


Table 6-13: EE potential trends in % for Lighting (EU-12 & EU15)

	2010	2015	2020	2025	2030
EU-12 LPI-S	0.9%	2.4%	5.4%	11.4%	24.9%
EU-12 HPI-S	1.9%	5.2%	12.2%	27.4%	62.9%
EU-12 TS	2.5%	6.9%	16.4%	37.8%	89.2%
EU15 LPI-S	1.8%	4.3%	8.2%	14.5%	24.9%
EU15 HPI-S	3.8%	9.3%	18.7%	34.8%	62.9%
EU15 TS	5.0%	12.3%	25.2%	48.0%	89.2%

Figure 6-43: EE potentials trends in % for Lighting EU-12 & EU15)

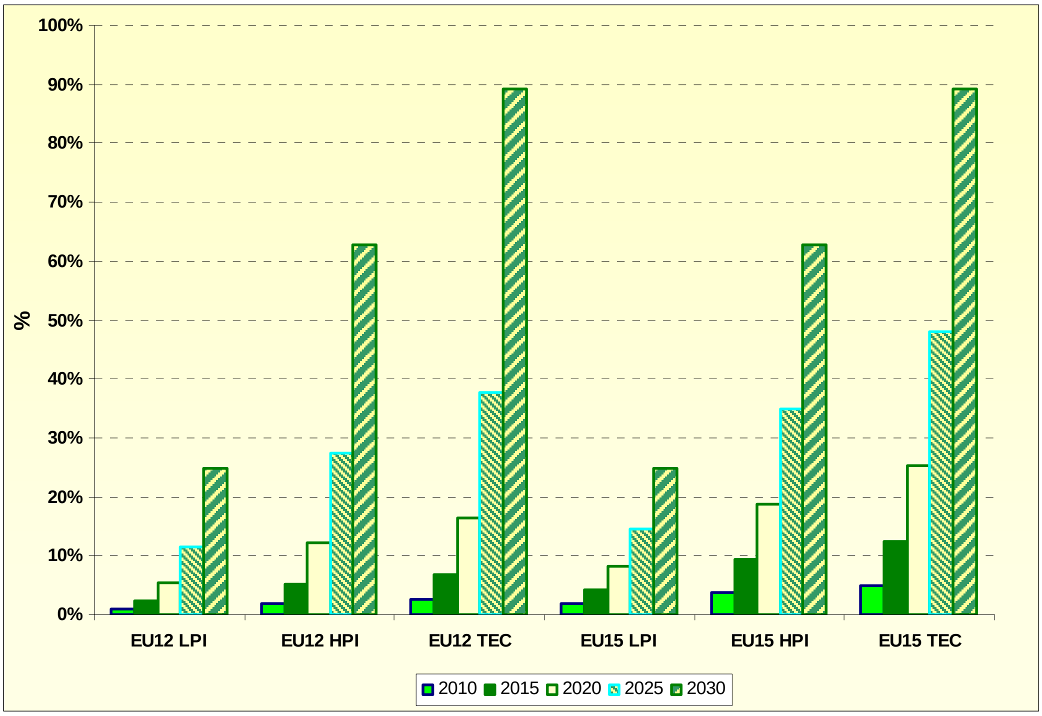
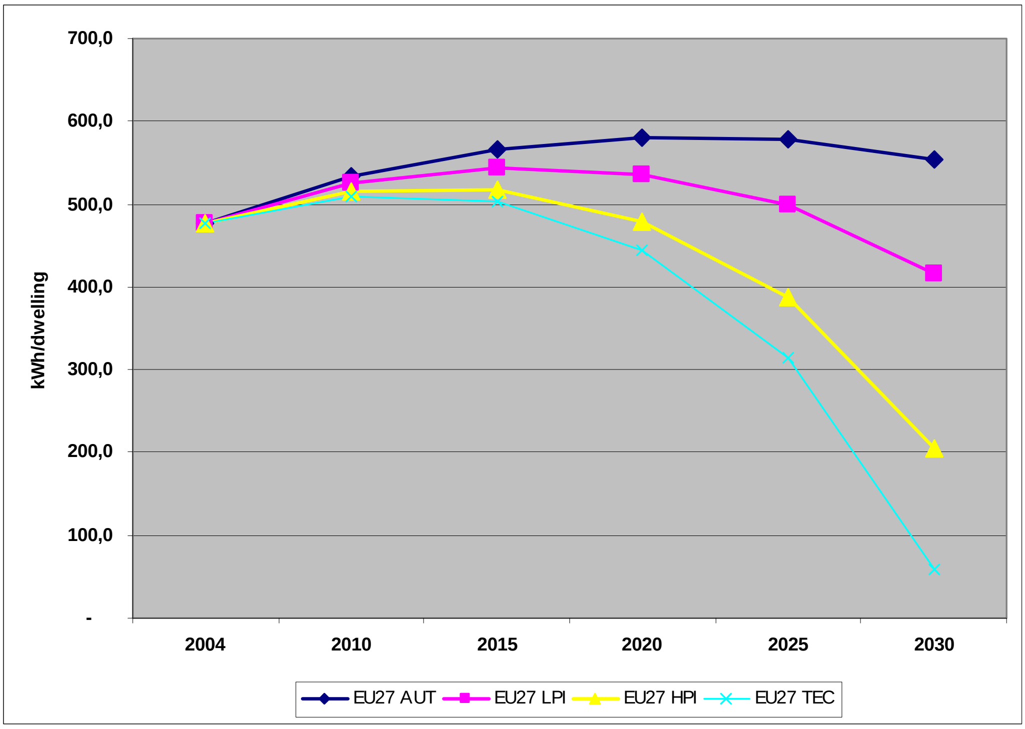


Figure 6-44: EU27, Lighting – Unit consumption trend by scenario



7 Residential buildings

7.1 Useful energy demand of residential buildings

7.1.1 Description of the sector/end-use

Energy efficiency measures in the building sector provide enormous potentials to reduce CO_2 emissions in Europe. The energy use of the building segment accounts for 40 % of the total energy use in the EU and represents Europe's largest source of emissions. This high amount of emissions could be reduced up to 80 % by simple measures, e.g. better insulation of the different components of the existing building stock, of already refurbished dwellings, as well as for new buildings (EURIMA, ECOFYS 2005a,b, Wuppertal Institut 2005). Measures can be different in their target. There are:

- measures reaching only technical installations, e.g. surfaces as roofs, facades, floors and windows and
- measures targeted at changing the behaviour of the inhabitants.

In the following context, measures targeting technical installations will be analysed and therefore it is necessary to discuss:

- the current characteristics and past trends of the building stock in the analysed European countries (e.g. living area per household)
- the potentials of energy savings and CO_2 emission reduction and
- the economics of energy savings measures in buildings (costs for better insulation).

The principal task is to analyse the most important potential energy saving measures and their costs in the four different scenarios presented in Chapter 3. The structure of the analysis is as follows:

1. At the first stage of the analysis, sector-specific data were collected and analysed in order to examine the characteristics and changes in the (residential) building sector in the European Union MS, Norway, Croatia, Iceland and Liechtenstein. This data is described in the first part.
2. Afterwards, the report gives an overview about building typologies used, like building age and type, technical potentials of refurbishment, climate zones and a brief overview of the status and projection of the living area per building type in the analysed countries.
3. The technology costs are important drivers for the model. Technology costs used are mainly insulation or retrofit costs divided into material and labour

costs. They are indexed in relation to European average to compare them on a European level.

4. Then the scenarios, describing the penetration of the different technical options are set up.

7.1.2 Sector-specific / use-specific data sources and modelling issues

This section describes the data used to build up a database for EU-building stock within the specialised WI building model which provides inputs for the MURE residential model. A great amount of data was analysed and therefore, just the most important sources will be presented in this context. This includes databases on current building stock, the distribution of building types and ages and their current specific energetic standard, as well as the costs of different options to improve energy efficiency in the building shell.

To cover the current EU building stock and its distribution by age and type, the following data sources have been used:

- *Odyssee* data provide a detailed overview and database on energy efficiency data and indicators for the EU27 members and Norway as associated country to the EU. Among others, the database provides important information on the construction of dwellings, single and multi-family dwellings (new and existing) and detailed information on the average square metres, new and existing, for single and multi-family dwellings. The time period covers the years 1990 to 2004.
- Additionally, "Housing Statistics in the European Union 2004" from *Boverket and MMR*[17] (2005) gives a detailed overview of the housing development and living conditions in the European Union. It is the 10th edition and, for the first time, it covers the whole EU25. The database of the quality of the housing stock is of special interest. It concentrates on the average living area and the age of the EU-building stock as well as the distribution of the building types, like single and multi-family buildings. The last update of the Housing Statistics, by the *Italian Ministry of Infrastructure and Italian Housing Federation* (MIIR) has been used to refresh these data.
- The PRIMES model provides projections of household numbers for each country of the European Union by 2030. Also, detailed values of their current and future energy use and CO_2 emissions trends to 2030 are given.
- The study "Cost-effective Climate Protection in the EU-Building Stock" carried out by *ECOFYS* for *EURIMA*[18] (2005) analyses the energy saving poten-

---

17 Boverkert = National Board of Housing, Building and Planning, Sweden; MMR = Ministry for Regional Development of the Czech Republic.

18 European Insulation Manufacturers Association (EURIMA).

tial of the building stock in the countries investigated that could be realised by an expansion of the *Energy Performance of Buildings Directive (EPBD)*. Additionally, the last study *U-values – For better energy performance of buildings*, from November 2007, was used to refresh data.

- In order to create realistic material and labour costs and to make realistic cost assumptions for refurbishment and new buildings, *Eurostat* is used which provides detailed information about the recent development in the construction sector (salaries and material costs) on the level of the EU Member States, Norway and Iceland. As a main information source for the costs of different refurbishment measures, Institut für Wohnen und Umwelt (IWU 2006) provides detailed calculations for the refurbishment of each surface component, for instance for roofs, floors, façades and windows. In order to calculate these costs for all countries, a labour cost and material cost index was defined. These indices take into account different developments of the regions and their special social and economic background.
- Miscellaneous data at national and regional level complement the databases.

7.1.3 Step 1 – Definition of energy saving options

Besides the definition of the technical potential and the energy saving options, the model categories and definitions used will be explained.

Building age and type

Differentiated data about the age and distribution of the European building stock is quite rare but necessary in order to define the building stock, its age, its physical characteristics and the breakdown of the building types within the EU MS, Croatia and the remaining EEA-countries. However, the building quality depends also on the extent of refurbishment and the point in time at which refurbishment has been or will be carried out. First insights are provided by *Housing Statistics in the European Union 2004* and its revision from 2005/2006 (Boverket, MMR 2005; MIIR, FIHF 2007) and several other reports like the EURIMA report (EURIMA 2005) which analysed the European building stock.

All in all, the data about construction periods between each country vary and therefore some inaccuracies may exist. Table 7-1 gives an overview about the building stock in the two main construction periods of the existing building stock and the share of single and multi-family buildings. Single family buildings are subdivided into detached houses, semi detached houses and row houses. The main construction periods are:

- old buildings, built before 1975
- intermediate buildings, built between 1976 and 2000 and
- new buildings, built between 2001 and 2030.

Table 7-1: Residential building stock 2004 by construction period

in % of all residential dwellings	Old buildings (< 1975)	Intermediate Buildings (1976-2004)	Share of single-family buildings (existing buildings)	Share of multi-family buildings (existing buildings)
Austria	48	52	56	44
Belgium	79	21	70	30
Bulgaria	86	14	56	44
Croatia	47	53	56	44
Cyprus	38	62	43	57
Czech Republic	33	67	42	58
Germany	81	19	47	53
Denmark	72	28	59	41
Estonia	60	40	25	75
Greece	55	45	43	57
Spain	62	38	50	50
Finland	53	47	54	46
France	61	39	57	43
Hungary	46	54	61	39
Ireland	46	54	92	8
Iceland	56	44	76	24
Italy	71	29	29	71
Liechtenstein	43	57	56	44
Lithuania	64	36	25	75
Luxemburg	49	51	70	30
Latvia	64	36	25	75
Malta	63	37	82	18
Netherlands	57	43	70	30
Norway	65	35	76	24
Poland	47	53	33	67
Portugal	43	57	50	50
Romania	82	18	56	44
Sweden	71	29	43	57
Slovenia	69	31	36	64
Slovakia	31	69	49	51
United Kingdom	71	29	81	19

Source: WI calculations based on Boverket, MMR (2005); MIIR, FIHF (2007) and EURIMA, Ecofys (2005a)

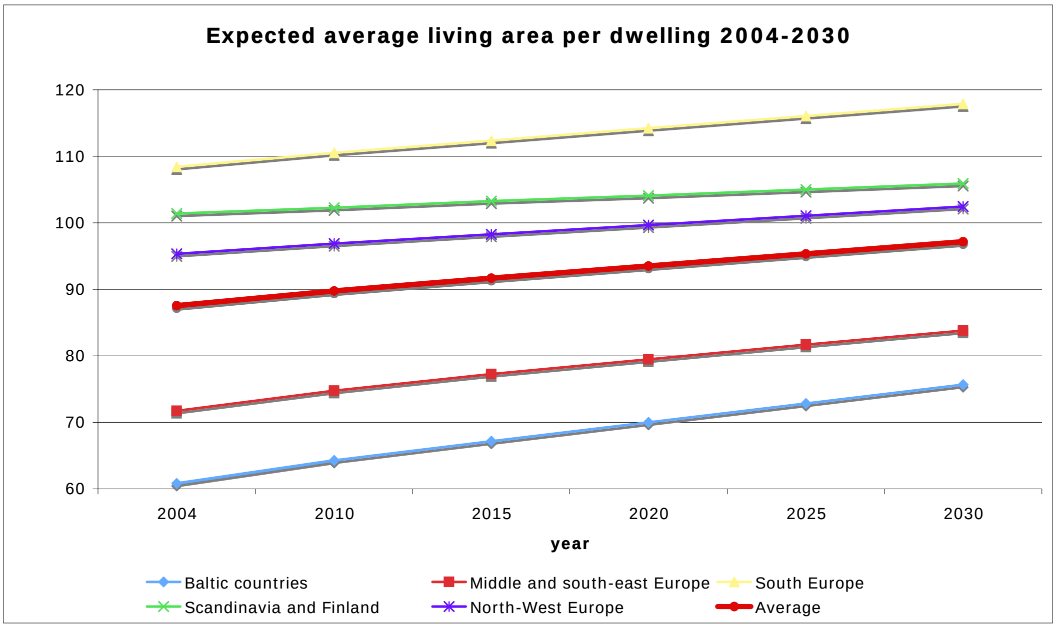
Due to regional differences in each country it can be observed that some countries have almost the same amount of single and multi-family buildings, e.g. Portugal, Spain, Austria, Romania, Slovakia, Bulgaria, Germany and a projected equal share in Croatia. In the Netherlands, Belgium, Luxemburg, Ireland, Norway and United Kingdom the amount of single family buildings is much higher, meanwhile the amount of multi-family buildings in almost every new EU Member State is twice as high or more than single-family buildings. This is to be observed especially in the Baltic countries and in Poland.

Average living area in Europe

The total amount of living area will grow by 2030. Based on PRIMES, Odyssee and national statistics from Croatia, Norway, Iceland and Liechtenstein, it is projected that in general the total number of households will grow but the number of inhabitants per household will decrease by 2030 due to the demographic and social changes.

The outcome of this is that an increasing size of new dwellings is projected until 2030. The total increase of the floor space is 29 % between 2004 and 2030, and an increase of average living area from 88 m^2 up to 97 m^2 per dwelling in 2030 is projected. Figure 7-1 shows the increasing average living area for all countries analysed in this report.

Figure 7-1: Expected average living area per dwelling 2004 – 2030 in m^2 by EU-regions



Source: WI calculations based on Primes, Odyssee and Eurostat

It is expected that the trend differs between the countries by 2030. Especially in the Baltic countries and in Poland an increase of approx. 25 % of the average living area per dwelling is expected, whereas in North-West Europe and in Scandinavia, France and Germany the average increase is about 5 to 7 %.

Building types

In order to compare different types of buildings, two typical residential buildings representing the bulk of dwellings across Europe have been chosen for model calculations with all simplifications this implies as compared to the complexity of the real building stock. The exact dimensions of the building types have been derived as typical average values from empirical studies from the Wuppertal Institute and IWU (Wuppertal Institute 2000, 2001; IWU 2005).

In order to cover possible variations, both are calculated with typical m^2 values of 120 m^2 for single-family buildings and 1,457 m^2 for multi-family buildings and corresponding values for typical surface components (Table 7-2). In the table, the relevant details and specifications are listed, e.g. ceiling height, roofs, façade, floor and windows.

Table 7-2: Average surface components of residential building types in m^2

Building components of the residential building types in m^2						
	Dwelling space	**Ceiling height**	**Standard component surfaces**			
Building type			**Roof**	**Facade**	**Floor**	**Windows E/W**
Single/two family house	**120**	**2.5**	**90**	**166**	**63**	**29**
Large apartment house	**1457**	**2.5**	**354**	**1189**	**354**	**380**

Source: WI calculations based on Wuppertal Institute 2000, 2001; IWU 2005

Climate Zones

The different climatic conditions in Europe are taken into account. The most important indicator is heating degree days[19]; this value is characteristic for the typical useful energy demand to heat buildings (residential and non-residential buildings). Therefore, the building stock of each country is assigned to one of three climate zones: cold, moderate and warm. The breakdown between these climate zones is listed below:

19 Heating degree days are quantitative indices and result from national temperature observations. Over one year (typically) the differences between each day´s daily temperature and 18°C (or another reference temperature) are added. Above a temperature of 18°C, it is assumed not to need any heating (the corresponding indoor temperature will be higher due to the insulation of the building).

- *Cold*, above 4,200 heating degree days,
- *Moderate*, between 2,200 and 4,200 heating degree days and
- *Warm*, below 2,200 heating degree days.

The values are relating to long-term average heating degree days (1980-2004) and characterise the coldness and country specific useful heat demand. For Bulgaria, Romania, Norway, Iceland, Liechtenstein and Croatia own values have been assumed respectively compared to countries with similar climatic conditions. Table 7-3 gives an overview of the classification of each country into climate zones and its country specific heating degree days in brackets taken into account for this report. The warmest countries are Malta and Cyprus, whereas Finland, Sweden, Norway and Iceland belong to the coldest countries in Europe.

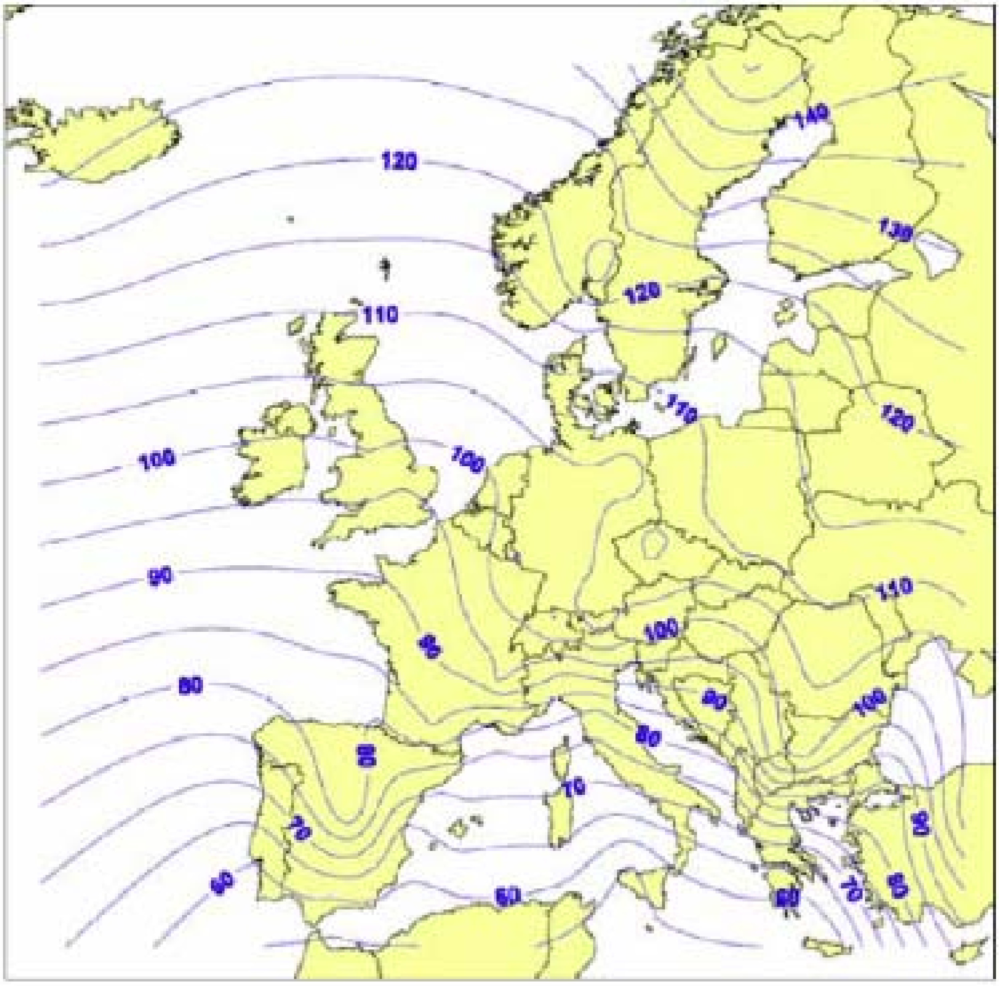
Table 7-3: Classification of climate zones

Cold	Moderate	Warm
Estonia (4420)	**Austria (3569)**	**Bulgaria (2101)** 1
Finland (5823)	**Belgium (2882)**	**Cyprus (787)**
Iceland (4977) 1	**Croatia (3044)**1	**Greece (1698)**
Latvia (4243)	**Czech Republic (3559)**	**Italy (2085)**
Norway (5423) 1	**Denmark (3479)**	**Malta (564)**
Sweden (5423)	**France (2494)**	**Portugal (1302)**
	Germany (3244)	**Spain (1856)**
	Hungary (2917)	
	Ireland (2916)	
	Liechtenstein (3569)1	
	Lithuania (4017)	
	Luxemburg (3216)	
	the Netherlands (2905)	
	Poland (3605)	
	Romania (2917)1	
	Slovakia (3440)	
	Slovenia (3044)	
	United Kingdom (3354)	

Source: Eurostat (2006), WI calculations

The Eurostat classification is also comparable with the 2006 published European Heating Index from the Ecoheatcool project. 100 is equivalent to the average European value of heating degree days. Figure 7-2 shows a map concerning this index.

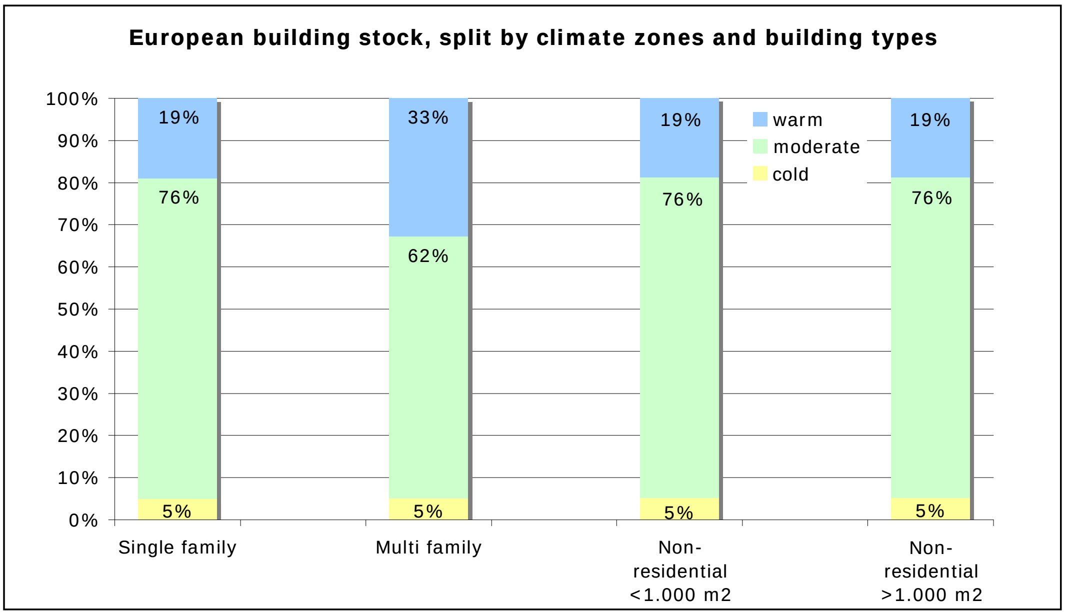
Figure 7-2: European Heating Index (Ecoheatcool Project)



Source: Ecoheatcool Project (2006)

Relating to the climate zones Figure 7-3 gives an overview about the split of the European building stock, residential as well as non-residential buildings, in 2004 per climate zone. It shows that about three-quarter of single family buildings and nearly two-third of multi-family buildings exist in the moderate climate zone. The share of non-residential buildings (above and below 1,000m^2) in these countries is as high as for single family buildings. 19 respectively 33 % of single and multi-family buildings are located in the warm climate zone and 19 % of non-residential buildings, whereas the share of the cold climate zone is only approximately 5 %.

Figure 7-3: Distribution of building types per climate zones, existing buildings 2004 in %



Source: WI calculations based on ECOFYS 2005b; WI 2000

Energetic standard of residential buildings

This chapter shows the definition of the energetic standard (U-values) of the existing building stock, defined as

- old (not refurbished and already refurbished buildings) and
- intermediate (IM) buildings.

U-values of the different buildings types characterize the energetic standard of the buildings and are differentiated by climate zones: cold, moderate and warm climate zone. Furthermore they are differentiated by surface components: roof, façade, floor and window.

The energetic quality of the building envelope has been taken from internal data from Wuppertal Institute, ISIS as well from the EURIMA, Ecofys report (2005b). All together, these values give an overview about the climate-specific energy standard of EU residential buildings. Table 7-4 shows the current energetic standard by surface components for old and intermediate buildings for each climate zone.

Table 7-4: Energetic standard of building components by climate zone and construction period of the building

			U-values in Wm²K
	Old		**Intermediate (IM)**
	Built before 1975 not refurbished	Built before 1975 already refurbished	Built 1976 - 2000
Cold Climate Zone			
Roof	0.50	0.20	0.18
Facade	0.50	0.30	0.25
Floor	0.50	0.20	0.19
Windows	3.00	1.60	1.60
Moderate Climate Zone			
Roof	1.50	0.50	0.45
Facade	1.50	1.00	0.75
Floor	1.20	0.80	0.65
Windows	3.50	2.00	2.75
Warm Climate Zone			
Roof	2.46	1.00	0.65
Facade	1.97	1.40	0.90
Floor	2.50	1.00	0.68
Windows	4.70	3.50	3.85

Source: WI calculations based on EURIMA, Ecofys (2005b); WI (2000); IWU (1994); ISIS

In order to calculate the energy saving potentials by 2030 it is necessary to define the energetic standard, by U-values, for new dwellings as well as for dwellings to be refurbished, differentiated by the specific value for each building component. New buildings are characterized by four building codes, New 1 to New 4, and refurbished buildings by three options from Ref 1 to Ref 3. The energetic standard Ref 1 corresponds to New 1, Ref 2 to New 2 and Ref 3 to New 3.

- **Ref 1 and New 1** correspond to current building code standards from 2003 until 2006,
- **New 2 and Ref 2** are synonymous with more advanced standards which are assumed to be promoted by current European Performance of Buildings Directive (EPBD) and from other national standards like the German Energy Saving Directive (EnEV).
- **New 3 and Ref 3** are comparable with a low energy house.
- **Building code New 4** is an improved standard and comparable to the currently best available standard, which is also called Passive House standard.

Table 7-5 gives an additional overview about the standards used to calculate the specific energy consumption for each building type per m^2.

Table 7-5: Energetic standard of building components by climate zone and construction period of building

	Old buildings		IM build.	Refurbished (Ref) buildings			New buildings			
U-values in Wm²K	Not ref.	Alr. Ref		1	2	3	1	2	3	4
Cold Climate Zone										
Roof	0.50	0.20	0.18	0.15	0.13	0.11	0.15	0.13	0.11	0.10
Façade	0.50	0.30	0.25	0.18	0.17	0.15	0.18	0.17	0.15	0.10
Floor	0.50	0.20	0.19	0.18	0.17	0.15	0.18	0.17	0.15	0.10
Windows	3.00	1.60	1.60	1.42	1.33	1.03	1.42	1.33	1.03	0.78
Moderate Climate Zone										
Roof	1.50	0.50	0.45	0.25	0.23	0.16	0.25	0.23	0.16	0.10
Façade	1.50	1.00	0.75	0.41	0.38	0.20	0.41	0.38	0.20	0.10
Floor	1.20	0.80	0.65	0.44	0.41	0.28	0.44	0.41	0.28	0.10
Windows	3.50	2.00	2.75	1.84	1.68	1.30	1.84	1.68	1.30	0.60
Warm Climate Zone										
Roof	2.46	1.00	0.65	0.50	0.43	0.30	0.50	0.43	0.30	0.10
Façade	1.97	1.40	0.90	0.59	0.48	0.25	0.60	0.48	0.25	0.10
Floor	2.50	1.00	0.68	0.55	0.48	0.33	0.55	0.48	0.33	0.10
Windows	4.70	3.50	3.85	3.04	2.71	1.26	3.04	2.71	1.26	0.60

Source: WI calculations based on EURIMA, ECOFYS (2005b); WI (2000); IWU (1994); ISIS

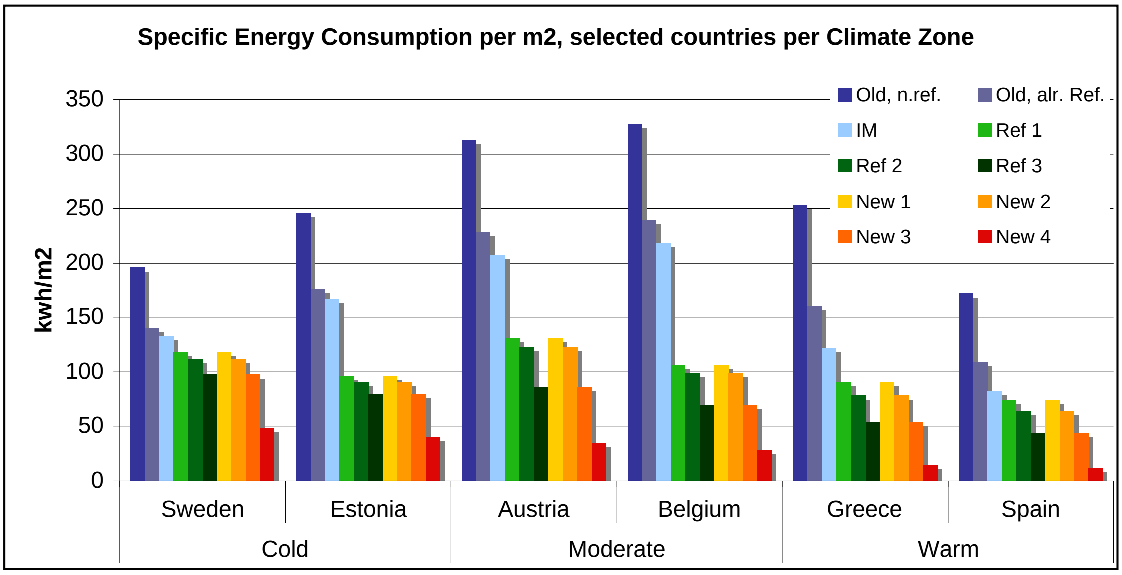
Table 7-6 shows the specific energy consumption for single and multi-family buildings for the three climate zones in detail (Cold, Moderate and Warm). The specific values are the amount of the possible specific energy consumption, if the building is refurbished respectively built new. For the HPI Scenario and the Technical Scenario a full compliance with the respective standard is assumed while a partial compliance is supposed in the Autonomous Progress and the LPI Scenarios (see next section). The presented energetic standards result in country specific energy consumption per m^2 for each building type, single-family as well as multi-family buildings. They are shown for some selected countries in Figure 7-4.

Table 7-6: Average specific energy consumption per m² for High Policy Intensity Scenario and Technical Potential Scenario

Average specific energy consumption of a single-family building in kWh/m²			
Building standard	**Cold**	**Moderate**	**Warm**
Old without refurbishment	197	269	272
Old, already refurbished	141	197	173
Intermediate	134	179	133
REF 1/2/3	118/112/98	113/106/74	98/85/59
New 1/2/3/4	118/112/98/49	113/106/74/30	98/85/59/16
Average specific energy consumption of a multi-family building in kWh/m²			
Building standard	**Cold**	**Moderate**	**Warm**
Old w/o ref.	142	177	168
Old, already ref.	102	130	98
Intermediate	93	86	75
REF 1/2/3	89/78/74	80/60/56	65/50/39
New 1/2/3/4	89/78/74/34	80/60/56/22	65/43/38/12

Source: WI calculations based on WI (2001); WI (2000)

Figure 7-4: Specific energy consumption per m², selected countries



Source: WI calculations based on WI (2001); WI (2000)

Partial non-compliance to regulation

Jakob and Madlener have already identified that many barriers still exist, in order to prevent a more effective diffusion of energy efficiency technologies. One important barrier is the fact that the renewal or refurbishment of the building stock is relatively slow and not every refurbishment is done as it should be done. Aside, investments into the building stock are not essential, in order to use the building (Jakob, Madlener 2004).

Taken into account that for the Autonomous Progress Scenario as well as for the Low Policy Intensity (LPI) Scenario the compliance with the technical possibilities will not be 100 %, it is assumed that the specific energy consumption for both scenarios will be higher than shown in Table 7-6. In order to project the level of compliance to be expected, expert opinions[20] about the compliance of refurbishment measures as well as of new buildings with the building codes have been used. According to Warren and Hjorth (2008), between 50 % and 65 % of all new homes fail to meet basic energy standards.

According to these expert opinions, the following assumptions have been made, in order to calculate the specific energy consumption for the Autonomous Progress and the Low Policy Intensity Scenarios. It is to be considered that the compliance of refurbishment measures and implementation of new building codes could vary between countries. Thus, socio-economic country groups are defined as follows:

- North-Western Europe (NW Europe):
  - *Cold Climate Zone*: Finland, Iceland, Norway and Sweden;
  - *Moderate Climate Zone*: Austria, Belgium, Denmark, France, Germany, Ireland, Liechtenstein, Luxemburg, the Netherlands and United Kingdom;
- Southern Europe (S Europe):
  - *Warm Climate Zone: Greece, Spain, Italy and Portugal*
- New Member States 2005 (NMS 2005):
  - *Cold Climate Zone: Estonia and Latvia;*
  - *Moderate Climate Zone: Czech Republic, Hungary, Lithuania, Poland, Slovakia and Slovenia;*
  - *Warm Climate Zone: Cyprus and Malta;*
- New Member States 2007 and Croatia (New Member States 2007 + CR):
  - *Moderate Climate Zone: Bulgaria, Croatia and Romania*

Table 7-7 gives an overview about the non-compliance factors of refurbished buildings. This means that buildings which are built as Ref 3 or New 3 and New 4 do not achieve the energetic standard of this building code, due to bad insulation or un-

[20] In February 2008 a workshop about energy efficiency and their enhanced compliance took place in Paris, organised by International Energy Agency (IEA). http://www.iea.org/Textbase/work/workshopdetail.asp?WS_ID=349

skilled workers. No entry in Table 7-7 means that no country belongs to the climate zone.

Table 7-7: Non-compliance factors for refurbished buildings, Autonomous Progress (APS) and Low Policy Intensity Scenario (LPI-S) (%)

%	North-Western Europe	Southern Europe	New Member States 2005	New Member States 2007 and Croatia
Cold Climate Zone				
APS	50	-	40	-
LPI-S	35	-	25	-
Moderate Climate Zone				
APS	45	-	40	35
LPI-S	30	-	25	20
Warm Climate Zone				
APS	-	40	40	-
LPI-S	-	25	25	-

Source: WI calculations based on Hjorth and Warren (2008)

Table 7-8 gives a similar overview for new buildings. Both tables show the non-compliance factors of the Autonomous Progress and Low Policy Intensity (LPI) Scenarios. It is supposed that the compliance with new building codes is high for new buildings. Therefore the non-compliance factor is set at two thirds of the amount of the value for refurbished dwellings.

Table 7-8: Non-compliance factors for new buildings, Autonomous Progress (APS) and Low Policy Intensity Scenario (LPI-S) (%)

	North-Western Europe	Southern Europe	New Member States 2005	New Member States 2007 and Croatia
Cold Climate Zone				
APS	33	-	26	-
LPI-S	23	-	17	-
Moderate Climate Zone				
APS	30	-	26	23
LPI-S	20	-	17	13
Warm Climate Zone				
APS	-	26	26	-
LPI-S	-	17	17	-

Source: WI calculations based on Hjorth and Warren (2008)

Taken into account these assumptions, new specific energy consumption values are calculated by standard and by climate zone for both, the Autonomous Progress and Low Policy Intensity Scenario (Table 7-9 and Table 7-10).

Table 7-9: Average specific energy consumption per m^2 for the Autonomous Progress Scenario

Average specific energy consumption of a Single Family Building in kWh/m^2			
Building standard	**Cold**	**Moderate**	**Warm**
Old without refurbishment	197	269	272
Old, already refurbished	158	225	212
Intermediate	165	219	188
REF 1/2/3	157/154/147	182/178/160	167/159/143
New 1/2/3/4	144/140/130/97	159/153/131/99	144/134/115/83
Average specific energy consumption of a multi-family building in kWh/m^2			
Building standard	**Cold**	**Moderate**	**Warm**
Old without refurbishment	142	177	168
Old, already refurbished	122	150	126
Intermediate	117	125	112
REF 1/2/3	115/109/107	122/110/109	106/97/91
New 1/2/3/4	106/99/96/69	108/93/91/66	92/76/72/53

Source: WI calculations based on WI (2001); WI (2000)

Table 7-10: Average specific useful energy consumption per m^2 for the Low Policy Intensity Scenario

Average specific energy consumption of a Single Family Building in kWh/m^2			
Building standard	**Cold**	**Moderate**	**Warm**
Old without refurbishment	197	269	272
Old, already refurbished	141	197	173
Intermediate	134	179	133
REF 1/2/3	118/112/98	113/106/74	98/85/59
New 1/2/3/4	118/112/98/49	113/106/74/30	98/85/59/16
Average specific energy consumption of a multi-family building in kWh/m^2			
Building standard	**Cold**	**Moderate**	**Warm**
Old without refurbishment	142	177	168
Old, already refurbished	102	130	98
Intermediate	93	86	75
REF 1/2/3	89/78/74	80/60/56	65/50/39
New 1/2/3/4	89/78/74/34	80/60/56/22	65/43/38/12

Source: WI calculations based on WI 2001; WI 2000

Calibration of specific energy consumption values

The energetic standards, as described before, highlight the theoretical technical standard of the buildings and the specific energy consumption per m^2 for each climate zone, but do not integrate consumer habits, which differ from country to country.

In South European countries the energy demand is typically not as high as projected, because of shorter heating periods per year and in eastern European countries the energy demand will be higher as projected, due to worse insulation of buildings, which could not be reflected by u-values. Therefore, the projected demand per dwelling has been calibrated to the actual values from Kemna et al. (2007), Odyssee and PRIMES. PRIMES projects the energy demand until 2030 and Odyssee reflects the energy demand of the past for each EU-country.

Furthermore it is known that countries such as the Netherlands, Denmark and Sweden have better insulated buildings as projected with climate corrected values. But the different climate zones cannot be the only explanation for outliers: Whereas the energy demand for the Netherlands is too high and should be reduced, the energy demand for Belgium and Luxemburg is too low, and all three countries are in the same climate zone and are neighbouring countries. Kemna et al. (2007) have shown that 50 % of the difference can be attributed to insulation and ventilation losses and the other half is caused by heating boiler efficiency.

Table 7-11 shows a comparison between the latest EU-Baseline scenario and Odyssee values from 2004 compared to theoretical energy demand per dwelling in 2004. From this comparison it appears that the actual energy demand for countries like Belgium, Luxemburg, Finland, France, Latvia and Estonia is higher than calculated. In contrast to this the useful energy demand for Spain, Portugal, Italy, Poland, Bulgaria, Slovakia, Lithuania, Denmark, the Netherlands and United Kingdom is lower than expected. Hence, the specific energy demand has to be calibrated for these countries, in order to calculate realistic values.

Table 7-11: Comparison EU-Baseline, Odyssee and theoretical useful energy demand

Country	EU-Baseline Scenario	Odyssee	Theoretical useful energy demand
Austria	1.75	1.53	1.73
Belgium	2.05	2.38	2.00
Bulgaria	0.61	0.52	0.63
Croatia	-	1.31	1.15
Cyprus	1.15	1.16	1.09
Czech Republic	1.30	1.49	1.33
Germany	1.55	1.41	1.61
Denmark	1.45	1.21	1.41
Estonia	1.45	1.66	0.93
Greece	1.12	0.96	1.21
Spain	0.81	0.46	1.08
Finland	1.63	1.13	0.83
France	1.52	1.39	0.93
Hungary	1.25	1.58	1.37
Ireland	1.81	1.54	1.18
Iceland	-	-	1.26
Italy	1.09	0.92	1.41
Liechtenstein	.	-	1.11
Lithuania	0.96	0.74	1.64
Luxemburg	3.33	3.60	1.39
Latvia	1.44	1.26	0.77
Malta	0.46	0.18	1.61
Netherlands	1.20	0.98	0.66
Norway	-	1.17	2.87
Poland	1.18	0.97	0.93
Portugal	0.58	0.85	0.56
Romania	0.98	1.11	0.90
Sweden	1.53	1.22	1.59
Slovenia	1.46	1.03	1.03
Slovakia	0.90	1.22	0.67
United Kingdom	1.47	1.16	0.71

Source: WI calculations, PRIMES, Odyssee

Table 7-12 shows the calculated energy demand per dwelling before adjustment to the actual energy demand per m^2. It can be seen, in which countries the demand is higher or lower than expected due to the influence of climate zones and behaviour.

Table 7-12: Average specific useful energy demand per m² before and after calibration for single-family buildings

Country	Age	Model result	Cali-brated	Country	Age	Model result	Cali-brated
Belgium	Old	252	328	Lithuania	Old	356	196
	Old, alr. ref.	184	240		Old, alr. ref.	260	143
	IM	168	218		IM	237	130
Bulgaria	Old	184	131	Luxemburg	Old	282	383
	Old, alr. ref.	134	95		Old, alr. ref.	206	280
	IM	122	87		IM	187	255
Cyprus	Old	117	142	Netherlands	Old	254	150
	Old, alr. ref.	74	90		Old, alr. ref.	186	110
	IM	57	68		IM	169	100
Denmark	Old	305	198	Poland	Old	316	265
	Old, alr. ref.	223	145		Old, alr. ref.	231	194
	IM	203	132		IM	210	176
Estonia	Old	160	246	Portugal	Old	194	159
	Old, alr. ref.	114	176		Old, alr. ref.	123	101
	IM	109	167		IM	94	77
Finland	Old	211	255	Slovakia	Old	301	235
	Old, alr. ref.	151	182		Old, alr. ref.	220	172
	IM	143	173		IM	200	156
France	Old	218	251	Spain	Old	277	172
	Old, alr. ref.	160	184		Old, alr. ref.	176	109
	IM	145	167		IM	133	83
Italy	Old	311	159	UK	Old	284	196
	Old, alr. ref.	197	101		Old, alr. ref.	208	143
	IM	150	76		IM	189	130
Latvia	Old	154	238				
	Old, alr. ref.	110	170				
	IM	104	162				

Source: WI calculations, based on PRIMES, Odyssee

7.1.4 Step 2 – Technology costs

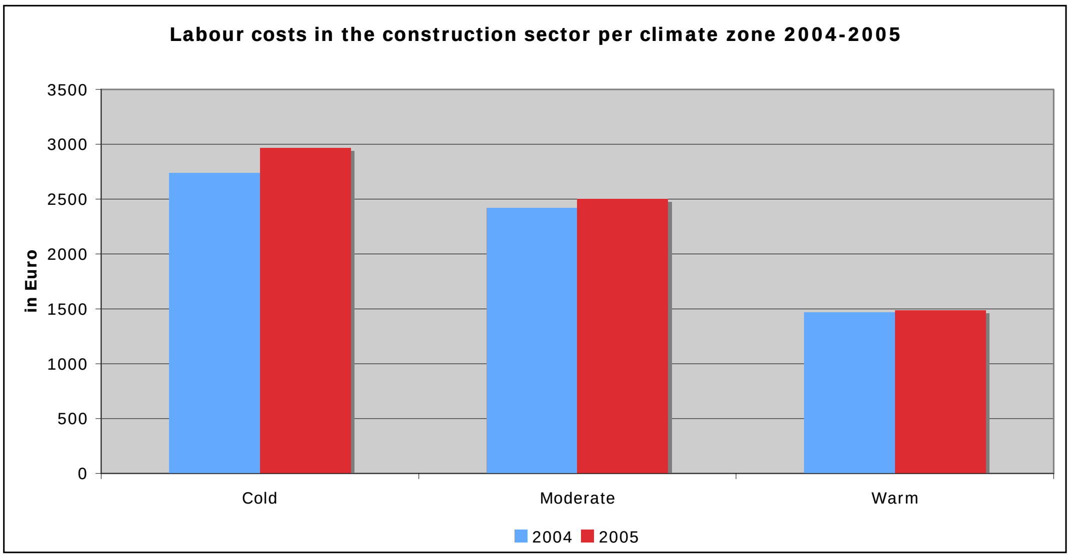
Whether refurbishment measures are carried to save energy and emissions depends also on their cost-effectiveness. The decision to refurbish a building is a deducted decision. Generally, it has to be decided how to use the building and for which time period. One important reason to refurbish a building is the potential to realize energy savings and thus reduce operational costs for the owner. To determine the potential in economic terms it is useful to evaluate data which allow an economic view on the refurbishment measure.

For the three different types of refurbishment measures and the four types of new buildings material and labour costs are provided by a technological analysis of *Institut Wohnen und Umwelt* (IWU) from 2006 and additionally from EURIMA (2005) and Jakob et al. (2002). The IWU values integrate already labour costs as well as material costs and are given in detail for each surface component, façade, roof, ceiling and window and represent the costs per m^2 for Germany (Moderate Climate Zone). Based on this information, costs are converted for the Cold and Warm Climate Zone. To translate the costs into country-specific values, two indices are used: a material and a labour cost index. First, the indices are explained, and then the costs for the components façade, roof, floor and windows are documented for each climate zone. Finally, learning curves are introduced, in order to project costs into the future. According to Jakob et al. (2002), learning curves for each refurbishment measure have been integrated, because it is assumed that costs for skilled workers will decrease over the years.

Country specific labour costs

Labour costs of skilled workers in the construction sector are calculated country by country, because of the differences in labour costs between the European Member States, other EEA countries and Croatia. Therefore, the following labour cost index was introduced to differentiate the costs of skilled workers per country. As basis for the assumption, Eurostat data from 2007 were analysed. Table 7-13 gives a detailed overview of the development of monthly salaries for skilled workers in the construction sector from 2000 until 2005. Additionally, Figure 7-5 shows the average salaries in the construction sector for each climate zone.

Figure 7-5: Salaries in the construction sector



Source: WI calculations based on Eurostat (2007), Ireland, National Statistics

They are weighted by the current technical condition of the existing buildings in each zone. With respect to the climate, specific costs for refurbishment measures for each surface component have been calculated.

Table 7-13: Salaries per month for skilled workers in the construction sector 2000 - 2005

Euro	2000	2001	2002	2003	2004	2005
Austria	3036	3126	3205	3248	3345	3418
Belgium	2995	3150	3304	3560	3455	3490
Bulgaria	151	159	157	168	176	186
Croatia	395	462	547	562	608	658
Cyprus	1821	1883	1986	2111	2217	2284
Czech Republic	538	609	736	707	778	855
Germany	2788	2867	2949	3027	3012	3008
Denmark	2826	2918	3780	3868	3974	3996
Estonia	386	455	516	583	651	737
Greece	1104	1111	1133	1161	1138	1148
Spain	1718	1720	1781	1880	1975	2034
Finland	2838	2868	2919	2977	3013	3127
France	3700	3820	3947	4016	4206	4293
Hungary	395	462	547	562	608	658
Ireland	3122	3276	3600	3778	3928	4307
Iceland	n.a.	3852	4288	4344	4436	5271
Italy	n.a.	2419	2469	2519	2569	2619
Liechtenstein	5108	5227	5345	5378	5411	5507
Lithuania	327	382	425	427	516	543
Luxembourg	n.a.	n.a.	n.a.	n.a.	2834	2882
Latvia	289	295	295	301	330	381
Malta	n.a.	n.a.	858	841	1000	863
Netherlands	3156	3369	3602	3761	3996	4045
Norway	3656	3540	3725	3915	4001	4152
Poland	604	692	673	596	600	716
Portugal	1035	1076	1120	1166	1213	1263
Romania	176	194	202	195	224	302
Sweden	3656	3540	3725	3915	4001	4152
Slovenia	1130	1150	1227	1281	1395	1474
Slovakia	434	410	443	501	550	621
United Kingdom	3836	3965	4095	3872	4091	4317

Source: Eurostat 2007, Ireland National Statistics and WI projections

As indicator for projections of future development of salaries the GDP-development of each country taken from the latest EU Baseline Scenario was used. Thus, an index was created. Additionally, it is assumed that by 2030 the labour costs of the countries within the European Union will further converge in the future. Based on these assumptions, the development of country-specific GDP values and the adjustment of salaries, Table 7-14 illustrates the Index until 2030 for each country.

Table 7-14: Labour Cost Index 2004-2030 2030 for refurbishment and construction of buildings

	2004	2010	2015	2020	2025	2030
Austria	114	115	115	114	112	110
Belgium	116	112	109	106	101	96
Bulgaria	6	10	13	18	25	34
Croatia	22	25	29	32	36	39
Cyprus	76	82	88	91	92	92
Czech Republic	28	32	36	39	41	43
Germany	100	100	100	100	100	100
Denmark	133	128	125	122	118	114
Estonia	25	30	36	41	47	52
Greece	38	47	54	60	71	82
Spain	68	68	71	75	78	81
Finland	104	103	102	101	99	98
France	143	135	1,28	122	110	99
Hungary	22	25	29	32	36	39
Ireland	143	143	141	139	131	20
Iceland	175	1,60	151	143	128	114
Italy	87	86	90	93	96	99
Liechtenstein	183	197	208	220	236	257
Lithuania	18	25	33	41	52	64
Luxembourg	96	123	148	168	195	217
Latvia	13	21	29	37	49	63
Malta	29	32	35	39	46	52
Netherlands	134	124	118	112	100	87
Norway	138	142	146	151	153	158
Poland	24	28	33	38	43	48
Portugal	42	45	48	53	60	68
Romania	10	13	17	21	26	32
Sweden	138	133	130	127	118	110
Slovenia	49	53	55	57	57	57
Slovakia	21	23	26	29	31	33
United Kingdom	144	143	142	141	134	126

Source: WI calculations based on PRIMES, Eurostat (2007), Another important issue are material costs. They are different for each country but do not differ as much as labour costs. The following material cost index was created taking into account price variations for materials, in order to allow a comparison between the costs of materials for each country.

Country specific material costs

In order to calculate country specific material costs for insulation and construction of buildings, a report from *Federal Office for Building and Regional Planning* (BBR) from 2005 was considered. This report gives the current state of the art about the differences of material and insulation costs for Germany as well as for Central and Eastern European countries. These calculated costs have been confirmed by stakeholders in the construction segment. The values are taken into account to identify cost differences between each country.

Five country groups were defined, differentiated by their economic development. Table 7-15 gives an overview about these groups and shows the index for the base year 2004. Germany, as well as most other countries from North-West of Europe are classified with an index value of 100 (reference group). Due to the BBR report, it is assumed that costs for materials are alike in middle and west European countries for the same climate zone, while material costs of Scandinavian countries and Finland are 10% higher than the reference group. Furthermore it is assumed that material costs are only about 10 % lower in the New Member States from 2005, whereas Greece, Spain, Portugal and Slovenia have a 5 % lower index than the reference group. The latest EU Member States Bulgaria and Romania as well as the forthcoming Member State Croatia have a 12 % lower share.

Table 7-15: Material Cost Index

110	100	95	90	88
Denmark	Austria	Greece	Cyprus	Bulgaria
Finland	Belgium	Spain	Czech Republic	Croatia
Iceland	Germany	Portugal	Estonia	Romania
Liechtenstein	France	Slovenia	Hungary	
Norway	Ireland		Lithuania	
Sweden	Italy		Latvia	
	Luxemburg		Malta	
	Netherlands		Poland	
	United Kingdom		Slovakia	

Source: WI calculations based on BBR (2005)

The following sections describe the cost assumptions for refurbishment.

Façade insulation

Table 7-16 shows the cost assumptions for compound systems for heat insulation for façades. The assumptions are equivalent to Ref 3 in the moderate climate zone. The total costs amount to 100 Euro per m^2.

Table 7-16: Cost structure for the refurbishment of façades (Ref 3)

Façade (Ref 3)	Costs (€/m^2)
Scaffolding etc.	11
Fire prevention education	2
Preliminary work	4
Labour costs	25
Material costs	20
Overcoating and providing mesh to cracks in plaster or render	11
Expansion joints	4
On-wall and painting costs	14
Renewal and demolition of downpipes	3
Window connection etc.	6
Total	**100**

Source: IWU (2006)

Different qualities of refurbishment are differentiated by the variation of the insulation thickness. Table 7-17 gives an overview about the costs and fix components for each type of refurbishment measure and for all climate zones.

Table 7-17: Costs for façade insulation per refurbishment standard, all Climate Zones

Façade	Costs for thermal improvement in €								
	Cold			**Moderate**			**Warm**		
	Ref 1	Ref 2	Ref 3	Ref 1	Ref 2	Ref 3	Ref 1	Ref 2	Ref 3
U-value before	0.50	0.50	0.50	1.50	1.50	1.50	1.97	1.97	1.97
U-value after	0.18	0.17	0.15	0.41	0.38	0.20	0.59	0.48	0.25
Labour costs	**66.0**	**66.0**	**66.0**	**50.6**	**50.6**	**50.6**	**30.4**	**30.4**	**30.4**
Fix component	*36.3*	*36.3*	*36.0*	*27.8*	*27.8*	*27.8*	*16.7*	*16.7*	*16.7*
Material costs	**88.9**	**92.9**	**99.0**	**36.9**	**38.30**	**49.4**	**31.9**	**35.3**	**45.6**
Fix component	*34.4*	*34.4*	*34.3*	*27.2*	*27.2*	*27.2*	*25.1*	*25.1*	*25.1*
Total	**154.9**	**158.9**	**165.0**	**87.5**	**88.9**	**100.0**	**62.3**	**65.7**	**76.0**

Source: WI calculations based on IWU (2006)

To calculate costs for a new building, the above created values are used and costs typical for refurbishment such as the renewal and demolition of downpipes and the overcoating to cracks in plaster are not completely taken into account. Table 7-18 shows the additional costs for the energetic standard of New 2 vs. New 1, New 3 vs. New 1 and New 4 vs. New 1 for facades.

Table 7-18: Additional costs for façade insulation (insulation standards New 2/3/4 vs New1, all Climate Zones)

Façade	Additional costs New 2/3/4 versus New 1 in € per m^2								
	Cold			**Moderate**			**Warm**		
Building code	New2	New3	New4	New2	New3	New4	New2	New3	New4
U-value	0.17	0.15	0.10	0.38	0.20	0.10	0.48	0.25	0.10
Additional Costs	**5.6**	**13.9**	**41.1**	**2.8**	**25.1**	**60.8**	**5.6**	**22.3**	**55.7**

Source: WI calculations based on IWU (2006)

Roof insulation

When considering an improved insulation of roofs, costs for pitched roofs are presented. If the insulation thickness has to be improved, it will be done beneath the rafters. But not in every case it is possible to carry out the insulation in such an easy way. In such cases, additional insulation material must be fitted between the joists of the roof. The following table shows cost assumptions for the insulation of roofs (energetic standard Ref 2) according to EURIMA, Ecofys (2005) which were completed with information from IWU, for example on the labour costs of skilled workers. Therefore, the cost elements presented in Table 7-19 are more detailed compared to the EURIMA report, where only total investment costs are given. The total insulation costs amount to 31.9 Euro per m^2 roof surface.

Table 7-19: Cost structure for roof insulation

Roof (Ref 2)	**Costs (€/m^2)**
Labour costs	21.3
Material costs	10.6
Total	**31.9**

Source: EURIMA, Ecofys (2005b); IWU (2006)

Due to the cost assumptions for Ref 2, it is assumed that 68 % of the total amount are fix components which have to be considered for each type of refurbishment, in order to maintain the roof and the current energetic standard. Only 32 % of the costs are considered to be costs necessary to reach the energetic standard of Ref 2. Labour costs contribute largely to the fix costs; it has, however, already been mentioned that labour costs differ nevertheless because of additional work depending on the energetic standard to be reached, e.g. it is often necessary to fix additional rafters or to exchange joists. Therefore, Table 7-20 gives an overview about the full and fixed costs for each type of refurbishment measure.

Table 7-20: Costs for roof insulation, per refurbishment standard, all Climate Zones

Roof	Costs for thermal improvement in €								
	Cold			Moderate			Warm		
	Ref 1	Ref 2	Ref 3	Ref 1	Ref 2	Ref 3	Ref 1	Ref 2	Ref 3
U-value before	0.50	0.50	0.50	1.50	1.50	1.50	2.46	2.46	2.46
U-value after	0.15	0.13	0.11	0.25	0.23	0.20	0.50	0.43	0.30
Labour costs	**37.8**	**39.1**	**44.9**	**20.6**	**22.3**	**24.4**	**13.2**	**13.6**	**15.6**
Fix component	*26.8*	*26.8*	*26.8*	*14.6*	*14.6*	*14.6*	*9.3*	*9.3*	*9.3*
Material costs	**18.9**	**19.6**	**22.3**	**10.3**	**10.6**	**12.1**	**6.6**	**6.8**	**7.8**
Fix component	*13.4*	*13.4*	*13.4*	*7.3*	*7.3*	*7.3*	*4.7*	*4.7*	*4.7*
Total	**56.7**	**58.7**	**67.3**	**30.8**	**31.9**	**36.6**	**19.3**	**20.4**	**23.4**

Source: WI calculations based on EURIMA, Ecofys (2005b); IWU (2006)

To calculate costs for new buildings, the above mentioned values are used to calculate additional costs for the energetic standard of New 2 vs. New 1, New 3 vs. New 1 and New 4 vs. New 1 for roofs. Table 7-21 gives an overview of these calculations for three climate zones.

Table 7-21: Additional costs for roof insulation (insulation standards New 2/3/4 vs New1, all Climate Zones)

Roofs	Additional costs versus New 1 in € per m^2								
	Cold			Moderate			Warm		
Building code	New2	New3	New4	New2	New3	New4	New2	New3	New4
U-value after	0.13	0.11	0.10	0.23	0.20	0.10	0.50	0.43	0.10
Add. Costs	**1.2**	**4.3**	**10.3**	**0.5**	**4.1**	**11.6**	**0.7**	**3.7**	**10.0**

Source: WI calculations based on EURIMA, Ecofys (2005b); IWU (2006)

Floor insulation

Table 7-22 shows cost assumptions for walkable insulation of floors, which is equivalent to Ref 3 in the moderate climate zone. The total costs amount to 33.0 Euro for each m^2 floor.

Table 7-22: Cost structure for floor insulation

Roof (Ref 3)	**Costs (€/m²)**
Demolition and renewing of insulating materials	8.0
Labour costs for installation	7.0
Insulating panel	9.0
Walkable surface	9.0
Total	**33.0**

Source: IWU (2006)

From these cost assumptions for Ref 3, it is calculated that, similar to the insulation costs of facades, 55 % of the total costs are fixed; 45 % are necessary to achieve energetic standard Ref 3. This holds for labour as well as material costs. It is assumed that labour costs for floors will not depend on the energetic standard. Table 7-23 gives an overview about the full and fix components for all climate zones.

Table 7-23: Costs for floor insulation, per refurbishment standard, all Climate Zones

Floor	Costs for thermal improvement in €								
	Cold			**Moderate**			**Warm**		
	Ref 1	Ref 2	Ref 3	Ref 1	Ref 2	Ref 3	Ref 1	Ref 2	Ref 3
U-value before	0.50	0.50	0.50	1.20	1.20	1.20	2.46	2.46	2.46
U-value after	0.18	0.17	0.15	0.44	0.41	0.28	0.50	0.43	0.30
Labour costs	**21.8**	**21.8**	**21.8**	**13.8**	**13.8**	**13.8**	**10.0**	**10.0**	**10.0**
Fix component	*12.0*	*12.0*	*12.0*	*7.6*	*7.6*	*7.6*	*5.5*	*5.5*	*5.5*
Material costs	**29.3**	**30.7**	**32.7**	**15.3**	**16.1**	**19.2**	**6.6**	**6.8**	**7.8**
Fix component	*18.0*	*18.0*	*18.0*	*10.6*	*10.6*	*10.6*	*8.3*	*8.3*	*8.3*
Total	**51.1**	**52.5**	**54.5**	**29.1**	**29.9**	**33.0**	**20.6**	**21.7**	**25.1**

Source: WI calculations based on IWU (2006)

To calculate costs for new buildings, the above mentioned values are used to calculate additional costs for the energetic standard of New 2/3/4 vs. New 1 for floors. Table 7-24 gives an overview of theses calculations for the three climate zones.

Table 7-24: Additional costs for floor insulation (insulation standards New 2/3/4 vs New1, all Climate Zones)

Roofs	Additional costs versus New 1 in € per m²								
	Cold			**Moderate**			**Warm**		
Building code	New2	New3	New4	New2	New3	New4	New2	New3	New4
U-value after	0.13	0.11	0.10	0.23	0.20	0.10	0.50	0.43	0.10
Add. Costs	**1.5**	**3.6**	**4.8**	**0.7**	**3.6**	**20.9**	**0.7**	**2.9**	**15.3**

Source: WI calculations based on IWU (2006)

Windows

Table 7-25 shows cost assumptions for wooden windows with low-emission double glazing for general exchange of windows and for passive houses (low-emission triple glazing). It is assumed that these types of windows are used for the new building code 4. The standard exchange of windows amounts to 333 Euro per m^2 and the exchange with windows for passive houses 478 Euro per m^2. It also shows the additional costs of approx. 145 Euro/m^2 of window.

Table 7-25: Cost structure for windows

Windows	Basic Costs (€/m2)	Costs for windows New 4 (€/m2)
Demolition	22	22
Roller blind	71	71
Internal soffit	40	40
Frame and glazing	200	345
Total	**333**	**478**

Source: IWU (2006)

Due to this cost assumption for New 4, it is assumed that 36 % are labour and 64 % material costs. The costs for low-emission double glazing represent the basic costs of refurbishment. As the example shows, the costs for improvement are mainly determined by frame and glazing. Taking into account this approach, Table 7-26 shows the costs calculated for windows in each energetic standard Ref 1 to 3.

Table 7-26: Costs for windows, per refurbishment standard, all Climate Zones

Windows	Costs for thermal improvement in €								
	Cold			**Moderate**			**Warm**		
	Ref 1	Ref 2	Ref 3	Ref 1	Ref 2	Ref 3	Ref 1	Ref 2	Ref 3
U-value before	3.00	3.00	3.00	3.50	3.50	3.50	4.70	4.70	4.70
U-value after	1.42	1.33	1.03	1.84	1.68	1.30	3.04	2.71	1.26
Labour costs	**262**	**262**	**262**	**176**	**176**	**176**	**127**	**127**	**127**
Fix component	*182*	*182*	*182*	*118*	*118*	*118*	*101*	*101*	*101*
Material costs	**304**	**334**	**364**	**237**	**259**	**280**	**162**	**172**	**182**
Fix component	*274*	*274*	*274*	*215*	*215*	*215*	*152*	*152*	*152*
Total	**566**	**596**	**626**	**413**	**435**	**456**	**289**	**299**	**309**

Source: WI calculations based on IWU (2006)

Table 7-27 shows cost assumptions for windows, used in New 4 buildings. They are derived from IWU (2006).

Table 7-27: Costs for windows building code New 4, all Climate Zones

Windows	Costs for thermal improvement in €		
	Cold	**Moderate**	**Warm**
	New 4	New 4	New 4
U-value after	0.60	0.60	0.60
Labour costs	**262**	**176**	**127**
Fix component	*182*	*118*	*101*
Material costs	**393**	**302**	**192**
Fix component	*274*	*215*	*152*
Total	**655**	**478**	**319**

Source: WI calculations based on EURIMA (2005), IWU (2006)

Learning curves

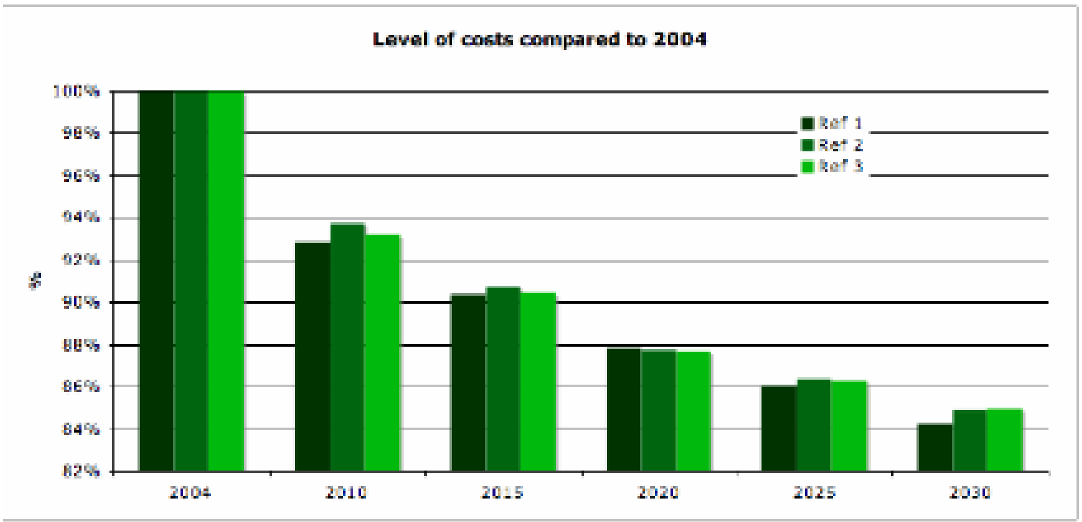
These curves, also known as experience curves, depict experience-driven cost reductions over production levels for the future. In order to take into account this phenomenon, a study by Jakob and Madlener (2002) has been analysed. They analysed the development of refurbishment costs in Switzerland over 25 years, from 1975 until 2000 and found out, that experience-curves are in fact not used efficiently in public policy respectively have seldom influence on it, in order to determine performances of energy-efficient technologies in the market. It is important to know that such curves are not easy to determine precisely because each specific region uses different materials to refurbish buildings and its transfer from one country to another is limited. This limit exists, because of different climate conditions and different performance of building codes and standards in each country or region. The results of the study which has been conducted by Jakob and Madlener have been put into a broader context and show that they are convertible into policy. The outcome of the Swiss study can therefore be applied in a similar way to other countries.

Why can we expect reduced costs in the future despite increasing U-values for surface components and better insulation standards? This result is based on the economies of scale and scope. They originate from a reduction of costs because of increasing production levels; fixed costs are lower per unit of produced products. Therefore, learning curves are relating to decreasing production costs. Furthermore, these curves are referring to the fact that skilled workers are better educated and the larger production volumes reduce the time to convert work habits and enhance speed. Especially in the construction sector cost degression in energy efficiency measures results from the use of pre-fabricated components and other progress.

Figure 7-6 to Figure 7-7 give an overview of the learning curves for roofs, facades and floors respectively windows from 2004 to 2030 according to experiences from Jakob and Madlener's study. It highlights the fact that learning effects by skilled workers and technical development of better insulation materials could reduce costs for the insulation of facades, roofs and floors as well as for windows. In the case of windows it was observed that the price of double glazing windows decreased by more than a factor of two, despite technical progress and a reduction of the U-value.

For example, costs for the refurbishment of roofs as well as of facades and floors are reduced by 16 % by 2030 for the energetic standard of Ref 1 and 15 % for Ref 2 and 3.

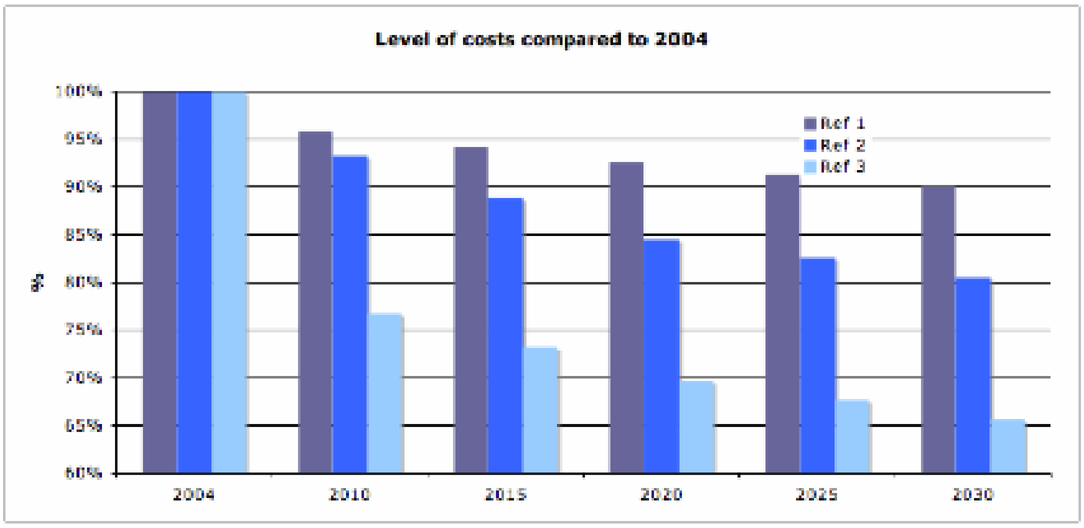
Figure 7-6: Learning curves for roof, façade and floor insulation



Source: WI calculations based on Jakob et al. (2002)

As already mentioned, the effect of learning curves is even more noticeable in the production of windows. Jakob and Madlener highlighted that over 25 years the costs of the most effective window have been reduced by 34 %. Taking into account that from 2004 until 2030 26 years will pass by, it is suggested that low-emission triple glazing, which are used for passive and low-energy houses and are comparable with the energetic standard of Ref 3 and New 3/4, will be even more cost-effective in the future and reduce their costs by 34 %. There are already existing vacuum insulation-glass windows with this high energetic standard. Figure 7-7 shows the reduction of costs for Ref 1 and Ref 2 in the coloured columns.

Figure 7-7: Learning curves for efficient windows



Source: WI calculations based on Jakob et al. (2002)

7.1.5 Step 3 – Definition of the four scenarios

As already described above, the U-values respectively the specific energy consumption per m^2 of the buildings by building component for existing, new and refurbished buildings present the energetic standard of the building (cp. Table 7-5). They are differentiated by three climate zones and by level of performance (Ref 1 - 3 and New 1 – 4). The U-values of refurbished and new buildings are improved as compared to Ref 1 / New 1 and correspond to current values of modern buildings inter alia from the *European Performance of Buildings Directive (EPBD)* (Ref 2 and New 2) and from other current standards in the European countries, e.g. the German Energy Saving Directive (Energieeinsparverordnung (EnEV))[21]. Ref 3 and New 3 are comparable with a low energy house and New 4 is synonym for passive houses. For the latter, the U-values used are comparable to German passive energy house standard, which stands e.g. for significantly improved window frames and better insulated facades and roofs which results in a lower specific energy consumption per m^2. Currently, in many Member States building codes are discussed and the values are just renewed or will be renewed.

For the analysis four different scenarios (Autonomous Progress, Low/High Policy Intensity and Technical Potential) are developed and therefore three potentials are calculated as a difference with the Autonomous Progress Scenario. In order to integrate different social and economic backgrounds of the countries, it is necessary to differentiate these countries. Thus, four socio-economic country groups have been

[21] The Energieeinsparverordnung EnEV is the present German Building Standard for new and old buildings in Germany.

defined and the four groups, listed below, represent the socio-economic development in these regions. These regions have been chosen because countries are linked to each other within the groups due to the same climate zone and some roughly similar political background. Hence, it is assumed that theses groups show comparable market situations with regards to the rate of renovation and energetic refurbishment:

- The Group *North-Western Europe* (NW) consists of Central and Western European countries like Austria, Belgium, Germany, France, Ireland, Liechtenstein, Luxemburg, the Netherlands and United Kingdom and furthermore Scandinavian countries (Sweden, Norway, Denmark, Iceland and Finland). It is supposed that 1.2 % of the building stock will be refurbished from the beginning of 2004. This value will increase until 2030. The new building codes are according to current standards. In many countries these building codes have already been legalized or will be legalized in a few years.
- The Group *Southern Europe* (South) consists of the following countries: Greece, Spain, Italy, Portugal and Slovenia, as one of the New Member States of 2005, acceding the European Union. In contrast to North-Western Europe the maximum refurbishment rate is assumed to be lower and new building codes are assumed to be less performant. The upper limit in 2004 for refurbishment is 0.9 % of the building stock.
- The New Member States of the European Union (Cyprus, Czech Republic, Estonia, Lithuania, Latvia, Malta, Poland and Slovakia, since May 2005) belong to the group *New Member States 2005* (NMS05), except Slovenia. Approximately 0.7 % of the building stock will be refurbished and building codes for new buildings will be as high as in Southern Europe.
- The most recently acceded Member States Bulgaria and Romania, and Croatia (as candidate country to the European Union), belong to the group *New Member States 2007* (NMS07). The upper limit of retrofit measures of the building stock is only approx. 0.5 % per year, but will increase until 2030 as well as the building codes for new buildings.

An overview about the scenario developments is given below. It is obvious that the share of refurbishment rates and the distribution of the new building codes vary in a number of aspects (New 1- to New 4). The Figures included show the distribution of the refurbishment rates over all groups and years more in detail.

Autonomous Progress Scenario

The definition of the *Autonomous Progress Scenario* is a comprehensive task. It could be observed that energy efficiency gains were achieved in the past through high efficiency technological processes in the construction sector. This also aligns with the findings of Jakob and Madlener and those stated in the EURIMA reports.

For example, the insulation of building components has been improved and their typical specific energy consumption has been reduced. On the one hand, the implementation of new legal incentives has promoted such technical progress but on the other hand, the development in the construction sector itself and increasing energy prices in the past, too, lead to the current results. As the state of the art review from TU Delft (Itardet al. 2007) has shown, many activities are currently in place and energy savings in the building sector, residential as well as non-residential building sector, seem to be an important goal to fulfil national and European wide targets for the reduction of energy consumption and CO_2-emission. Policy and the normal technical progress generate an increasing awareness to improve the energetic standard of buildings.

Total renovation rates, energetic refurbishment rates and the rate of new construction are decisive variables for the scenario definition. The scenarios are set up separately according to these parameters for existing and new buildings.

Refurbishment of existing buildings

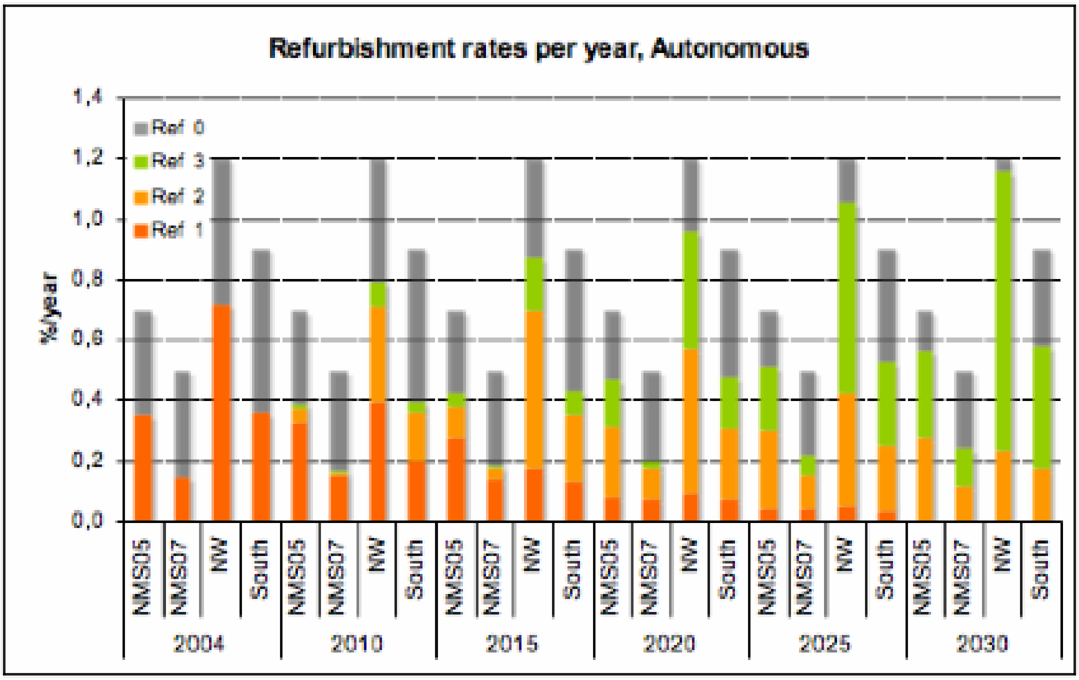
Figure 7-8 gives an overview of current refurbishment rates and possible future developments by socio-economic regions. Current refurbishment rates of buildings are significantly below the rates that would be necessary to cope with regular reinvestment due to the lifetimes of components, which are typically between 25 years for windows and 30 to 50 years for the façade, floors and the roof. In fact, current renovation rates are between 1.2 % in North-Western Europe and 0.5 % in the recently acceded countries Romania and Bulgaria (as also assumed for Croatia). During these renovations only a fraction of 40 to 60 % is also renovated energetically, i. e. refurbished as Ref 2 or 3 or newly built up as New 2, New 3 or New 4.

Thus, the *Autonomous Progress Scenario* consists of one refurbishment class in the first time frame (Ref 1). From beginning of 2010, a second (Ref 2) and third class of energetic standard (Ref 3) are introduced. Until 2030, the rates of the more ambitious refurbishment rates will be increasing, while Ref 1 is phased out. It is assumed that the *Autonomous Progress Scenario* will see increasing rates of energetic refurbishment out of more or less constant low frozen total renovation rates.

Penetration of new more efficient buildings in the market

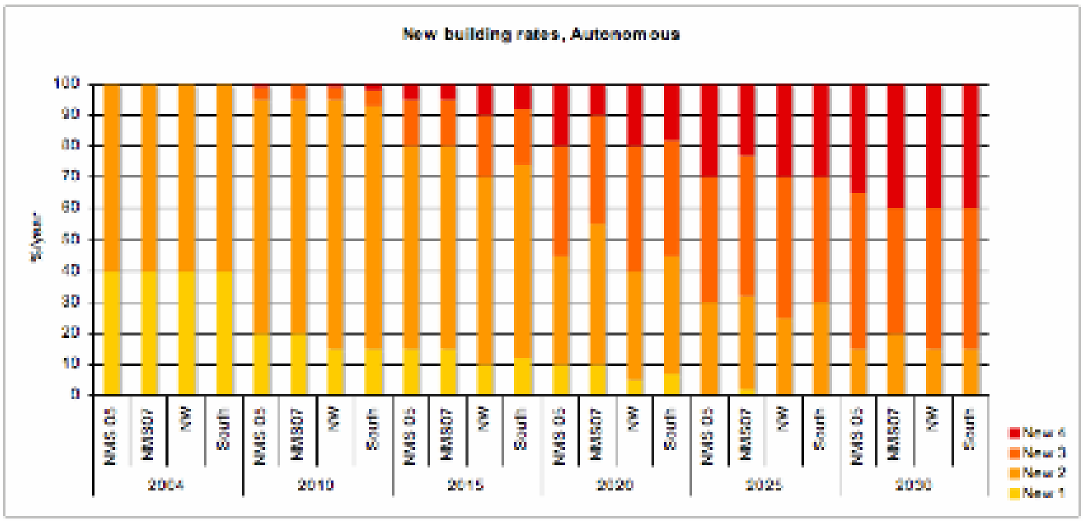
It is supposed to start with high shares of the current energetic standards for new buildings. From 2010 until 2030, the share of more demanding building codes should start, but with not very ambitious targets in order to reduce the energy consumption. Figure 7-9 shows the new building rates per building code (New 1-4) until 2030.

Figure 7-8: Rates of refurbishment rate per year, Autonomous Progress Scenario



Source: WI calculations based on ISI (2007); WI (2000)

Figure 7-9: Market shares of new building codes per year, Autonomous Progress Scenario



Source: WI calculations

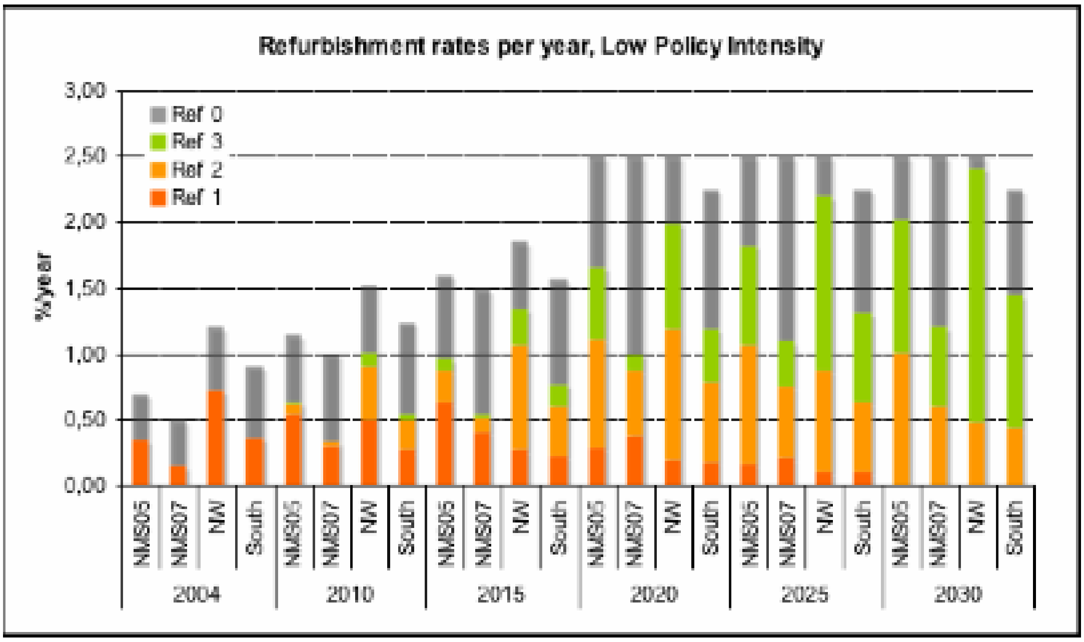
Low Policy Intensity Scenario

In the two policy scenarios investigated in this study, the introduction of new policies is envisaged and thus, the market will continue transforming. Two different intensities of policy influence are envisaged; the first policy scenario is the Low Policy Intensity Scenario.

Refurbishment of existing buildings

Due to the need for maintenance of the existing building stock and the demand of new buildings, the building stock will be supported. For the low economic scenario it is assumed that the total renovation rates will increase to higher levels around 2.5 % per year (Figure 7-10). The energetic refurbishment will achieve slightly increasing market shares of the total renovation rate. Similar to the Autonomous Progress Scenario, in the North-Western countries additional refurbishment measures (Ref 2 and Ref 3) will have been introduced by 2010 due to the fact that from beginning 2008 all over Europe new and stronger building codes are in force. The other regions follow the same pattern with some delay. The penetration rate of these improved standards will grow proportional from 2008 to 2030.

Figure 7-10: Rates of refurbishment per year, Low Policy Intensity Scenario

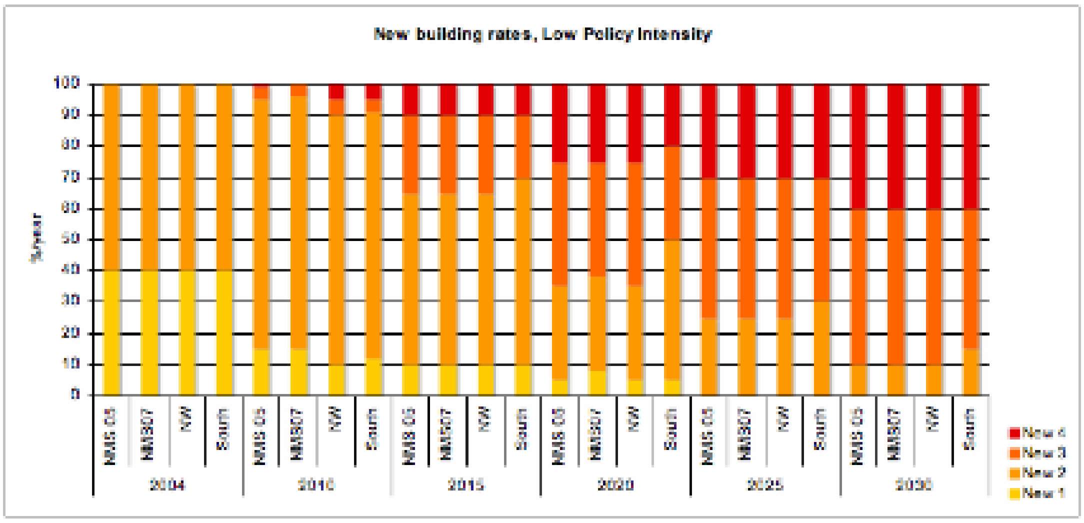


Source: WI calculations based on ISI (2007); WI (2000)

Penetration of new more efficient buildings in the market

Taking policy measures into account, the building codes will get stronger and more efficient measures like low energy houses and passive houses (New 3 and New 4) will penetrate the market more effectively than in the Autonomous Progress Scenario. Building code New 4 will start from less than 4 % in North-Western Europe respectively 1 % in the New Member States 2005 and grow up to 40 % in every region until 2030. Figure 7-11 shows the share of different building codes for the LPI-S.

Figure 7-11: Market shares of new building codes per year, Low Policy Intensity Scenario



Source: WI calculations

High Policy Intensity Scenario

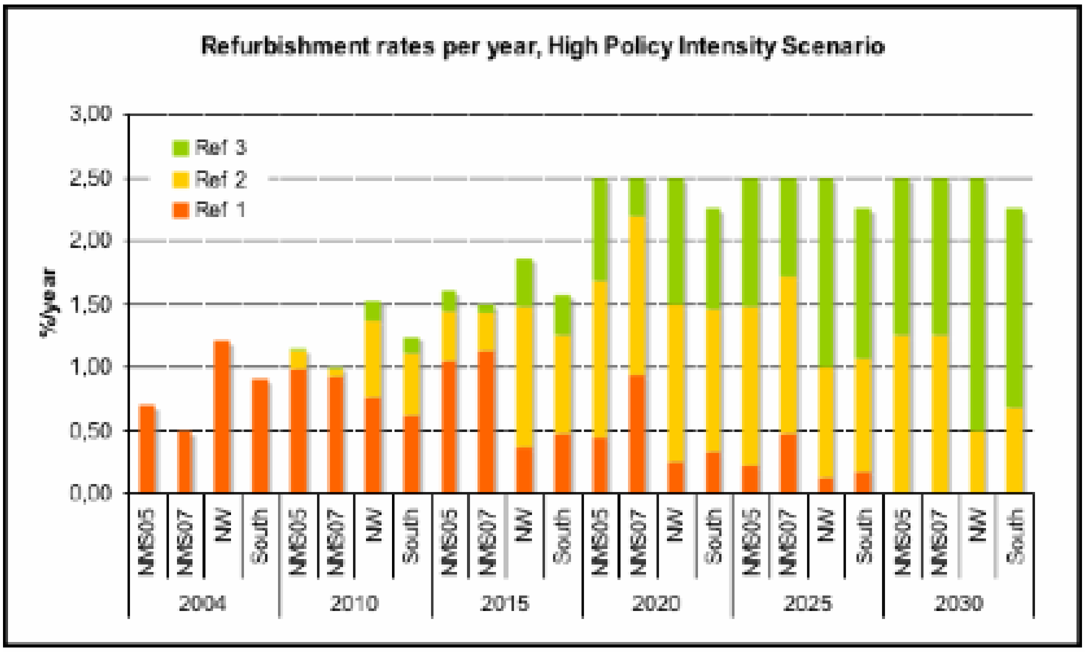
Refurbishment of existing buildings

In the high economic potential scenario the higher renovation rates of the Low Policy Intensity Scenario is coupled, starting from 2005, with additional energetic refurbishment at improved standards. A stronger role of policy measures than for the LPI-S is taken into account for this scenario. Thereby, the share of more efficient technologies will increase faster than in the Low Policy Intensity. This policy is implemented and promoted in every region. Figure 7-12 shows the assumptions for the rates of refurbishment for existing buildings in the regions.

Penetration of new more efficient buildings in the market

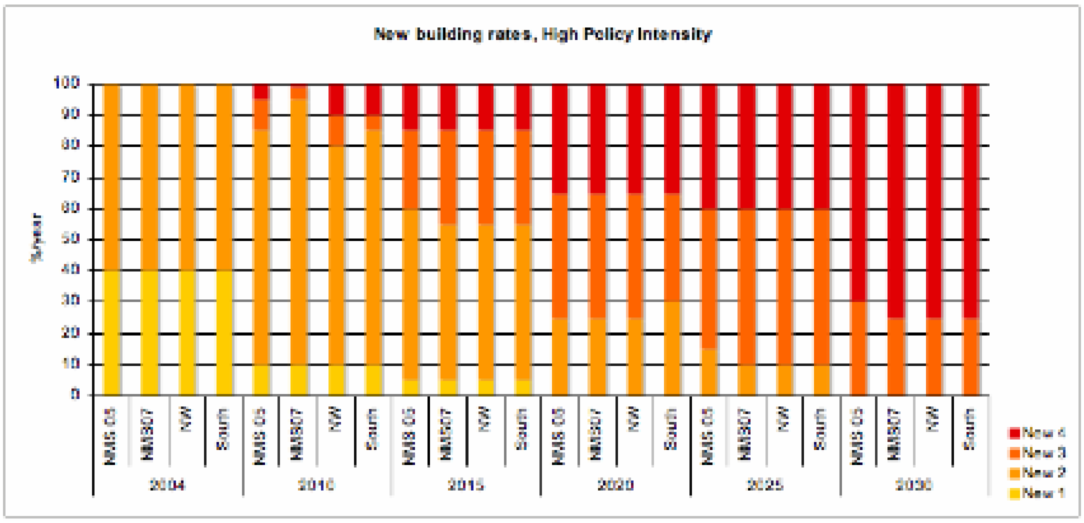
The introduction of the most efficient building technology reaches almost every region in 2010 (Figure 7-13). Thus, the market share is dominated by efficient building technologies in every country in the period 2010 to 2030. This leads to a share of new building code 4 up to 75 % in North-Western Europe in 2030 and up to 70% in the new acceded countries and in Croatia.

Figure 7-12: Rates of refurbishment rates per year, High Policy Intensity Scenario



Source: WI calculations

Figure 7-13: Rates of new building codes per year, High Policy Intensity Scenario

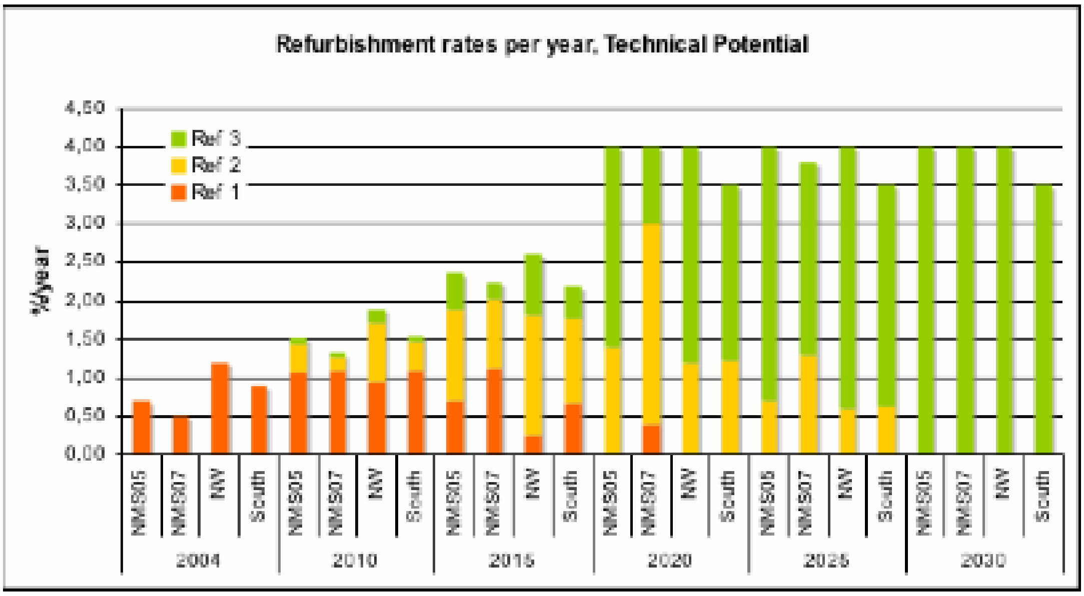


Source: WI calculations

Technical Potential Scenario

The Technical Potential Scenario assumes further speeding up of the total renovation rates up to the maximum feasible level together with 100 % energetic refurbishment rates at high standards. Thus, a politically supported increase of the renovation rates up to the maximum feasible level of about 4 % per year is supposed (Figure 7-14).

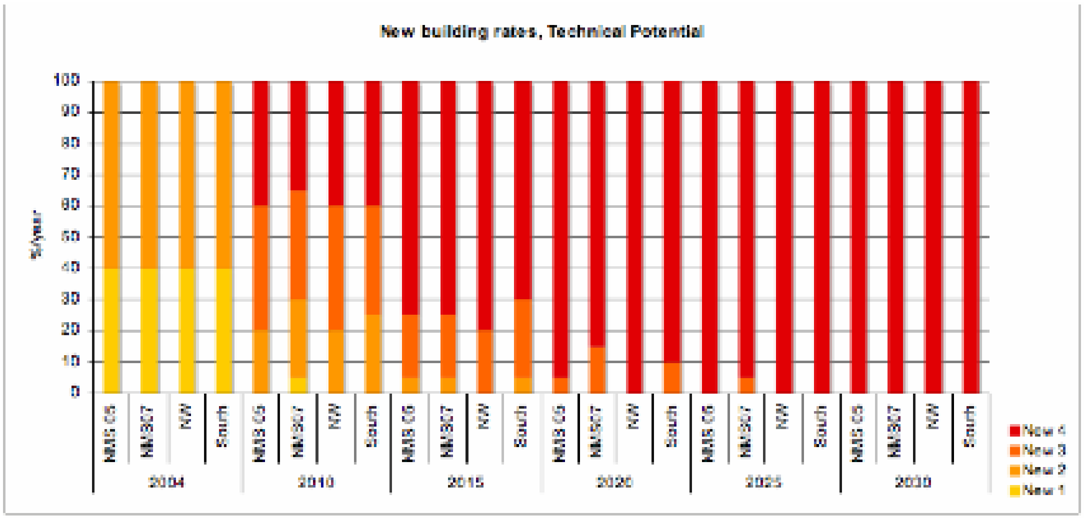
Figure 7-14: Rates of refurbishment rates per year, Technical Potential Scenario



Source: WI calculations

With a strong political promoting of the current most efficient building standard, it is assumed that in 2010 already 20 % of the new built buildings are equivalent to the New 4 standard in North-Western Europe, Southern Europe and in the New Member States which acceded to the EU in 2005. In North-Western Europe the market share of this building code will already reach 100 % in 2020, whereas in the New Member States 2007 and in Croatia it just reaches a value of about 85% (Figure 7-15). Until 2025 almost every region has reached 100 %, except the NMS07.

Figure 7-15: Rates of new building codes per year, Technical Potential Scenario



Source: WI calculations

7.2 Heating devices

7.2.1 Description of the sector/end-use

The following paragraphs deal with the way the energy efficiency potential due to the improvement of the energy efficiency of the heating equipment has been calculated. In practice this potential is cumulated to that provided by the interventions on the building shell described in 7.1 in terms of useful energy.

The heating devices are broken down into the following technologies:

- Gas standard and condensing boilers
- Heat pumps
- Biomass boilers (from classic wood to the advanced pellet boilers)
- Solar heating systems
- Traditional oil and coal boilers
- Electric radiators/stoves
- District heating systems

7.2.2 Sector-specific / use-specific data sources and modelling issues

First of all it is worth highlighting that building shell and heating technologies are interlinked. Therefore the energy efficiency potential is **differentiated by heating**

systems for the existing and the new (future) building stock[22]. As a matter of fact, the energy efficiency potential is surely higher for the existing than for the future stock and it is possible to affirm that the more the building technology of a new house is advanced, the less is the residual margin to improve its overall energy efficiency, till one arrives to the passive house standard for which we can say that their residual potential is practically zero.

According to this initial statement, the methodology for the calculation of the EE potentials due to the heating equipment improvement has been the following:

1. The input data are: the useful energy consumption, calculated in accordance with the settings outlined in 7.1, the energy consumption share of the heating technologies and the corresponding energy efficiencies.
2. The energy consumption shares of the heating technologies are the main scenario drivers. These technologies are the ones listed in 7.2.1:
3. For the reference year the data of the energy consumption shares at country level are provided by the EuP-Eco-design study on boilers[23]. These data have then been split between the existing and the new-future stock on the basis of the following criteria:
   a. In general, new buildings will not install coal or even oil boilers, the district heating connection is reduced, especially in the Eastern Countries, while, on the contrary, the majority of the share goes to the gas boilers as well as to renewables and heat pumps.
   b. The existing buildings take up the remaining energy consumption shares in order to be consistent with the overall breakdown provided by the Eco-Design study.
4. The conversion efficiencies of the heating technologies (boiler + heat distribution energy efficiency) have been estimated on the basis of the previous MURE data (MURE household 2000). To this end, like for the SHW systems (see paragraph 7.3), the countries considered here were divided in four groups in accordance with their supposed reference energy efficiency level:
   - Group 1: High reference conversion efficiency (i. e. high penetration of condensing boilers, average conversion efficiency for heating = 90 % in the existing buildings and 95 % in the new ones): Denmark, The Netherlands, Germany, Sweden, Norway, Austria, Iceland.
   - Group 2: Good reference conversion efficiency (country average conversion efficiency for heating = 85 % in the existing buildings and 90 % in the new ones): France, UK, Belgium, Finland, Luxemburg.

---

[22] According to the definitions provided in paragraph 7.1.3, the existing stock includes the buildings built up to 2004

[23] Kemna, R. et al.: Eco-Design of Boilers (Lot 1: Boilers and combi-boilers), Task 3 final report, http://www.ecoboiler.org/)

- Group 3: Medium reference conversion efficiency (country average conversion efficiency for heating = 75 % in the existing buildings and 90 % in the new ones): Italy, Spain, Portugal, Ireland, Czech Republic, Hungary, Poland, Slovak, Slovenia, the Baltic countries
- Group 4: Poor reference conversion efficiency: Bulgaria, Romania, Croatia, Cyprus, Greece, Malta (country average conversion efficiency for heating = 65 % in the existing buildings and 85 % in the new ones).

7.2.3 Step 1 – Definition of energy saving options

As outlined in point 2 of the previous numbered list, the energy consumption shares by heating technologies are the main scenario drivers. This means that the energy efficiency potentials mainly depend on the substitution rates of the less efficient heating technologies with the more efficient ones.

To this end it is important to underline that the substitutions occurring within the same energy market (gas, oil, electricity, renewables, biomass, district heating) do not depend on the scenario settings but only on the autonomous progress of each market. In practice, in this simulation framework, the policies only act upon the market shares and not on the technology performance within each single market. These markets are considered as being sufficiently mature to autonomously increase the energy efficiency of the equipment sold in the market itself. The consequence of this is that the final energy consumption of the building is a function of:

- The trend of the heating equipment efficiency within each energy market, set equal for all the scenarios
- The market share of each energy market over time, depending on the scenario settings.

We recognise that this approach is rather simplistic because it eliminates a degree of freedom in the policy simulation, i.e., the possibility to intervene within a single energy market. This has been adopted to cope with the data availability (i.e. very little information on the penetration of the condensing boilers in the gas markets) The consequence is that the potentials figures provided may be a little bit underestimated but we believe that the overall picture is more reliable.

Table 7-28 to Table 7-30 show the reference conversion efficiencies attributed to the selected heating technologies and the four country groups respectively for the existing and the new buildings. The new buildings are in turn split by those built in accordance with the building codes defined as New1, New2, and New3 and the passive houses (code New 4). It is supposed that the requirements of the passive house standard limit the choice of the heating systems.

Table 7-28: Existing buildings, reference efficiencies by heating technology and country group

	Group1	Group2	Group3	Group4
Natural gas boilers	93%	87%	82%	80%
Oil boilers	85%	81%	76%	74%
Coal boilers	60%	60%	55%	45%
Biomass boilers	70%	70%	65%	55%
Electricity	100%	100%	100%	100%
Renewables (solar or geothermal)[1)]	150%	150%	150%	150%
Heat pumps[2)]	3,5	3,5	3,5	3,5
District heating[3)]	100%	100%	100%	100%

Notes: 1)

Table 7-29: New buildings, reference efficiencies by heating technology and country group

	Group1	Group2	Group3	Group4
Natural gas boilers	95%	95%	95%	90%
Biomass boilers	85%	85%	80%	75%
Electricity	100%	100%	100%	100%
Renewables (solar or geothermal) [1)]	150%	150%	150%	150%
Heat pumps[2)]	3,5	3,5	3,5	3,5
District heating[3)]	100%	100%	100%	100%

Notes: see Table 7-28

Table 7-30: Passive houses, reference efficiencies by heating technology and country group

	Group1	Group2	Group3	Group4
Natural gas boilers	99%	99%	99%	99%
Biomass boilers	90%	90%	90%	90%
Electricity	100%	100%	100%	100%
Renewables (solar or geothermal) [1)]	150%	150%	150%	150%
Heat pumps[2)]	4	4	4	4
District heating[3)]	100%	100%	100%	100%

Notes: see Table 7-28

Starting from these values, a set of maximum achievable conversion efficienciesby heating technology has been devised (Table 7-31). As outlined before, these values are differentiated by country groups and not by policy scenarios and represent the average stock efficiencies in the 2030 markets.

Table 7-31: Heating technologies: maximum technical achievable conversion efficiency (market situation in 2030)

	Autonomous Progress			
	Group 1	Group 2	Group 3	Group 4
Natural gas boilers	99%	99%	91%	91%
Oil boilers	91%	87%	85%	84%
Coal boilers	No coal boilers in 2030			
Biomass boilers	84%	84%	81%	70%
Electricity	100%	100%	100%	100%
Renewables (solar or geothermal)	150%	150%	150%	150%
Heat pumps	4	4	4	4
District heating	100%	100%	100%	100%

7.2.4 Step 2 – Technology costs

Assumption on technology costs for heating are based on a cost degression hypothesis of 15 years.

7.2.5 Step 3 – Definition of the four scenarios

Table 7-32 shows the criteria followed to define the market share trends of the heating technologies defined in paragraph. 7.2.1. In accordance with the criteria outlined in this table, the main technological drivers are represented by:

- **The penetration of the gas condensing boilers in the market** (simulated in the model through the increasing of the boiler efficiency):
  - In the Autonomous Progress Scenario the gas market share increases steadily taking the place of the coal and, partially, of the oil boilers.
  - In the LPI Scenario the trend in the market share of the gas boilers is practically the same as in the Autonomous Progress Scenario in the existing building stock (or slowly decreasing); it is decreasing in the future building stock.
  - In the HPI Scenario the trend of the gas boilers is decreasing in both the existing and the new building stock in favour of the penetration of heat pumps and renewables (taking into account the climate zone of the country).
- **The penetration in the market of the renewables** (solar systems and geothermal). As a general rule, should the country climate allow this, the overall penetration targets with respect to the share in the starting year are:
  - Up to + 10 % in the autonomous scenario
  - Up to + 25 % in the LPI Scenario
  - Up to + 40 % in the HPI Scenario

- **The penetration in the market of the heat pumps.**
  - In the Autonomous Progress Scenario the heat pumps substitute the market of the traditional electric radiators and penetrates till reaching in the year 2030 9-10% of the heating equipments stock
  - In the LPI Scenario there is a further penetration of this technology by 2030 up to the triple of the penetration they have in 2010 (15 – 18 % of the heating equipment stock in 2030).
  - In the HPI Scenario, by 2030 the heat pumps have six times the penetration they have in 2010 (30 – 36 % of the heating equipments stock in 2030).

Table 7-32: Criteria followed to set the market share trends of the heating technologies

Technologies	*Criteria*
District heating	In the Western countries the penetration does not change across the scenarios (it remains the same as in the reference year) because it is supposed that the energy efficiency improvements will be carried out at the level of the transformation sector. In the Eastern countries in general only the existing buildings are connected to district heating. In some cases a decrease is foreseen in the penetration of district heating in existing buildings (due to the possible phase out of obsolete plants).
Gas boilers	The hypothesis is that: • by 2015 in the Autonomous Progress Scenario for the group 1 countries and in the LPI/HPI Scenarios for the other country groups, 15 % of the sales at EU level are constituted by condensing boilers; • and that up to 2030 this technology represents 100 % of the market also for the group 3 countries. Overall the gas boiler share in the existing and future buildings increases steadily in the Autonomous Progress Scenario, but does not increase or slowly decreases in the LPI Scenario and steadily decreases in the HPI Scenario.
Oil boilers	Residual technology. This market is mainly substituted by the gas boilers.
Coal boilers	Old boilers with a short residual life. This stock should disappear in the Autonomous Progress Scenario around 2010-2015 depending on the country (in some cases like Poland, the coal boiler stock disappears only in the policy scenarios and by the year 2020).
Biomass boilers	This is an option which is more triggered by environment (CO_2 emissions) rather than by energy efficiency considerations. The share of this technology, with the exception of the few cases in which the starting share is very high, is generally kept unaltered. Actually an increase of this market share decreases the average country energy efficiency.
Electricity	Decreasing market substituted by heat pumps
Renewables (solar heating/geothermal)	Strong increase in accordance with the country latitude, especially in future buildings
Heat pumps	Strong increase in all the scenarios but less than that in the SHW systems. In this framework the heat pump constitutes the leading energy driver for the increase of the electricity demand in the sector.

7.3 Sanitary Hot Water

7.3.1 Description of the sector/end-use

The following paragraphs deal with the way the energy efficiency potential due to the improvement of the energy efficiency of the sanitary hot water equipment has been calculated. The technological breakdown of this end-use is similar as for the heating devices described in section 7.2.1 but with some specialties for the SHW:

- District heating
- Hot water provided by the heating system
- Dedicated gas boilers (both instantaneous and storage)
- Dedicated solar thermal devices
- Dedicated electric instantaneous water heaters
- Dedicated electric storage water heaters
- Heat pumps

7.3.2 Sector-specific / use-specific data sources and modelling issues

The calculation of the efficiency potentials for the sanitary hot water (SHW) energy consumption has been set according to the following steps:

1. Calculation of the SHW energy overall demand
2. Break down of the SHW energy demand by water heater technologies
3. Calculation of the SHW energy consumption by water heater technology (final energy)
4. Definition of the criteria to set the penetration of the water heater technologies in the involved countries
5. Calculation of the EE potentials

The data for the calculation of the SHW energy consumption have been provided by the EuP Eco-design study on boilers[24]. The settings of the water heater technologies penetration trends have been provided by Fraunhofer ISI and completed by ISIS based on the eco-design study for boilers.

The main set of input variables and data sources were the following:

- Households number trend (PRIMES)

---

24 Kemna, R. et al.: Eco-Design of Boilers (Lot 1: Boilers and combi-boilers), Task 3 final report, http://www.ecoboiler.org/)

- Hot water consumption by household and per country (Eco-design study for boilers)
- Share of the market penetration trends of the water heaters technologies per EE scenario (Eco-design study for boilers for the reference year, own estimates, also based on the Eco-design study, for the scenario trends)
- Conversion efficiency of the water heater technologies per country (Eco-design study for boilers)

The yearly SHW energy demand per household has been calculated on the basis of the daily hot water consumption (by household) according to the following formula:

$$En\_demand\_SHW\_hh = Litres\_hh\_day \times 21.1 \text{ (kWh)}$$

Where

21.1 (kWh/Litre) = (365 days x 50 degree °C x 1.16 Wh/degree) / 1000 Wh/kWh

The energy demand up to the year 2030 has in turn been estimated by increasing the reference energy demand in accordance with the household growth rate (from PRIMES) and by keeping constant the reference annual SHW consumption. The break down of the final energy consumption by the most used water heaters technologies (see Table 7-33) has been then estimated by multiplying the SHW energy demand by the water heaters market penetration in the ESD countries and then by dividing the result by the energy efficiencies of the water heater technologies considered.

7.3.3 Step 1 – Definition of energy saving options

Like the heating devices, also in the case of the SWH the energy consumption shares by technology are the main scenario drivers. This means that the energy efficiency potential mainly depends on the substitution rates of the less efficient SWH technologies with the more efficient ones and that the substitutions performed within the same energy market (gas, electricity, renewables, district heating) do not depend on the scenario settings but are considered as autonomous progress for each market. The consequence of this is that, also for the SHW devices, the final energy consumption is a function of:

- The variation trend of the SWH equipment efficiency within each energy market, set equal for all the scenarios.
- The penetration trends of each energy market, depending on the scenario settings.

Table 7-33 shows the considered water heaters technologies and corresponding conversion efficiency:

Table 7-33: Conversion efficiency by water heater technology

Water heater technology	*Conversion efficiency*
District heating	100%
Hot water provided by the heating system	variable according to the reference countries and over time, see Table 7-34
Dedicated gas boilers (both instantaneous and storage)	
Dedicated solar thermal devices	150% (variable according to the reference countries and over time, see below)
Dedicated electric instantaneous water heaters	97%
Dedicated electric storage water heaters	65%
Heat pumps (COP)	From 3.5 [2005] up to 4.2 [2030]

All figures shown in Table 7-33 do not change over time with the exception of the heat pump COP for which an improvement of 20 % has been envisaged, the dedicated gas boilers and the dedicated solar thermal devices.

The average figure of 150 % for the conversion efficiency of these devices means that, on average, in each household in which this system is applied, the solar contribution is able to provide one third of the SHW energy demand. For the Mediterranean countries this figure is higher and increases overtime: it has been set to 200 % for Italy, Spain and Malta in 2004 (50 % of the energy demand provided by the sun) and reaches a level of 250 % in 2030 (300% for Malta) while it has been set to 500% in 2004 (80% of the energy demand provided by the sun) for Cyprus, reaching up to 100 % of energy provided by the sun in 2030 for this country.

Concerning the boilers, their conversion efficiency has been differentiated by group of countries according to the following grouping criteria (similar to those used for the conversion efficiency of the household heating systems):

- Group 1: High conversion efficiency countries (i.e. high penetration of condensing boilers): Denmark, The Netherlands, Germany, Sweden, Norway, Austria, Iceland
- Group 2:Good conversion efficiency countries: France, UK, Belgium, Finland, Luxemburg
- Group 3: Medium conversion efficiency countries: Italy, Spain, Portugal, Ireland, Czech Republic, Hungary, Poland, Slovak, Slovenia, the Baltic countries
- Group 4: Poor reference conversion efficiency: Bulgaria, Romania, Croatia, Cyprus,…

The conversion efficiency figures associated to the country groups are shown in Table 7-34. Like in the case of the heat pumps, a general improvement of 20 % of the conversion efficiency, linearly growing up to 2030, has been envisaged for all the country groups shown below. As outlined before, it is worth noting that this efficiency improvement is not ruled by policies but only by the autonomous progress of the SHW equipments.

Table 7-34: Conversion efficiencies for the SHW boilers

Country groups	*Hot water provided by the heating system*	*Dedicated boilers*
Group 1	75%	70%
Group 2	65%	65%
Group 3	55%	65%
Group 4	45%	55%

7.3.4 Step 2 – Technology costs

Assumption on technology costs for heating are based on a cost degression hypothesis of 15 years.

7.3.5 Step 3 – Definition of the four scenarios

Table 7-35 shows the criteria followed to set the market trends of the SWH technologies listed in Table 7-33. In accordance with these criteria, the market penetration shares of these technologies have been thus determined taking into account the starting situation (at the reference years) and the country profile (GDP, sensitiveness toward the energy efficiency issues, climate conditions..). Like in the case of household heating technologies, the overall criteria has been the progressive entrance in the market of the electric technologies together with the solar heaters systems. These two technologies represent the targets outlined in the technical scenario and generally arrive up to the 50 % of the market (according to the climate conditions) in the high policy intensity scenario.

Table 7-35: Main criteria followed to set the SWH market trends in the involved countries

Technologies	***Criteria***
District heating	The penetration does not change with the scenarios (it remains the same as in the reference year)
Hot water provided by the heating system	The conversion efficiency increases at the same rate in all scenarios but the market penetration is considered as residual (together with the dedicated boilers)
Dedicated gas boilers	As in the case of the systems linked to central heating boilers, these water heaters increase their efficiency in all the scenarios in the same way but decrease their penetration according to the entrance of the heat pumps.
Dedicated electric instantaneous electric water heaters	The penetration of this technology increases in all the scenarios taking the place of the storage electric systems but together, the instantaneous and storage systems decrease their penetration in favour of the heat pump technology. This loss of market position of both electric SHW systems is minimum in the autonomous scenario and maximum in the HPI Scenario.
Dedicated electric storage electric water heaters	This technology is rapidly phased out, starting from the autonomous scenario, in favour of the instantaneous water heaters.
Heat pumps	This technology, together with the solar thermal devices, is the main energy efficiency driver of the SHW systems. It corresponds to the BAT at the reference year and it is expected to steadily increase its penetration in the market in the following way: Up to 30 % in the Autonomous Progress Scenario Up to 50 % in the LPI Scenario Up to 70 % in the HPI Scenario Up to 90 % in the Technical Scenario (but this depends on the penetration of the solar systems) These targets has been be adjusted according to the reference country groups
Dedicated solar thermal devices	In accordance with the climate conditions of the involved countries, a strong penetration of these systems has been foreseen in all the scenarios. In the Autonomous Progress Scenario this technology reaches 10 – 20 % in the southern countries while in the HPI levels of 40 – 50 % are reached in countries like Greece or Spain and up to 100% in Cyprus[25].

[25] The share of the solar water heaters is shown in the ESD database within the “technology drivers/household/water heating” page

7.4 Results residential sector

7.4.1 Results useful energy demand of residential buildings

All assumptions described in section 7.1 are integrated in the model calculation and in the following the potentials of energy savings are given for the whole EU27. Because of the high amount of data, a more detailed overview can be obtained by using the online database.

Figure 7-16 shows the useful energy demand in toe per dwelling for all scenarios for the EU27 and Figure 7-17 shows the same demand expressed in kWh per square meters. The corresponding data are displayed in Table 7-36.

With regards to Figure 7-17 it is worth noting that the specific (useful) energy demand of the Technical Scenario arrives in 2030 to the value of 61 kWh/m^2 that is close to that of the passive houses.

Figure 7-16: Useful energy demand (EU27) – toe/dw

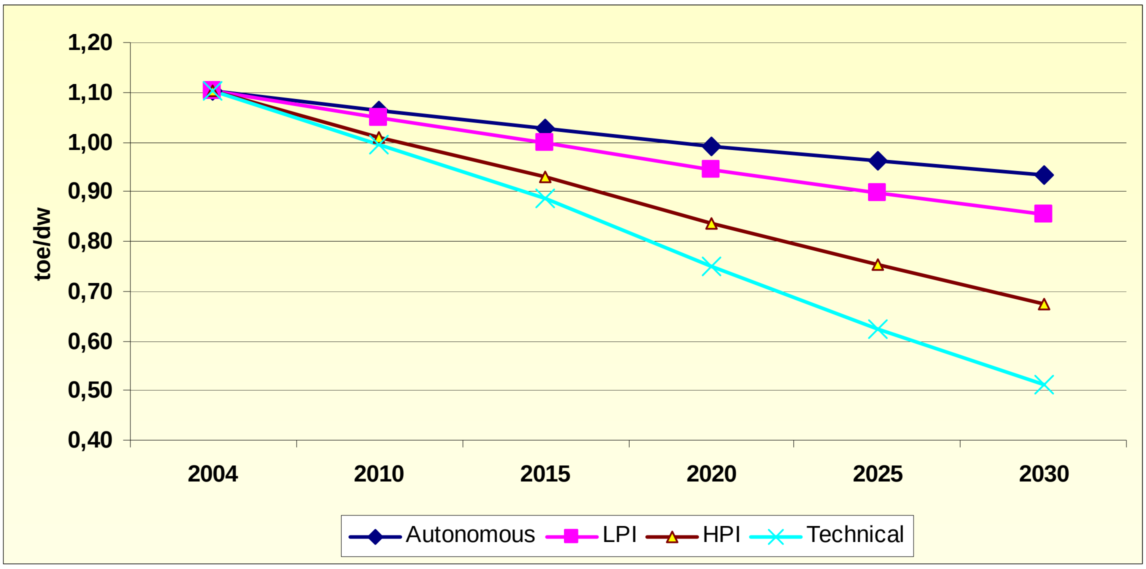


Figure 7-17: Useful energy demand per square metre (EU27) – kWh/m²

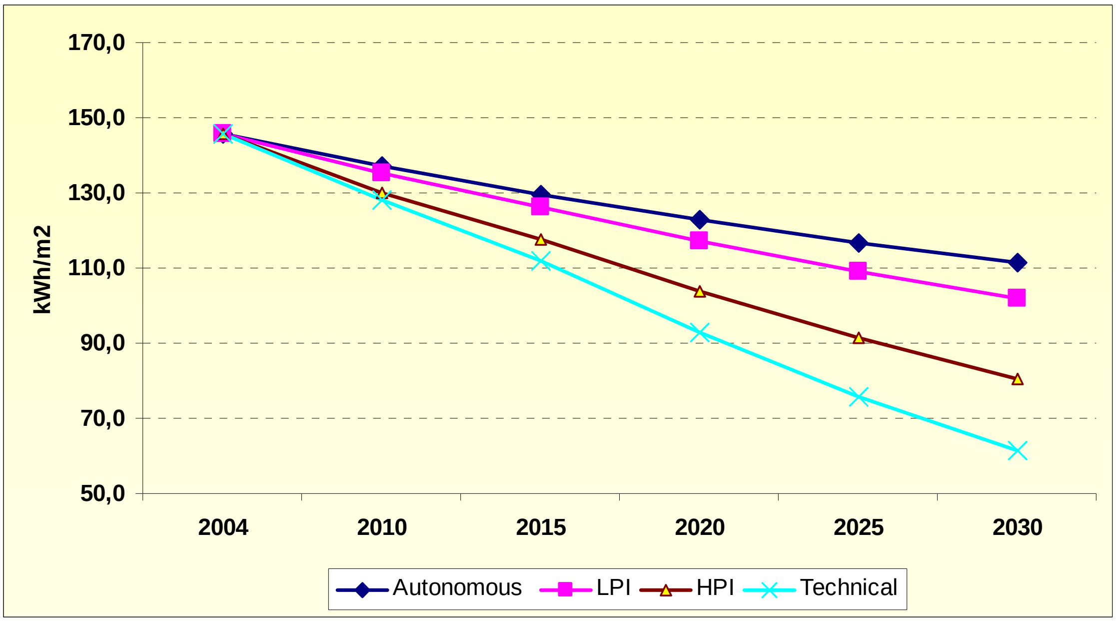


Table 7-36: Useful energy demand (EU27) per dwelling and per square meter

		2004	2010	2015	2020	2025	2030
APS	***toe/dw***	1.10	1.06	1.03	0.99	0.96	0.93
LPI-S		1.10	1.05	1.00	0.95	0.90	0.85
HPI-S		1.10	1.01	0.93	0.84	0.75	0.67
TS		1.10	0.99	0.89	0.75	0.62	0.51
		2004	**2010**	**2015**	**2020**	**2025**	**2030**
APS	***kWh/m2***	145.5	137.0	129.6	123.0	116.9	111.5
LPI-S		145.5	135.2	126.2	117.2	109.0	101.9
HPI-S		145.5	130.2	117.5	103.8	91.5	80.4
TS		145.5	128.2	111.9	92.8	75.9	61.3

Figure 7-18 to Figure 7-20 and Table 7-37 show the energy saving potentials for the three alternative scenarios vs the Autonomous Progress Scenario from the existing building stock (total[26] and refurbishment only[27]) and new building stock (new building codes).

[26] Total saving potential for heating from existing stock: savings stemming from both refurbishment of the EXISTING stock and the penetration of more efficient heating systems in the stock. Potentials from hot water are not included in this item.

[27] Total saving potential for heating from refurbishment existing stock: saving potentials from the increased penetration of refurbishment measures for the EXISTING stock (excl. heating systems).

Figure 7-18: Energy efficiency potential: total existing building stock EU27 (versus Autonomous Progress Scenario)

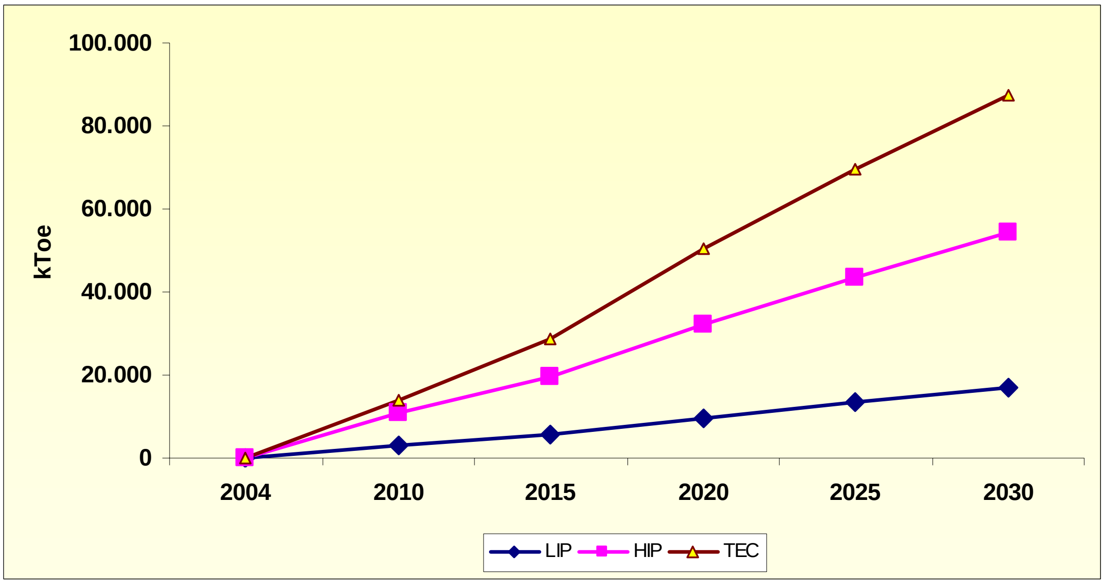


Figure 7-19: Energy efficiency potential: refurbishment of the existing stock EU27 (versus Autonomous Progress Scenario)

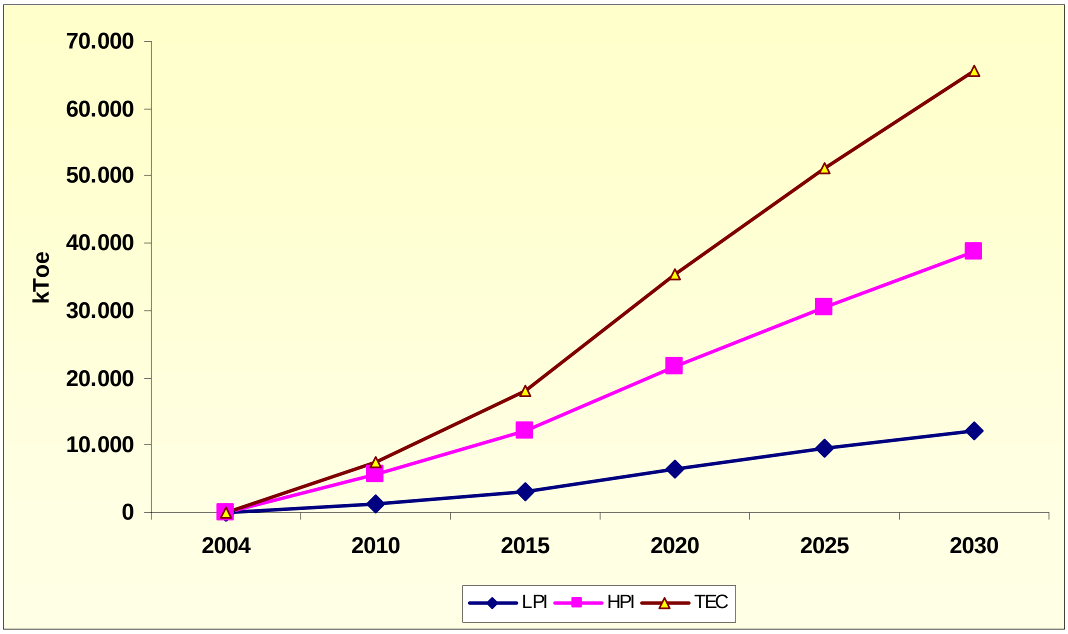


Figure 7-20: Energy efficiency potential: new building stock EU27 (versus Autonomous Progress Scenario)

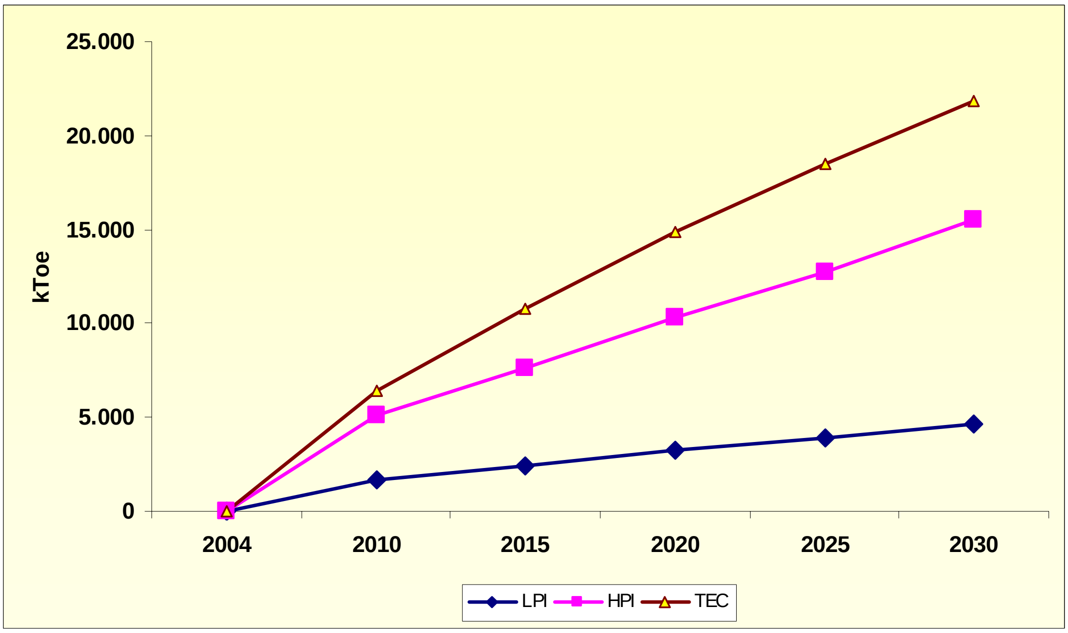


Table 7-37: Energy efficiency potentials from the existing and new building stock (EU27 – ktoe)

Total stock	2010	2015	2020	2025	2030
LPI	2.857	5.517	9.660	13.423	16.778
HPI	10.742	19.743	31.990	43.285	54.192
Technical Potential	13.990	28.728	50.270	69.720	87.388
Refurbishment existing stock					
LPI	1.187	3.078	6.417	9.431	12.163
HPI	5.620	12.115	21.683	30.505	38.651
Technical Potential	7.537	17.958	35.377	51.176	65.593
New building codes					
LPI	1.669	2.439	3.243	3.925	4.615
HPI	5.122	7.628	10.308	12.737	15.541
Technical Potential	6.453	10.770	14.893	18.529	21.794

It is essential to keep in mind that the figures show just the saving potentials for each scenario versus the Autonomous Progress Scenario. The Autonomous Progress Scenario includes already energy efficiency improvements and therefore the saving potentials can be seen as **additional savings**.

7.4.2 Results heating devices

Figure 7-21 and Table 7-38 show the trend of the final thermal energy consumption expressed in toe per dwelling. The final energy takes into account the energy consumption required by the use of the heating equipments. It is worth noting here that, starting from the year 2020 and for the policy and technical scenarios, the final energy consumption is progressively lower than the useful energy demand. This is the result of the combined effect of the introduction in the market of the heat pumps and the solar systems ad the progressive increase of the average decimal efficiency of the gas boilers. Moreover, in many EU Eastern countries and in some EU Western countries a non negligible portion of the heating systems is represented by the district heating to which it has been conventionally attributed the 100% of decimal energy efficiency (when the decimal energy efficiency is equal to 100%, the useful energy is equal to the final thermal energy).

Figure 7-21: Final thermal energy consumption (EU27) – toe/dw

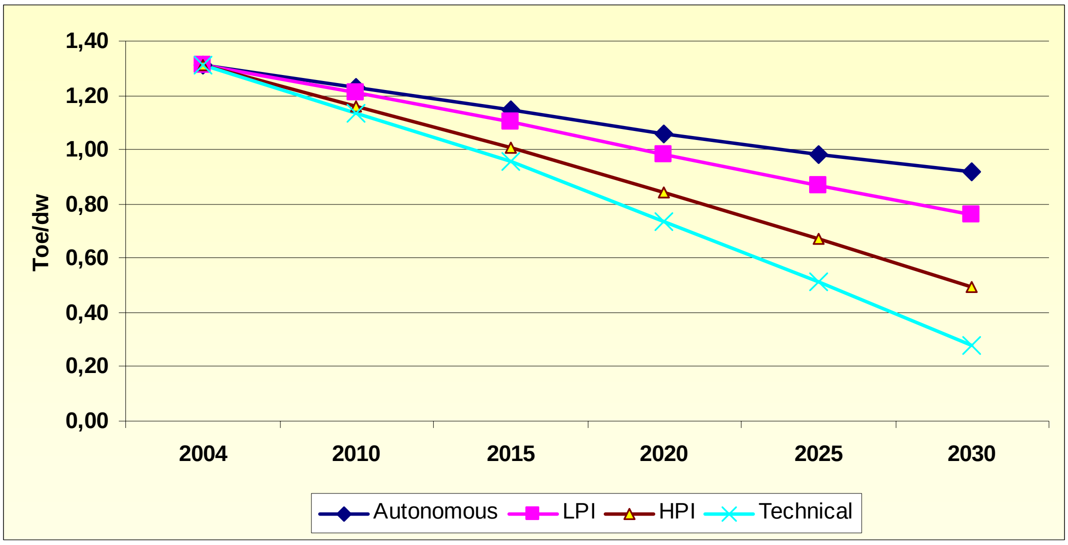


Table 7-38: Final energy consumption (EU27) – toe/dw

		2004	2010	2015	2020	2025	2030
Autonomous	*Toe/dw*	1,31	1,23	1,14	1,06	0,98	0,92
LPI		1,31	1,21	1,10	0,98	0,87	0,76
HPI		1,31	1,16	1,01	0,84	0,67	0,49
Technical		1,31	1,14	0,95	0,74	0,51	0,28

Figure 7-22 shows the EE potential trend of the final thermal energy consumption for the EU27 countries. The savings shown in this figure are the results of the savings provided by the refurbishment and new building codes interventions, as discussed in the previous paragraph (see Table 7-37), plus the savings provided by the increasing of the energy efficiency of the heating systems. The break-down of each of the curves shown in Figure 7-22 by these two classes of savings is provided in Figure 7-23 to Figure 7-25 and in Table 7-40. It is worth noting here that the contribution of the heating equipment to the overall savings is rather high, especially in the LPI scenario, where arrive in the year 2030 up to the 50 % of the total achievable savings.

Table 7-39 shows the percentage of the contribution of the heating systems to the overall final thermal energy consumption by EE scenario.

Table 7-39 Percentage of the contribution of the heating systems to the overall final thermal energy consumption

	2010	2015	2020	2025	2030
LPI-S	27%	39%	39%	41%	50%
HPI-S	26%	29%	29%	33%	39%
TS	27%	26%	24%	28%	34%

Figure 7-22: Energy efficiency potential from the final thermal energy demand for the– EU27 countries

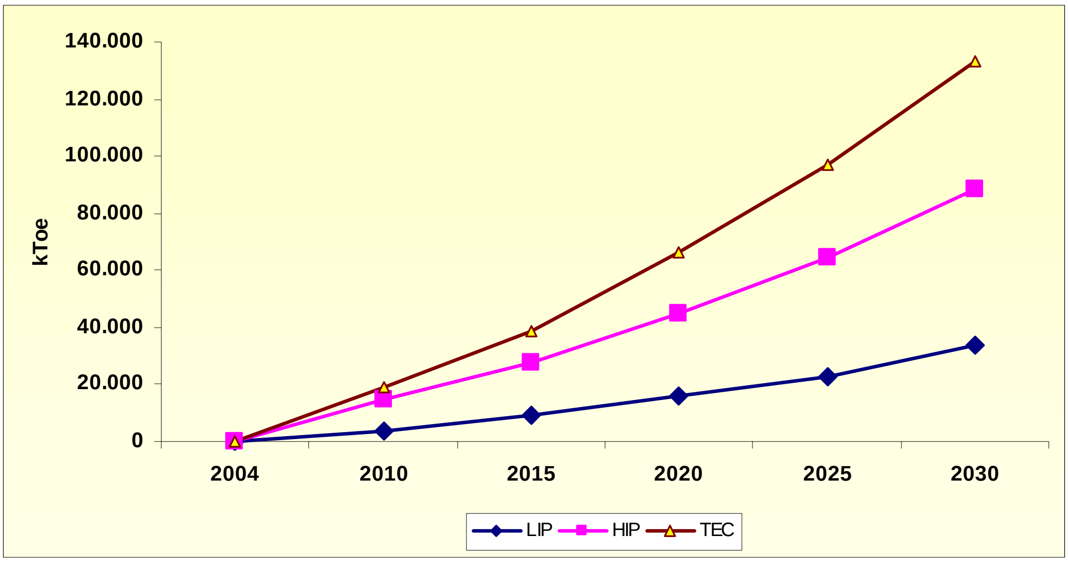


Figure 7-23: **Split of the savings between the useful and final energy, LPI scenario – EU27**

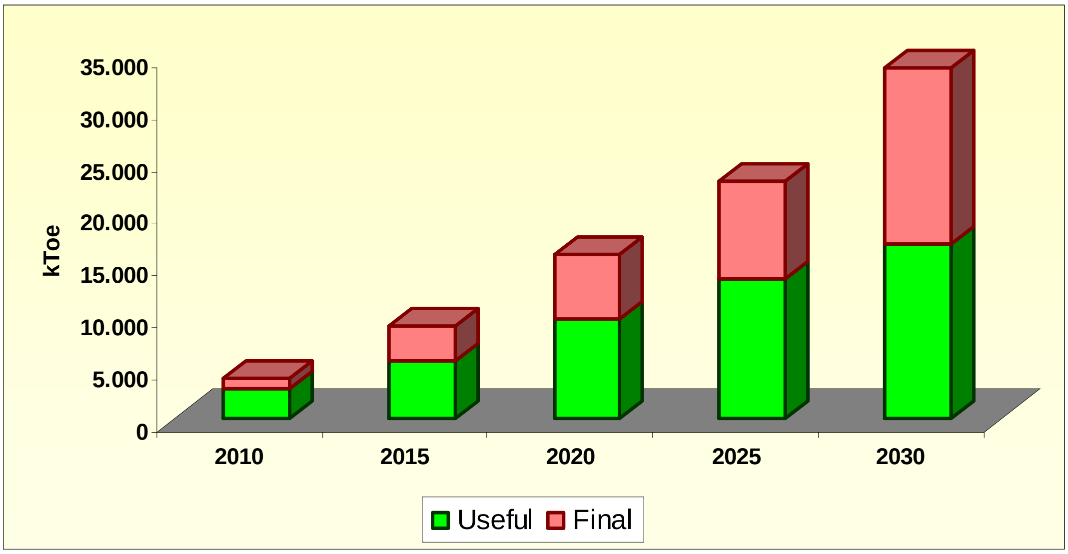


Figure 7-24: **Split of the savings between the useful and final energy, HPI scenario – EU27**

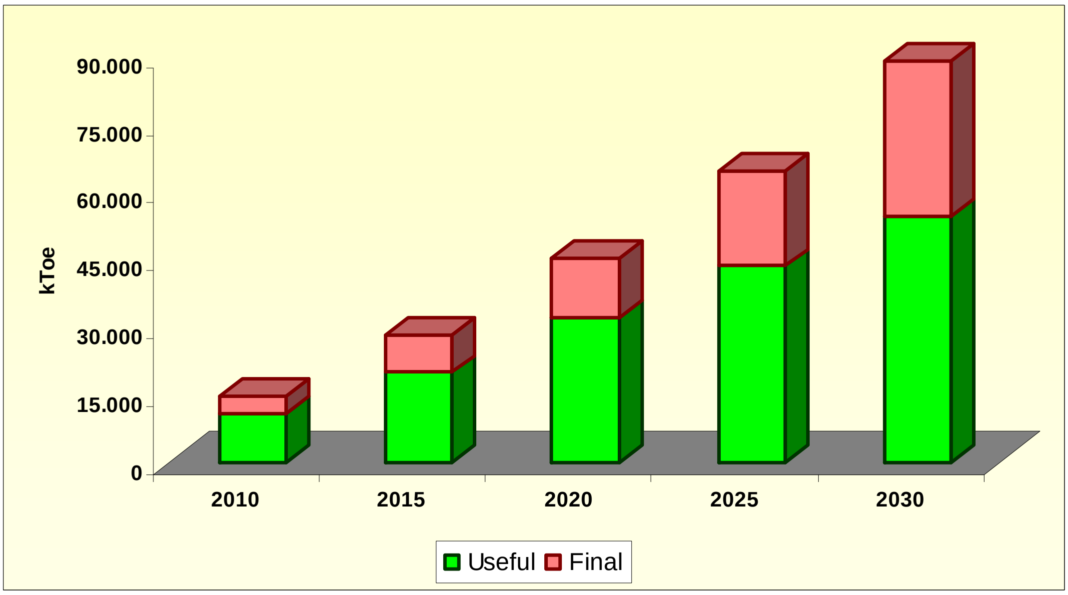


Figure 7-25: Split of the savings between the useful and final energy, Technical scenario – EU27

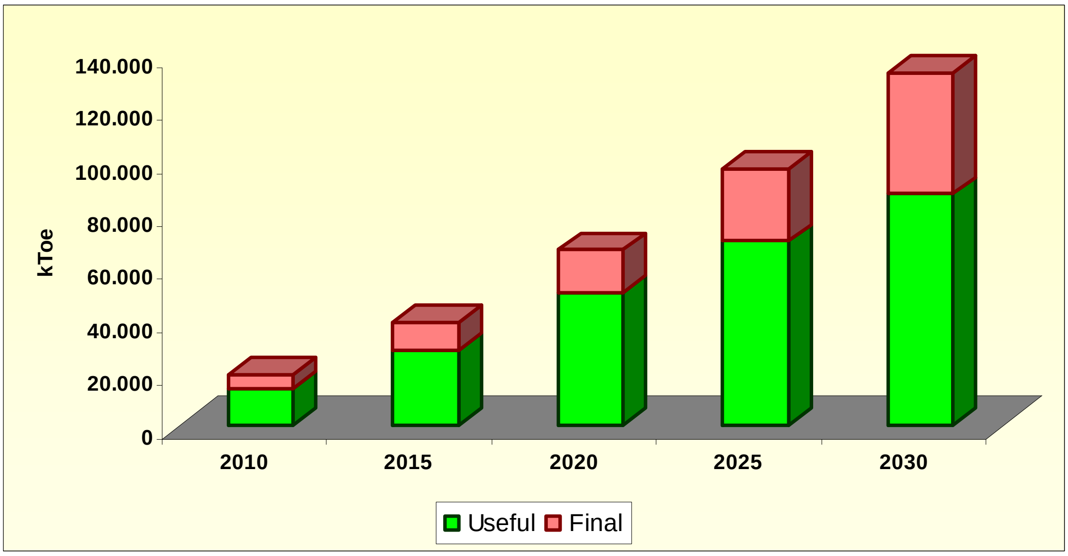


Table 7-40: Energy efficiency breakdown by scenario and useful/final energy consumption (EU27 – ktoe)

LPI-S	2010	2015	2020	2025	2030
Useful energy	2.857	5.517	9.660	13.423	16.778
Final energy	1.039	3.476	6.160	9.472	17.067
Total	3.896	8.993	15.820	22.895	33.845
HPI-S					
Useful energy	10.742	19.743	31.990	43.285	54.192
Final energy	3.783	8.180	12.904	21.077	34.380
Total	14.526	27.923	44.895	64.361	88.571
Technical Scenario					
Useful energy	13.990	28.728	50.270	69.720	87.388
Final energy	5.071	10.070	16.177	27.115	45.740
Total	19.061	38.798	66.447	96.835	133.128

7.4.3 Results sanitary hot water

Figure 7-26 and Table 7-41 show the EE potentials obtainable from the SHW systems. The high potential achieved in the technical scenario shows the maximum savings obtainable in this sector when the sanitary hot water demand is satisfied by the heat pumps + solar heaters systems. The share of the EE improvement provided by the thermal (mainly gas boilers + solar systems) and the electric (electric water heaters + heat pumps) devices separately, is the following:

- ➢ LPI scenario: thermal / electric = 30% / 70% (still little penetration of solar systems and high share of efficient electric water heaters)
- ➢ HPI scenario thermal / electric 50% / 50% (the solar systems penetration is equivalent to the heat pumps one, still high share of gas boilers)
- ➢ Technical scenario: thermal / electric = 70% / 30% (prevalence of solar systems)

Finally Figure 7-27 and Table 7-42 show the final energy consumption trends of the SHW systems by scenario. In practice with respect the starting energy consumption value (0.12 toe/dw) and thank to the penetration of the solar heaters and the heat pump devices, the unitary consumption is halved in the HPI scenario and reduced of two third in the technical one.

Figure 7-26: Energy Efficiency Potential from the SHW systems – EU27

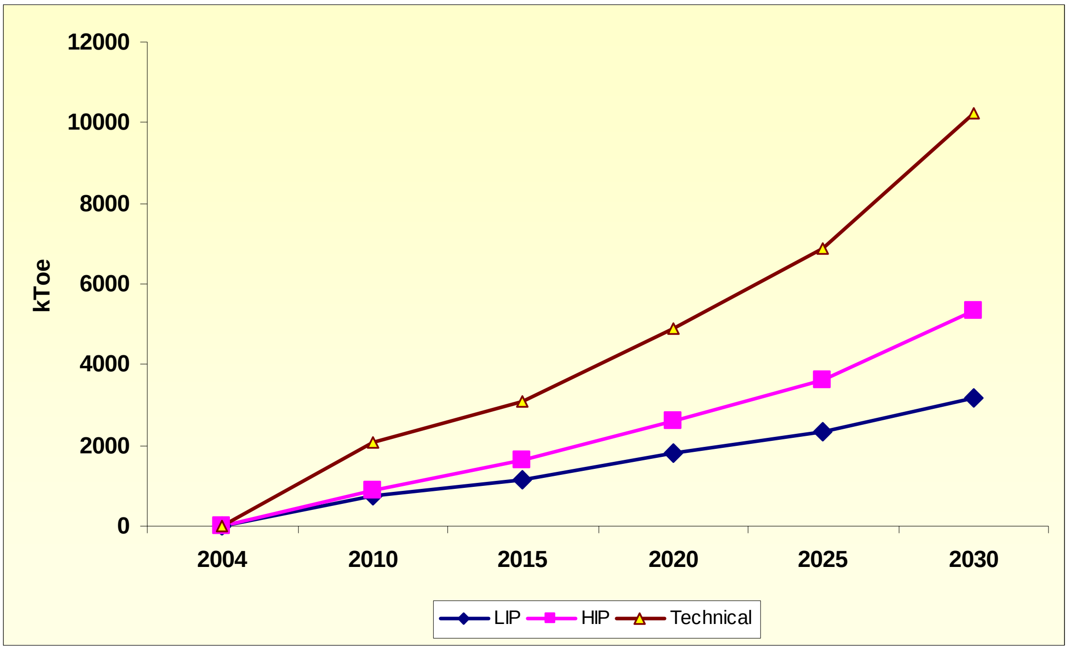


Table 7-41: Efficiency Energy Potential from the SHW systems (EU27, ktoe)

ktoe	2010	2015	2020	2025	2030
LPI-S	745	1.156	1.798	2.356	3.180
HPI-S	872	1.618	2.609	3.621	5.336
Technical Scenario	2.073	3.110	4.911	6.889	10.220

Figure 7-27: Final Energy Consumption trend by scenario of the SHW systems (EU27 – toe/dw) (EU27 toe/dw)

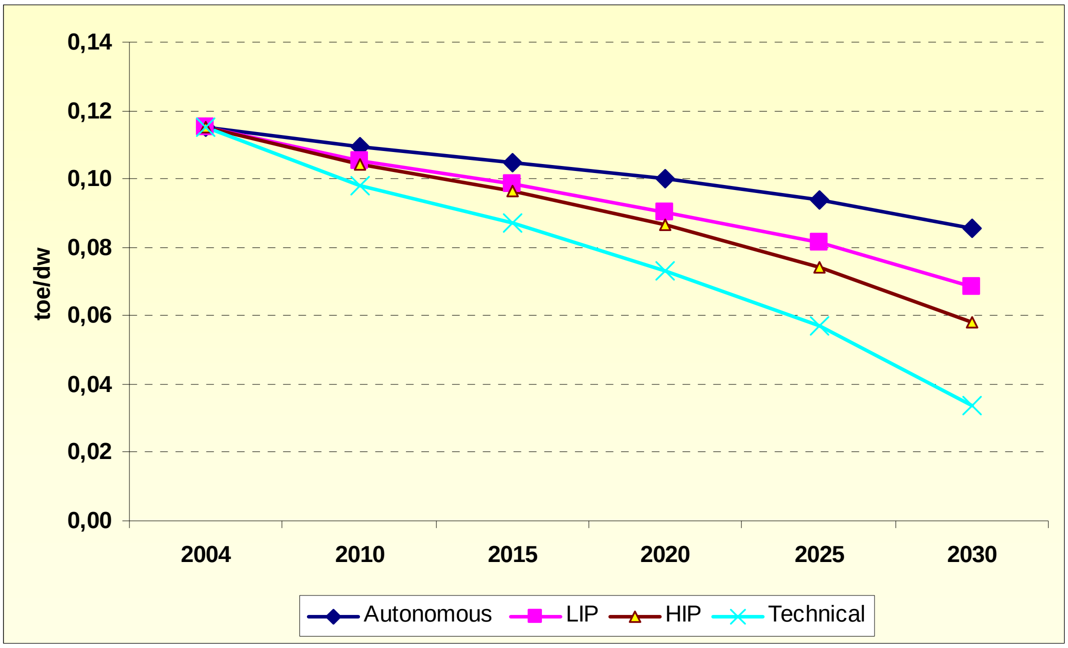


Table 7-42: Final Energy Consumption trend by scenario of the SHW systems (EU27 – toe/dw) (EU27 toe/dw)

	2004	2010	2015	2020	2025	2030
Autonomous Progress Scenario	0.12	0.11	0.10	0.10	0.09	0.09
LPI-S	0.12	0.11	0.10	0.09	0.08	0.07
HPI-S	0.12	0.10	0.10	0.09	0.07	0.06
Technical Scenario	0.12	0.10	0.09	0.07	0.06	0.03

7.4.4 Results overall residential sector (including electricity)

Figure 7-28 and Table 7-43 show the overall energy consumption trend (toe/dw) by scenario for the residential sector. In 2030, the achievable reduction of the total unitary consumption of the residential sector is:

- 41 % in the LPI Scenario;
- 57 % in the HPI Scenario
- and 73 % in the Technical Scenario.

Figure 7-29 and Table 7-44 show the overall EE Potential obtainable in this sector for all the 27 EU countries. In the LPI Scenario the savings arrive to 43 Mtoe (by

2030), corresponding to a relative savings with respect the Autonomous Progress Scenario of 17.5 %. In the HPI Scenario the savings are of 104.8 Mtoe (42.3 % compared to the APS) and in the Technical Scenario of 163.4 Mtoe (66 %).

Figure 7-28: Residential sector: Overall final energy consumption trend by scenario – EU27 toe/dw

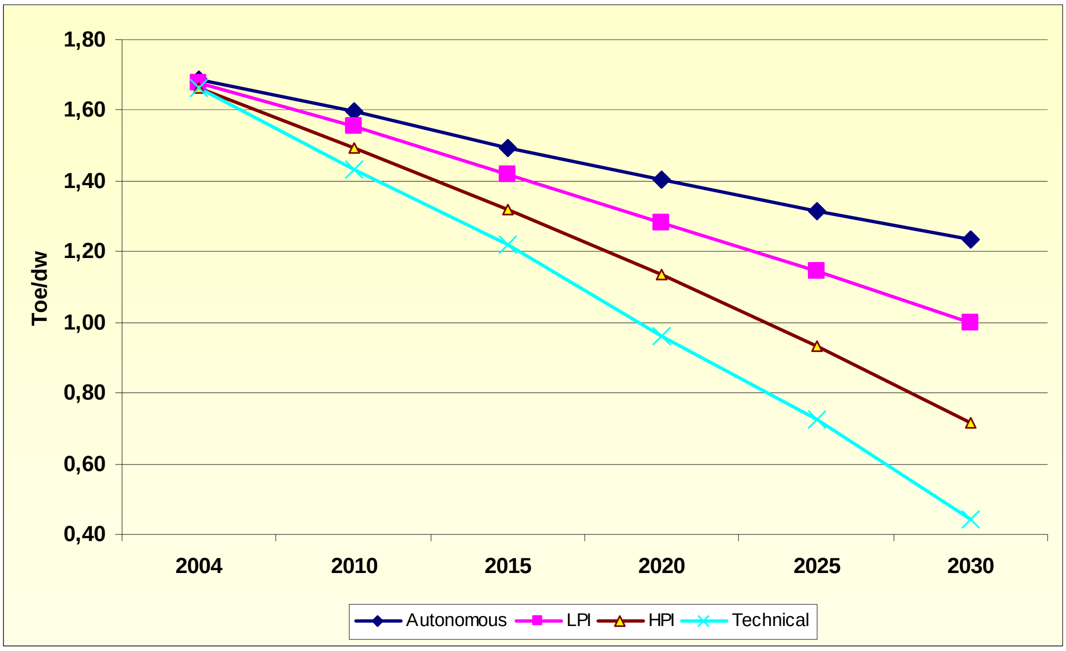


Table 7-43: Residential sector: Overall final energy consumption trend by scenario – EU27 toe/dw

Toe/dw	**2004**	**2010**	**2015**	**2020**	**2025**	**2030**
APS	1.68	1.60	1.49	1.40	1.31	1.23
LPI-S	1.68	1.56	1.42	1.28	1.14	1.00
HPI-S	1.66	1.49	1.32	1.13	0.93	0.71
Technical Scenario	1.66	1.43	1.22	0.96	0.72	0.44

Figure 7-29: Residential Sector: Overall Energy Efficiency Potential– EU27

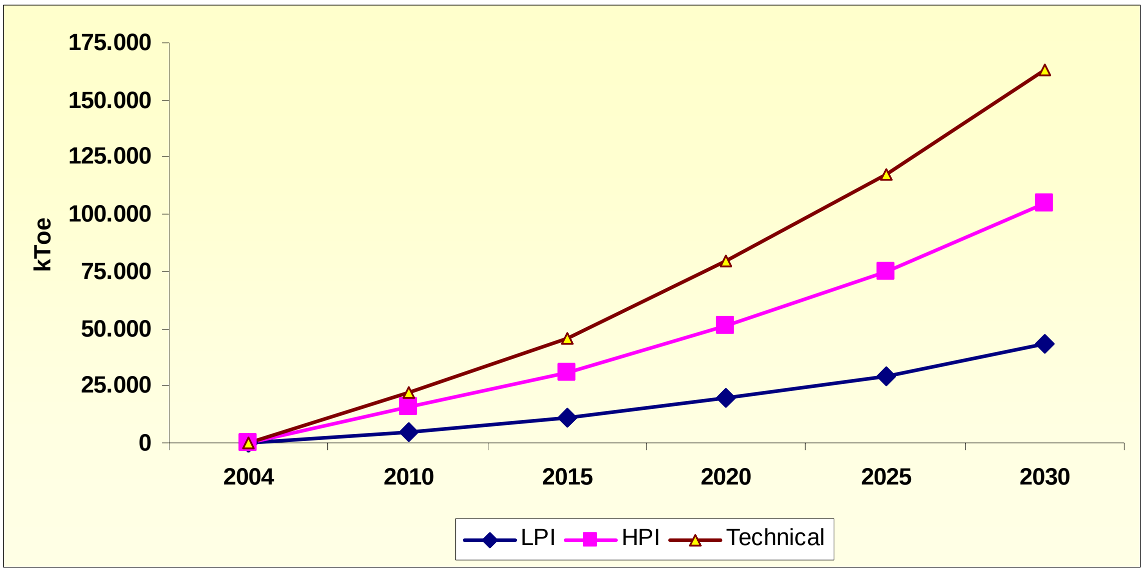


Table 7-44: Residential Sector: Overall Energy Efficiency Potential– EU27

		2010	2015	2020	2025	2030
LPI-S	**ktoe**	4,854	10,990	19,788	29,238	43,256
HPI-S		15,827	31,109	51,178	74,654	104,862
Technical Scenario		21,934	45,472	79,513	117,811	163,457
		2010	**2015**	**2020**	**2025**	**2030**
LPI-S	**%**	1.6%	3.8%	7.2%	11.2%	17.5%
HPI-S		5.2%	10.7%	18.6%	28.7%	42.3%
Technical Scenario		7.2%	15.7%	28.9%	45.3%	66.0%

Table 7-45 (ktoe) and Table 7-46 (%) show the break down of the total savings by the main final end uses considered in this study for the residential sector: heating, sanitary hot water and appliances plus lighting. The main contribution to the total savings is obviously provided by the heating subsector (building insulation + heating systems). The SHW contribution generally decreases in all the scenarios while the share of the savings provided by the appliances & lighting uses increase steadily in all the scenario steps of up to triple their contribution in the year 2030.

Table 7-47 and Table 7-48 (%) provide the total savings break down by the thermal (fossil fuels and solar systems) and electricity uses. Consistently with the break down by end uses above outlined, the thermal uses provide the major contribution to the overall savings. This contribution increases along the scenario steps reaching 90 % by 2030 (HPI and Technical Scenarios).

Table 7-45: Residential sector – Break down of the overall EE potential by the main final end uses and by scenario (EU27 – ktoe)

LPI-S	**2010**	**2015**	**2020**	**2025**	**2030**
Heating	3,896	8,993	15,820	22,895	33,845
SHW	745	1,156	1,798	2,356	3,180
Appliances and lighting	213	841	2,170	3,988	6,232
HPI-S	**2010**	**2015**	**2020**	**2025**	**2030**
Heating	14,526	27,923	44,895	64,361	88,571
SHW	872	1,618	2,609	3,621	5,336
Appliances and lighting	430	1,568	3,673	6,672	10,954
Technical Scenario	**2010**	**2015**	**2020**	**2025**	**2030**
Heating	19,061	38,798	66,447	96,835	133,128
SHW	2,073	3,110	4,911	6,889	10,220
Appliances and lighting	800	3,564	8,155	14,087	20,109

Table 7-46: Residential sector – Break down of the overall EE potential by the main final end uses and by scenario (EU27 – %)

LPI-S	**2010**	**2015**	**2020**	**2025**	**2030**
Heating	80.3%	81.8%	79.9%	78.3%	78.2%
SHW	15.3%	10.5%	9.1%	8.1%	7.4%
Appliances and lighting	4%	8%	11%	14%	14%
HPI-S	**2010**	**2015**	**2020**	**2025**	**2030**
Heating	91.8%	89.8%	87.7%	86.2%	84.5%
SHW	5.5%	5.2%	5.1%	4.9%	5.1%
Appliances and lighting	2.7%	5.0%	7.2%	8.9%	10.4%
Technical Scenario	**2010**	**2015**	**2020**	**2025**	**2030**
Heating	86.9%	85.3%	83.6%	82.2%	81.4%
SHW	9.5%	6.8%	6.2%	5.8%	6.3%
Appliances and lighting	3.6%	7.8%	10.3%	12.0%	12.3%

Table 7-47: Residential sector – Break down of the overall EE potential by thermal and electricity uses and by scenario (EU27 – ktoe)

LPI-S	**2010**	**2015**	**2020**	**2025**	**2030**
Thermal	3.438	8.615	15.648	23.227	36.064
Electricity	1.416	2.376	4.140	6.012	7.192
HPI-S	**2010**	**2015**	**2020**	**2025**	**2030**
Thermal	12.621	26.249	44.424	64.902	94.304
Electricity	3.206	4.860	6.753	9.753	10.558
Technical Scenario	**2010**	**2015**	**2020**	**2025**	**2030**
Thermal	17.518	37.658	67.775	101.572	147.303
Electricity	4.416	7.815	11.738	16.239	16.154

Table 7-48: Residential sector – Break down of the overall EE potential by thermal and electricity uses and by scenario (EU27 – %)

LPI-S	**2010**	**2015**	**2020**	**2025**	**2030**
Thermal	70,8%	78,4%	79,1%	79,4%	83,4%
Electricity	29,2%	21,6%	20,9%	20,6%	16,6%
HPI-S	**2010**	**2015**	**2020**	**2025**	**2030**
Thermal	79,7%	84,4%	86,8%	86,9%	89,9%
Electricity	20,3%	15,6%	13,2%	13,1%	10,1%
Technical Scenario	**2010**	**2015**	**2020**	**2025**	**2030**
Thermal	79,9%	82,8%	85,2%	86,2%	90,1%
Electricity	20,1%	17,2%	14,8%	13,8%	9,9%

8 Energy efficiency potentials in the transport sector

This section investigates energy efficiency potentials from three different types of options:

- Potentials from technical measures to improve energy efficiency from passenger and goods transport
- Potentials from the modal shift towards public transport means for both passenger and goods transport
- Potentials from behavioral measures (such as eco-driving) for cars and for road goods transport

8.1 Energy efficiency potentials from technical measures

8.1.1 Description of the sector/end-use

The first type of potentials considered within the transport sector concerns technical interventions. After having analysed the technical measures identified by the European Commission[28] the conclusions have been that the technical interventions with the largest impact on energy saving potentials are the ones regarding the reduction of transport fuel consumption. In particular, with respect to cars the simulation of energy efficiency potentials carried out here with the MURE simulation model are derived from the new car efficiency standards based on the decrease in CO_2 emissions, while the potentials arising from the technical improvement of trucks and trailers engines have been calculated starting from the hypothesis of a specific consumption decrease up to 2030.

8.1.2 Sector-specific / use-specific data sources and modelling issues

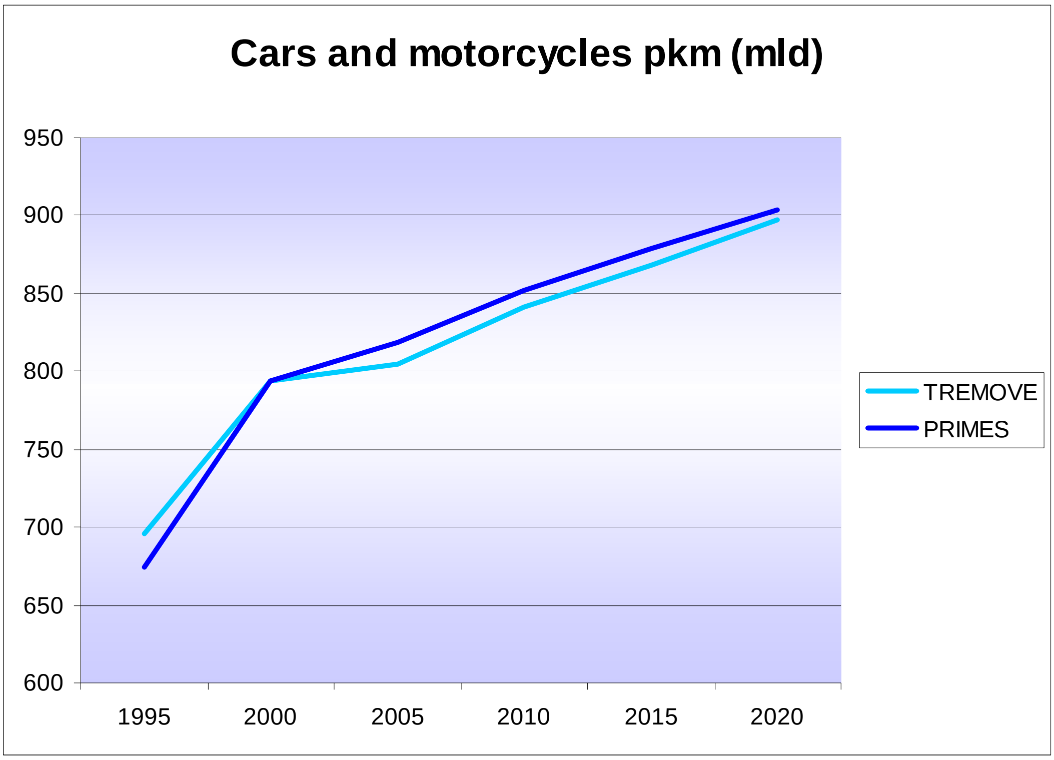
In the first phase of the work we analysed the available data sources and their consistency with the PRIMES baseline scenario data. After a probing comparison between different data sources, data from the TREMOVE model have been chosen as the source from which all data needed to fill up the transport section of the database, were taken. This is due to the fact that the energy drivers considered by this model are taken from PRIMES. Figure 8-1 shows the consistency of this assumption for cars and motorcycles traffic, one important driver for the transport sector.

Therefore, all data relevant for the "Autonomous Progress Scenario" were provided by TREMOVE.

---

[28] See paragraph 8.1.3

Figure 8-1: Consistency of PRIMES and TREMOVE cars and motorcycles passenger-km trends



BOX 8-1: THE TREMOVE TRANSPORT DATABASE

TREMOVE is a transport and emissions simulation model developed for the European Commission in the context of the Mid-term Assessment of the White Paper on European Transport Policies for 2010[29]. The baseline transport volumes have been extracted from the SCENES transport model and harmonised with national statistics. TREMOVE models both passenger and freight transport in the EU15 region plus Switzerland, Norway, Czech Republic, Hungary, Poland and Slovenia. The basic assumptions taken within this transport model are as follows:

- macro-economic figures are from DG TREN “Transport and Figures”, 2005[30]
- the demographic development is from DG TREN and EUROSTAT
- specific consumptions and emissions are drawn from European standards and voluntary agreements between the EC and ACEA

---

29 http://ec.europa.eu/transport/white_paper/documents/doc/lb_texte_complet_en.pdf - „European Transport Policy for 2010: time to decide”

30 „European Energy and Transport – Trends to 2030, update 2005“ - Directorate-General for Energy and Transport

- policies and measures included are either planned or already implemented before 2010 by the EC or the member states

The version 2.4.4 – the one taken into account - of the TREMOVE transport database distinguishes three types of areas: Metropolitan city area (identifies the capital of the country), other cities (other urban areas), non urban areas.

For all EU Countries (EU21), SCENES and NUTS2003 GIS programmes are used that allow to define the geographic areas and to characterize them according to:

- the number of inhabitants
- the distribution of the population in the territory
- the topographic map
- the geographic border of the urban areas
- the various ways of transport for each type of vehicle

Table 77: Urban and metropolitan definition by country

Country	Metropolitan area	Urban settlement size threshold	Number of settlements
Austria	Vienna	50000	13
Belgium	Brussels	75000	16 (Brussels communities counted as 1)
Czech Republic	Prague	50000	22
Denmark	Copenhagen	50000	7
Finland	Helsinki	50000	12
France	Paris	50000	111
Germany	Berlin	50000	148
Greece	Athens	50000	14
Hungary	Budapest	75000	11
Ireland	Dublin	75000	3
Italy	Rome	50000	38
Luxembourg	*none*	Luxembourg	1
The Netherlands	Randstad	100000	23
Norway	Oslo	50000	n/a (aggregate total)
Poland	Warsaw	250000	13 (urban aggregates)
Portugal	Lisbon	50000	6 (Lisbon counted once but assigned to multiple micro-zones)
Slovenia	*none*	Ljubljana	1
Spain	Madrid	250000	20
Sweden	Stockholm	75000	19
Switzerland	Zürich	50000	12
United Kingdom	London	100000	70

Moreover TREMOVE distinguishes the following modes of transport: urban road, non urban road, motorways, rail, air, waterways

From the elaboration of TREMOVE data, the evolution of the detailed vehicle fleet, the related number of vehicle-km and the specific energy consumption split by size and by fuel have been estimated based on three major elements:

1. the historical vehicle fleet
2. the growth of transport volumes
3. the characteristics of the available vehicle types and technologies on the market (e.g. vehicle size, fuel type, annual mileage)

All these data have been inserted into the MURE Transport tool in order to set up the Autonomous Progress Scenario trend. The table below (Table 8-1) shows the break down by mode used by the MURE tool for the different modes (road, rail, inland waterways and air).

Table 8-1: Overview of the MURE mode break down structure

	Vehicle Category	*Units*
Road Transport		
	Small car	vehicles
	Large/Medium car	vehicles
	Light Duty Vehicles	vehicles
	Heavy Duty Vehicles	vehicles
	Bus	vehicles
	Coach	vehicles
Rail Transport		
	Metro/Tram	vkm
	Passenger train	vehicles
	Freight train	vehicles
Inland waterways Transport		
	Inland ship	vkm
Air Transport		
	Airplane	pkm

The figures below show the trends (baseline or autonomous progress) of some exogenous figures for a sample of European countries, obtained by filling up the MURE transport database with the TREMOVE data. In particular the first one illustrates the trend of the specific consumption of the stock of gasoline cars, while the second projects the specific consumption of the Diesel stock, both from the year 2005 to the year 2030.

Figure 8-2: Average specific consumption trend of the gasoline car stock (Autonomous Progress Scenario)

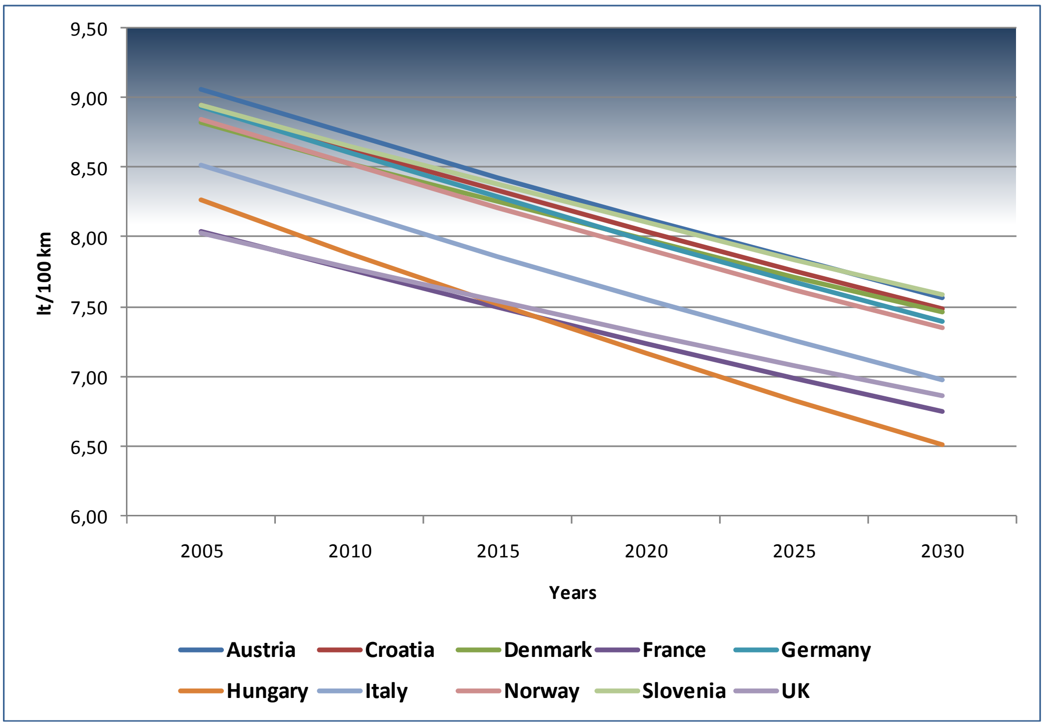
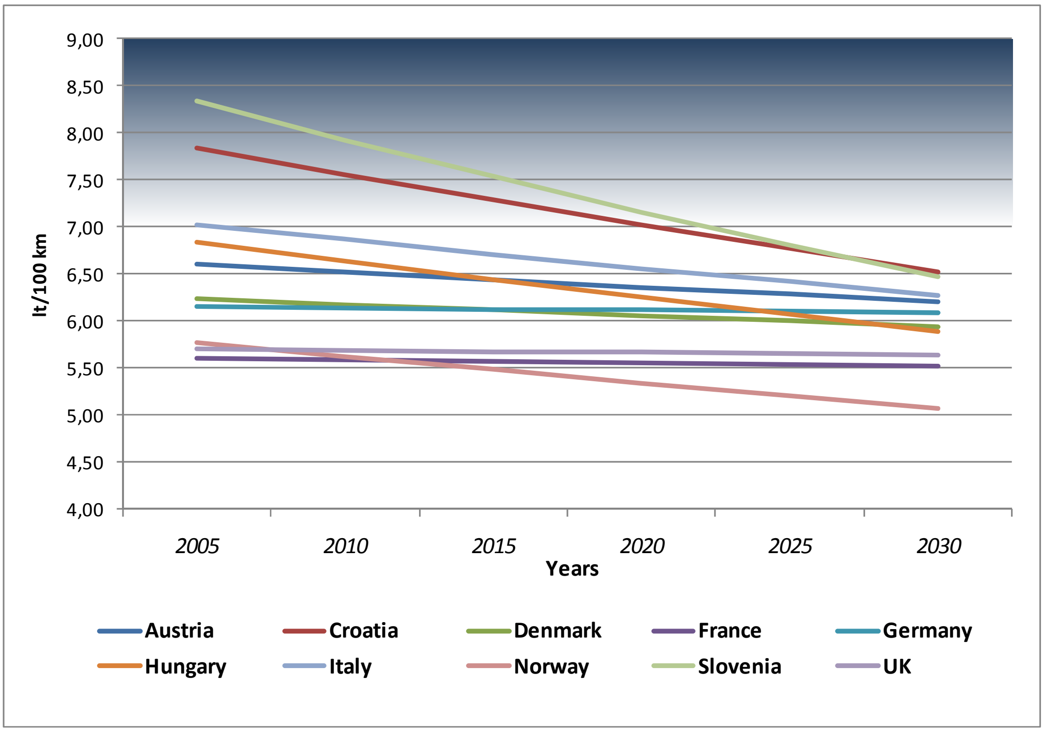


Figure 8-3: Average specific consumption trend of the Diesel car stock (Autonomous Progress Scenario)



It is important to note that the different values characterizing each country are due to the different split by size and the corresponding trends up to 2030 considered by the TREMOVE model and consequently taken up for the Autonomous Progress Scenario by the MURE Transport tool (see Table 8-2).

Table 8-2: Share of car size over time

		2005	2010	2015	2020	2025	2030
Austria	Small	24.92%	21.66%	20.77%	20.17%	19.33%	18.40%
	Medium	62.44%	64.55%	64.54%	64.59%	64.66%	64.65%
	Large	12.64%	13.80%	14.69%	15.24%	16.01%	16.96%
Belgium	Small	30.08%	27.67%	27.07%	26.62%	25.88%	24.95%
	Medium	59.30%	61.50%	61.88%	61.96%	62.19%	62.48%
	Large	10.61%	10.84%	11.05%	11.41%	11.93%	12.57%
Bulgaria	Small	46.52%	44.47%	43.80%	43.37%	43.19%	42.97%
	Medium	48.30%	50.45%	51.18%	51.48%	51.63%	51.82%
	Large	5.18%	5.08%	5.02%	5.15%	5.18%	5.21%
Croatia	Small	54.68%	55.52%	54.55%	53.39%	52.72%	51.85%
	Medium	39.96%	39.47%	40.32%	41.09%	41.55%	42.15%
	Large	5.35%	5.01%	5.13%	5.52%	5.73%	6.00%
Cyprus	Small	35.41%	35.88%	36.31%	36.71%	36.94%	36.86%
	Medium	53.46%	53.11%	52.69%	52.29%	52.02%	51.98%
	Large	11.13%	11.02%	11.00%	11.00%	11.04%	11.16%
Czech Repub-lic	Small	52.95%	51.81%	52.02%	51.93%	51.66%	51.42%
	Medium	41.67%	43.17%	43.07%	43.16%	43.36%	43.56%
	Large	5.38%	5.02%	4.91%	4.91%	4.98%	5.02%
Denmark	Small	38.94%	31.94%	28.66%	28.11%	27.12%	25.70%
	Medium	55.20%	62.28%	65.36%	65.63%	66.23%	67.04%
	Large	5.86%	5.79%	5.99%	6.26%	6.65%	7.26%
Estonia	Small	25.11%	25.25%	25.21%	25.02%	24.82%	24.63%
	Medium	59.21%	59.14%	59.07%	59.02%	59.10%	59.24%
	Large	15.69%	15.61%	15.72%	15.96%	16.08%	16.14%
Finland	Small	35.42%	27.18%	20.88%	20.04%	19.43%	18.58%
	Medium	55.09%	62.44%	67.71%	67.97%	68.11%	68.24%
	Large	9.49%	10.38%	11.41%	11.99%	12.46%	13.18%
France	Small	31.58%	28.45%	27.35%	26.73%	25.92%	24.97%
	Medium	58.50%	61.12%	61.67%	61.81%	62.09%	62.41%
	Large	9.91%	10.44%	10.98%	11.47%	11.99%	12.62%
Germany	Small	28.42%	26.96%	25.85%	24.87%	23.87%	22.76%
	Medium	53.72%	53.57%	53.24%	52.98%	52.84%	52.70%
	Large	17.87%	19.47%	20.91%	22.15%	23.29%	24.53%
Greece	Small	76.91%	75.27%	72.70%	70.25%	68.38%	67.33%
	Medium	21.13%	22.88%	25.58%	28.14%	30.04%	31.03%
	Large	1.97%	1.85%	1.72%	1.62%	1.58%	1.64%
Hungary	Small	64.92%	67.32%	68.63%	68.74%	68.48%	68.24%
	Medium	31.63%	29.76%	28.81%	28.72%	28.94%	29.15%
	Large	3.45%	2.91%	2.57%	2.55%	2.58%	2.61%
Ireland	Small	59.47%	54.26%	49.68%	46.79%	45.10%	43.78%
	Medium	35.95%	40.80%	44.78%	47.16%	48.43%	49.34%
	Large	4.57%	4.95%	5.53%	6.06%	6.47%	6.88%
Italy	Small	57.83%	53.80%	51.34%	50.03%	49.26%	48.54%
	Medium	35.30%	37.93%	39.20%	39.60%	39.78%	40.07%
	Large	6.87%	8.27%	9.46%	10.37%	10.96%	11.39%
Latvia	Small	25.19%	25.24%	25.22%	10.37%	41.84%	53.32%
	Medium	59.29%	59.24%	59.02%	0.50%	98.61%	126.89%
	Large	15.52%	15.52%	15.76%	1.17%	27.32%	35.21%

		2005	2010	2015	2020	2025	2030
Lithuania	Small	25.32%	25.37%	25.30%	25.04%	24.87%	24.71%
	Medium	59.30%	59.26%	59.17%	59.09%	59.15%	59.26%
	Large	15.38%	15.37%	15.53%	15.87%	15.98%	16.03%
Luxembourg	Small	17.53%	20.66%	20.45%	18.79%	17.03%	15.22%
	Medium	61.11%	60.85%	60.80%	60.51%	59.98%	58.96%
	Large	21.36%	18.50%	18.76%	20.69%	22.99%	25.82%
Malta	Small	63.74%	63.13%	62.55%	61.93%	61.29%	60.60%
	Medium	32.86%	33.52%	34.08%	34.64%	35.17%	35.72%
	Large	3.41%	3.35%	3.36%	3.43%	3.54%	3.68%
Poland	Small	52.27%	52.88%	54.01%	53.80%	53.50%	53.26%
	Medium	43.34%	42.87%	41.81%	41.95%	42.22%	42.44%
	Large	4.39%	4.24%	4.18%	4.24%	4.28%	4.30%
Portugal	Small	59.82%	58.77%	55.18%	53.68%	53.38%	52.96%
	Medium	32.70%	32.67%	33.97%	34.35%	34.48%	34.72%
	Large	7.48%	8.55%	10.85%	11.97%	12.14%	12.32%
Romania	Small	47.26%	44.86%	44.12%	43.70%	43.52%	43.29%
	Medium	47.62%	50.17%	51.01%	51.32%	51.46%	51.67%
	Large	5.12%	4.96%	4.87%	4.98%	5.01%	5.04%
Slovak Re-public	Small	55.89%	54.23%	53.92%	53.71%	53.46%	53.16%
	Medium	41.75%	43.13%	43.25%	43.38%	43.60%	43.87%
	Large	2.36%	2.64%	2.83%	2.91%	2.94%	2.97%
Slovenia	Small	57.10%	55.86%	56.44%	56.05%	55.23%	54.27%
	Medium	39.71%	40.94%	40.32%	40.57%	41.22%	41.98%
	Large	3.20%	3.20%	3.24%	3.38%	3.55%	3.75%
Spain	Small	33.51%	27.38%	23.79%	22.30%	21.77%	21.36%
	Medium	58.23%	65.06%	69.02%	70.61%	71.11%	71.39%
	Large	8.26%	7.56%	7.19%	7.09%	7.13%	7.25%
Sweden	Small	22.07%	16.92%	14.40%	14.41%	13.93%	13.04%
	Medium	55.70%	56.80%	56.46%	55.23%	54.33%	53.53%
	Large	22.23%	26.28%	29.14%	30.36%	31.74%	33.44%
The Nether-lands	Small	36.37%	33.04%	32.75%	32.14%	31.09%	29.91%
	Medium	55.56%	58.63%	58.68%	59.10%	59.70%	60.33%
	Large	8.08%	8.32%	8.57%	8.76%	9.21%	9.76%
United King-dom	Small	36.09%	36.43%	37.02%	36.96%	36.30%	35.40%
	Medium	52.15%	51.94%	51.34%	51.23%	51.54%	51.96%
	Large	11.76%	11.63%	11.64%	11.81%	12.16%	12.64%
Norway	Small	30.53%	29.83%	30.07%	30.67%	30.15%	28.73%
	Medium	60.78%	63.04%	63.26%	62.25%	62.43%	63.18%
	Large	8.69%	7.13%	6.67%	7.08%	7.42%	8.09%

8.1.3 Step 1 – Definition of energy saving options

The first step in defining which of the technical interventions would have to be simulated was to analyze the technical measures identified by the European Commission[31] and particularly:

- ➢ The technical options to reduce fuel consumption at the vehicle level

---

[31] Taken from *"Review and analysis of the reduction potential and costs of technological and other measures to reduce CO2-emissions from passenger cars"* – Final Report, TNO Science and Industry, IEEP (Industry for European Environmental Policy) and LAT (Laboratory for Applied Thermodynamics), 2006.

- The application of fuel efficient air conditioning systems
- The options to reduce vehicle and engine resistance factors
- The options for the application of alternative fuels based on fossil energy
- The increased application of biofuels
- The possibilities to include N1[32] vehicles (Light Duty Vehicles) into the Commitments

The conclusions of the analysis have been that the technical interventions with the largest impact on energy potential savings are the ones regarding the fuel consumption reduction. Concerning cars the simulation of energy efficiency potentials carried out here with the MURE simulation model are based on new car efficiency standards derived from the decrease in CO_2 emissions, while the potentials arising from the technical improvement of trucks and trailers engines have been calculated starting from the hypothesis of a specific consumption decrease up to 2030.

8.1.4 Step 2 – Technology costs

Assumption on technology costs for cars are based on TNO (2006).

8.1.5 Step 3 – Definition of the four scenarios

Passenger Cars

As said before, the baseline provided by the TREMOVE database corresponds to the ESD ***Autonomous Progress Scenario***. The basic assumptions considered within this transport model are as specified in Box 8-1. However, due to the fact that the baseline scenario would then include already the success of the presently planned CO_2 policies for cars up to 2012/15, it was decided to establish the Autonomous Progress Scenario based on the penetration of the current new cars which gives already quite some improvement in the stock. In addition, new cars in this scenario initially improve at a similar rate as in the period 1996-2006 (around 1%/year) which drops later on to 0.5% improvement per year, considering the without additional efforts the more easily available potentials will be exhausted. In addition to this a ***scenario "Autonomous progress + Recent Policies" (APS+RP)*** was introduced which includes the assumption that the CO_2 policies for cars as currently decided, will be successful. In this scenario the new car fleet would reach a value of 130g CO_2/km in 2012/15 (see the notes to Table 8-3). The potentials are all measured against the first scenario.

---

32 "Vehicles of category N1" is defined by Annex II to the Framework Directive as goods vehicles with a maximum mass not exceeding 3.5 tonnes. OJ No. L42, 23.2.1970, as last amended by Directive 2006/40/EC of the European Parliament and of the Council dated 17th May 2006, OJ No. .L161, 14.06.2006

The ***Economic Potential-Low Policy Intensity*** (LPI) and the ***Economic Potential-High Policy Intensity*** (HPI) scenarios represent an additional economic saving potential with different CO_2 emissions targets up to 2030 (see Table 8-3), whereas the fourth scenario, the ***Technical Potential***, presents the maximum target technically achievable regardless of cost-effectiveness but nevertheless including essentially near economic potentials. Based on the development of energy consumption in these four scenarios (plus the APS+RP Scenario), we calculate saving potentials that represent the difference of energy demand in each scenario to the energy demand in the Autonomous Progress Scenario.

Taking into account the new efficiency of cars related to CO_2 emission reduction, the differentiation of the scenarios is done in the following way.

- First of all it was assumed that the specific consumption of new cars, as the main driver, will be the same for all countries in 2030, while drivers like the yearly pkm and tkm, the share of small, medium and big cars and the fuel split trend - for each specific country - will be the same for all scenarios.
- Then different CO_2 emission developments per kilometer have been established as shown in Table 8-3.

Table 8-3: Scenario hypothesis for new cars

SCENARIO	HYPOTHESIS
Autonomous Progress Scenario (APS)	165g CO_2/km decreasing first at an average rate of 1%/year observed in 1996-2006 then declining to 0.5% annually up to 2030 [33]
APS + recent CO_2 policies for cars (APS + RP)	130g CO_2/km in 2012/15 [34] (value constant after 2015 up to 2030)
Economic Potential – LPI	125g CO_2/km in 2015 [35] (value constant after 2015 up to 2030)
Economic Potential – HPI	95g CO_2/km in 2020 [36] (125g CO_2/km in 2012, 95g CO_2/km in 2020; value constant after 2020 up to 2030)
Technical Potential	80g CO_2/km in 2025 [37] (125g CO_2/km in 2012, 95g CO_2/km in 2020; 80g CO_2/km in 2025; value constant after 2025 up to 2030)

---

33 The assumption of decreasing changes for new cars in the baseline may still considered as optimistic in that improvements in car technology have been compensated in the past by the shift towards larger cars. In future, this trend may, however, be less important given the signal from the oil price market. For this reason the trend towards larger cars was considered relevant for the earlier periods up to 2020.

34 Value adopted by the European Commission. The value adopted is 120g CO_2/km for 2012. However, this value is to be reached by a combination of technical measures (which shall reach 130g CO_2/km) and the remainder through while complementary measures would contribute a further emissions cut of up to 10g/km, thus reducing overall emissions to 120g/km. These complementary measures include efficiency improvements for car components with the highest impact on fuel consumption, such as tyres and air conditioning systems, and a gradual reduction in the carbon content of road fuels, notably through greater use of biofuels. Efficiency requirements will be introduced for these car components. It can, however, be expected that the major additional impact will come from the addition of biofuels which is not considered here as being part of the energy efficiency potentials. The target was adopted for 2012 with penalties foreseen starting in 2012 and increasing up to 2015. In the present analysis it was assumed that for the “Autonomous Progress + Recent Policies” Scenario the target would only be reached in 2015, See: http://ec.europa.eu/environment/air/transport/co2/co2_home.htm

35 Target adopted by the European Parliament for 2015. In the present analysis it was assumed that for the Low Policy Intensity (LPI) Scenario the target would only be reached in 2015, while for the High Policy Intensity (HPI) Scenario and the Technical Scenario, it was assumed that the target would be replacing the 130 g CO2 target in 2012.

36 According to the EU Commission research efforts are sustained to reach a fleet average of 95 g CO_2/km in 2020 http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/07/597&format=HTML&aged=0&language=EN&guiLanguage=en

37 According to the European Parliament, long-term targets should be determined by no later than 2016: these targets “will possibly require further emissions reductions to 70g CO_2/km or less by 2025.” Nevertheless, it can be assumed that such a target may also require additional adding of biofuels. The ability to add further biofuels (at least the ones of first generation) is currently an issue of debate. This issue can, however, not further be debated here. Therefore 80g CO_2/km was chosen as the value for 2025. http://www.greencarcongress.com/2007/10/european-parlia.html

The LPI scenario is characterized by the target value of 125g of CO_2 per kilometer fixed by the European Parliament to be reached by 2015. After this point in time no further improvement is assumed.

The first step in setting the scenario was to take into account the combined fuel consumption[38] of new cars per each size and fuel type as shown in Table 8-4.

Table 8-4: Fuel consumption of reference models

Fuel Consumption of the Reference Model			
Fuel type	**Size**	**Reference model[39]**	**Specific combined consumption (lt/100km)**
Gasoline	Small	FIAT Grande Punto 1.2	6.1
	Medium	FORD Focus 1.6	6.6
	Large	AUDI A6 2.4	9.7
Diesel	Small	FIAT Grande Punto 1.3	4.7
	Medium	FORD Focus 1.6	4.5
	Large	AUDI A6 2.7	6.9

Starting from these values for each country we calculated the specific consumption of new cars by fuel weighting with the vehicle-km and secondly the specific consumption of new cars by fuel at European level.

The HPI has a more restrictive value of 95g of CO_2 per kilometer for the CO_2 emissions that has to be achieved by 2020. Finally the Technical Scenario has been defined by choosing the most ambitious target equal to 80g of CO_2 per kilometer up to 2025[40]. The value in 2020 is the same as for the HPI scenario. Therefore the difference between both scenarios is small up to 2020.

Then we have determined the differentiation of scenarios also in terms of specific consumption by fuel by considering the energy consumption corresponding to a certain CO_2 emission value as described in the table below. Starting from the values described in the second column of Table 8-5 we obtained the energy consumption for each scenario.

---

[38] The combined figure presented is for the urban and the extra-urban cycle together. It is therefore an average of the two other parts of the fuel consumption test, Urban and Extra-urban cycles, weighted by the distance covered in each part.

[39] "Quattroruote" Magazine, May 2008.

[40] These values have then been multiplied by a coefficient taking into account the difference between theoretical and real consumption of cars.

Table 8-5: Conversion from CO_2 emission targets to kWh/km for each scenario and each type of fuel

Energy consumption when emitting : →	APS 165 g CO_2/km kWh/km	APS+RP 130g CO_2/km kWh/km	LPI 125g CO_2/km kWh/km	HPI 95g CO_2/km kWh/km	TS 80g CO_2/km kWh/km
regular grade petrol	0.621	0.489	0.470	0.357	0.301
super petrol	0.632	0.498	0.479	0.364	0.306
Diesel fuel	0.618	0.487	0.468	0.356	0.300
natural gas	0.784	0.618	0.594	0.451	0.380
Abbreviations:	APS: Autonomous Progress Scenario, APS+RP: Autonomous Progress + Recent Policies, LPI: Low Policy Intensity Scenario, High-Policy Intensity Scenario, TS: Technical Scenario				

Source: EMEEES EU Project – Task 4.1 "Definition of the process to develop harmonized bottom-up evaluation methods"; own calculations

Starting from these values, we calculated the weighted average specific consumption data of the new cars for the reference year by considering the national cars registration data by size and fuel. The trend values by scenario have been then calculated in accordance with the scenario settings outlined in Table 8-3. The resulting average specific consumption figures of the new cars, corresponding to the four scenarios settings, are shown in Table 8-6. The legend below the table shows the years in which the market transformation starts.

Table 8-6: EU27 average specific consumption trends of new cars by scenario

Scenarios	2004	2010	2012	2015	2016	2020	2025	2030
Autonomous Progress Scenario	6.37	6.00	5.89	5.73	5.69	5.51	5.32	5.16
Autonomous Progress Scenario + Recent Policies	6.37	5.63	5.39	5.02	5.02	5.02	5.02	5.02
Low Policy Intensity Scenario	6.37	5.53	5.25	4.83	4.83	4.83	4.83	4.83
High Policy Intensity Scenario	6.37	5.38	4.83	4.56	4.47	3.67	3.67	3.67
Technical Scenario	6.37	5.31	4.83	4.43	4.29	3.67	3.09	3.09

Legend:

Linear trend

Start 125 g CO_2/km

Arrive to 95 g CO_2/km

Arrive to 80 g CO_2/km

Once set the new cars specific consumption trends by country they have been inserted in MURE for the stock energy consumption and energy efficiency potentials calculation. It is worth noting that a sort of rebound effect has been implicitly taken into account by envisaging an increase of the average car size (expressed in cubic centimetres) over time obtained from the TREMOVE model data (see Table 8-2). The split by fuel and the average yearly travelled km are on the contrary kept almost constant along the scenario steps.

It is finally worth signaling that:

- we assumed an average car life time of 13 years;
- in accordance with the TREMOVE database, the real-life energy consumption conditions imply an over consumption of approximately 20 % as compared to the theoretical performance of the new cars. This is compensated in the HPI Scenario and the Technical Scenario by behavioral changes.

Light duty vans

For light duty vans the scenario hypothesis are described in Table 8-7.

Table 8-7: Scenario hypothesis for light duty vans

SCENARIO	HYPOTHESIS
Autonomous Progress Scenario (APS)	201g CO_2/km decreasing first at an average rate of 0.5%/year in order to reach 190g CO_2/km in 2015 then declining to 0% annually up to 2030 [41]
APS + recent CO_2 policies for cars (APS + RP)	175 g/km CO2 by 2012 and 160 g/km CO_2 by 2015 [42] (value constant after 2015 up to 2030)
Economic Potential – LPI	160g CO_2/km in 2012 [43] (value constant after 2012 up to 2030)
Economic Potential – HPI	145g CO_2/km in 2020 [44] (160g CO_2/km in 2012; value constant after 2020 up to 2030)
Technical Potential	130g CO_2/km in 2020 [45], [46] (160g CO_2/km in 2012; value decreasing to 120g CO_2/km up to 2030)

Trucks and Trailers

Heavy Duty Vehicle (HDV) fuel efficiency has historically improved at a rate of approximately 0.8%-1% per year. This trend would likely continue, though there may be a temporary drop-off in response to mandated emission controls. There remains a large potential for near-term energy efficiency improvements in heavy-duty vehicles on the order of 10-20%. Reaching this potential, however, requires con-

41 According to Institute for European Environmental Policy (2007): Possible Regulatory Approaches to Reducing CO_2 Emissions from Cars, 070402/2006/452236/MAR/C3, December 2007, p.51, the baseline value (without policy aimed at efficiency improvement in N1s) for 2012 is expected to be around 190 g CO_2/km based on autonomous efficiency improvements stemming in part at least from technology improvements diffusing into light vans from equivalent passenger cars. It is assumed here that this value is only reached in 2015, and then continues to decrease slowly to 185g CO_2/km in 2030.

42 Value adopted by the European Commission in its most recent proposal on the reduction of CO_2 emissions from cars and light duty vehicles COM(2007)856 final and SEC(2007) 1723. http://ec.europa.eu/environment/air/transport/co2/co2_cars_regulation.htm

43 According to TNO (2006), p.190: Package 2 (Least cost 2012). http://ec.europa.eu/enterprise/automotive/projects/report_co2_reduction.pdf

44 According to TNO (2006), p.190: Package 3 (Least cost 2012). http://ec.europa.eu/enterprise/automotive/projects/report_co2_reduction.pdf

45 According to TNO (2006), p.190: Package 4 (Least cost 2012). http://ec.europa.eu/enterprise/automotive/projects/report_co2_reduction.pdf

46 According to Handelsblatt (9/7/2007) the Japanese producer of vans, Nissan, has introduced the Atlas 20 with a 35 PS electric motor and a 130-PS-Diesel motor on the domestic market. The fuel consumption is 10-35 % lower than for a Diesel-only driven lorry. The Diesel-Hybrid-„Canter Eco Hybrid“ of the Daimler-Chrysler-daughter Mitsubishi Fuso is around 20 % more economic. These developments also support the figures chosen for the potentials of light vans. http://www.handelsblatt.com/technologie/energie_technik/neuer-antrieb-fuer-lkw-hersteller;1291617

certed action on a number of HDV sub-systems including engines, integrated cab and trailer aerodynamics, drive-trains, tyres and embarked auxiliary systems. Of these, the greatest absolute increases in energy efficiency are likely to stem from advances in engine design. However, improvements in the energy efficiency of engines will be somewhat offset by increases in fuel consumption resulting from mandated NO_x and particulate matter emission reductions. The greatest relative improvements in energy efficiency are likely to stem from improvements in auxiliary systems. Reductions in total vehicle weight (tractor plus trailer), decreases in tyre rolling resistance and drive-train improvements can also contribute to improved energy efficiency. Regular maintenance and vehicle upkeep are also important to achieve better fuel efficiency – e.g. simple wheel and chassis alignment can result in up to an 18 % improvement in fuel efficiency[47].

There also exists a significant potential for increasing the efficiency of HDV use through better operational practices, improved driver training and enhanced logistics management.

The potentials for trucks and trailors have also been investigated empirically by Mercedes and described in DVZ (2008), see Table 8-8.

Table 8-8: Potentials for trucks and trailors[48]

	Current truck	**34 l/100km**
Improvements in:	**Mercedes Actros 1844, 40t (Test, 13000km, loaded)**	**19,9 l/100km**
Engine	Automatic fine-tuned gears	
	Ecoroll-System	0,5 l/100km
	Electronic coupling of propulsion and water pump+ electronic regulation of air compressor	0,34 l/100km
Aerodynamics and equip	Energy saving tyres (Supersingle tyres/saving tyres)	0,68 l/100km
	Tyre pressure (too low in 30% of all cases)	0,8 l/100km
	Improvement on Aerodynamics	5 l/100km
Behaviour	Reduced speed (80km reglementary speed compared to 90km/h)	2,7 l/100km
	Driving behaviour	3,4 l/100km
Diesel and lubricants	Improved Diesel and lubricants	0,68 l/100km

Source: DVZ (2008)

Derived from this empirical work, with respect to the technical improvements of trucks and trailers we have assumed an increase of efficiency in terms of energy savings different for each scenario but characterized by the same percentage applied to the different specific consumption values of each EU country as shown in the table below.

47 “Fuel Efficiency for HDVs Standards and Other Policy Instruments: Towards a Plan of Action”, IEA – International Transport Forum Workshop on Standards and Other Policy Instruments on Fuel Efficiency for HDVs, 21-22 June 2007, International Energy Agency – Paris.

48 Based on DVZ (2008): Rekordjagd im Kreisverkehr. 40-t-Sattelzug verbraucht im Dauertest unter optimalen Bedingungen unter 20 l Diesel. Nr. 73, 17/6/2008, p.13

Table 8-9: Scenario hypothesis for trucks and trailers (new settings)

SCENARIO	HYPOTHESIS
Autonomous Progress Scenario – APS	4% up to 2030 1)
Economic Potential – LPI	9% up to 2030 2)
Economic Potential – HPI	14% up to 2030 3)
Technical Potential (excluding driver behaviour/reduced speed)	24% up to 2030
Technical Potential (including driver behaviour/reduced speed)	41% up to 2030
Technical Potential (including driver behaviour/reduced speed/avoidance of empty driving)	44% up to 2030

1) Based on the extrapolation of historical time series from 1990-2006 (Odyssee Database)
2) Continued existence of previous barriers such as low attention to tyre pressure; includes highly economic options
3) Supposes removal of barriers and includes also more expensive but still economic options

In addition for trucks it is assumed in the technical scenario that about one third of the roughly 20-30 % of empty driving[49] can be avoided by 2030. This leads to an additional net reduction of 3 % of the truck energy consumption.

Other traffic modes

The potentials of other traffic modes such as air traffic, rail traffic and navigation on water ways have been investigated in the EX-TREMIS study[50]. Other information on more efficient air planes was also used[51]. For rail traffic there is a trade-off between increased speed and more efficient engines and rolling infrastructure that may diminish the available potential. This may be characterized as a rebound effect. For navigation little potential for improvement was found. But in general the data situation for this mode is bad.

---

49 see EEA: http://themes.eea.europa.eu/Sectors_and_activities/transport/indicators/TERM30,2001/Load_factors_TERM_2001.doc.pdf

50 JRC-IPTS (2008): EXploring non road TRansport EMISsions in Europe. Development of a Reference System on Emissions Factors for Rail, Maritime and Air Transport. Final Report. http://www.ex-tremis.eu/

51 e. g. Silent Airplane - Highly Energy Efficient Design which may achieve around 25 % improvement in the fuel consumption and which is intended for the generation after next of aircraft for entry into service in 2030. (http://sustainabledesignupdate.com/?p=1016),

Table 8-10: HPI potentials for other transport modes

	2010	2012	2015	2016	2020	2025	2030
Public road transport	4.9%	6.5%	9.0%	9.9%	13.2%	17.5%	21.8%
Motor cycles	3.8%	5.0%	6.9%	7.5%	10.0%	13.1%	16.3%
Rail	3.4%	4.5%	6.2%	6.8%	9.0%	11.8%	14.6%
Aviation	2.6%	3.5%	4.8%	5.3%	7.0%	9.2%	11.4%
Inland navigation	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Public road transport was treated in a similar way as light duty vans, assuming similar potentials.

8.2 Modal Shift

8.2.1 Description of the sector/end-use

Modal shift is defined as covering distances that would have been travelled anyway with less energy intensive transport modes. In practice, many existing policies aim at both shifting towards "more sustainable" transport modes and avoiding trips. In our case the simulation only applies for the former aim. There are many different policies to facilitate the increase of the share of less energy-extensive transport modes. The majority of them concentrate on shifting from individual motorised transport to public transport.

8.2.2 Sector-specific / use-specific data sources and modelling issues

The modal shift we distinguish between urban and interurban transport volumes and flows. The distinction between urban and interurban modal shift estimates is justified by the different scale of transport flows, determining different tools of assessment, assumptions and order of magnitude of results.

Also in this case the so-called baseline or autonomous progress has been obtained by filling up the MURE transport database with the TREMOVE data. Moreover, in order to calculate the percentage of modal shift at urban level in this scenario, the average past public transport investment expenditure per capita has been derived from the annual average of the five years (1997-2001) in 44 metropolitan areas of 20 EU countries from the UITP Mobility in Cities Database (2001). The key reference scenario used for the interurban modal shift assessment, instead, comes from the ASSESS[52] study, carried out for the DG TREN in the context of the Mid Term Assessment of the EU CTP to 2010.

---

52 ASSESS study (2005) "Assessment of the contribution of the TEN and other transport policy measures to the midterm implementation of the White Paper on the European Transport Policy for 2010"

8.2.3 Step 1 – Definition of energy saving options

The general methodology for the assessment of potential energy savings from transport modal shift is based on the MURE transport tool, which requires as input the modal shifts from cars to collective modes along a variable time span classified by regular steps, distinguishing urban/interurban transport and passenger/freight transport.

As a consequence, the key issue addressed by this chapter is how to provide sound estimates of the modal shift over 25 years on a wide geographical scope (the EEA countries today, in practice the EU27 members plus Croatia, Norway, Iceland and Liechtenstein), in order to feed the MURE transport tool and providing the impacts in terms of potential energy savings.

This challenging task can only be fulfilled on the basis of a specific set of assumptions, extrapolations and hypothesis, making at the same time the best use of existing statistical sources and studies.

The **interurban transport** addresses in fact regional transport flows (a common classification is to distinguish between short distance < 500 km and long distance > 500 km), the assessment of which requires the use of transport models and Origin-Destination-Trip matrices (O-D matrices) generally set up at the EU level.

Modal shift is in such a context estimated as an outcome of transport models whose output run over a time span of several years (usually up to 2020) under the effects of large-scale policies, e.g. the set up of the TEN-T infrastructure projects (the so called Van Miert list).

On the other hand, **modal shift at urban level** is usually estimated after field-trial experiments, e.g. the set up of new metro lines or new cycle paths, based on policies designed at local level and with lower impacts in terms of transport volumes shifting from one transport mode to another.

The following picture shows pros and cons of the two modal shift estimates obtained in the two different contexts.

Table 8-11: Modal Shift Pros and Cons

	PROS	CONS
URBAN LEVEL	Data on modal shift are real data derived from field trials	Few examples for a proper generalization at EU level, data only available for a given year
INTERURBAN LEVEL	Data available at EU25 and country level (2000-2020)	Data only available for the main EU corridors and routes

It can be observed that modal shifts assessed in urban areas suffer from a low level of transferability to the EU level, due to the fact that modal shift at urban level is highly site-specific. Furthermore, scenarios and projections over a long time span are quasi non-existent, due to the fact that the existing observations are related to given years with poor data collection of historical series.

However, it should be considered that the transferability at EU urban areas level of modal shift realized in a specific urban context represents a problem which is not possible to overcome even if an extensive database were available. The solution can only be based on assumptions and hypothesis of extrapolation to the overall Europe arena, as described in the section on the urban assessment.

Concerning the interurban level, modal shift is - in general – more easily assessed, being based on the outcome of transport models taking into account baseline scenarios consistent with the DG TREN scenarios projected at broad geographical scale (the EU25 level) as described next.

8.2.4 Step 2 – Technology costs

Assumption on technology costs for modal shift are based on investment levels.

8.2.5 Step 3 – Definition of the four scenarios

For what concerns the modal shift there are only two scenarios distinguished besides the Autonomous Progress Scenario: the Low and the High Policy Intensity scenarios. In fact, due to the approach chosen here of considering limitations to the capability to invest in public infrastructure, there is no meaning to consider a "technical" scenario when talking of measures like the modal shift. For this reason the Technical Scenario is considered equal to the HPI Scenario.

Secondly, it is worth noting that we have considered different hypothesis for urban and interurban modal shift scenarios which are discussed in the following sections.

8.2.5.1 The Urban Level

There is a flourishing activity of projects and initiatives funded by the EC aiming at assessing the impacts of transport measures at urban level[53].

In general, the urban transport measures and policies can be classified in two main categories:

---

53 We mentioned, among others, the CANTIQUE project, the AUTO OIL II project and the CIVITAS initiative, in addition to the ELTIS website (www.eltis.org), in which is possible to review more that 100 case studies of transport measures in European urban areas.

1) Supply side measures, focussing on the provision of new infrastructures or services, e.g. new metro lines, new buses, or improving the existing ones, e.g. increasing the frequency of buses, etc. Also the growing use of information technologies in traffic management, e.g. the Intelligent Transport Systems and Services (ITS), can be included in this category.

2) Demand side policies, in which the focus is how to modify the existing demand patterns through - for example - pricing measures for curbing congestion or traffic demand management policies, like parking management, park and ride schemes and so on.

In principle, both categories cause impacts in terms of modal shifts. However, given the objectives of the ESD study, we prefer to focus on the supply side measures in the light of the following two arguments:

1) *The time scale of the impacts*. The supply side measures have a long term effect, in the sense that the impacts of a new infrastructure can be assessed only after the infrastructure has been provided, i.e. after a certain number of years, depending on the type of infrastructure, or, in case of an improved transport service, the potential impacts can reach its maximum impact, when the new service is fully developed, scaling down the impacts in the years before proportionally. On the contrary, the impacts of the demand side measures, which have normally a short-time range, e.g. usually one year, are difficult to estimate in a long-term perspective;

2) *The magnitude of the modal shift*. In terms of modal shift potentials, the order of magnitude of the supply side measures is higher compared to the demand side measures. As suggested in the final report of the Urban Transport Benchmarking Initiative[54], the supply of public transport means (metro lines, buses) is a leading factor in explaining the use of public transport instead of private cars. The potentials of transport volumes subject to modal shifts are in such cases significant: "in the majority of the cities where there is a metro system present the proportion of passenger kilometres travelled by metro is in the **range of 25-30%**" (corresponding to approximately 7 billion of passenger kilometre in the London metropolitan area) [55]. On the contrary, the demand side measures are usually applied on small areas, e. g. the historical areas of the big cities, involving a lower number of passenger kilometres. For example, the road pricing measures applied in the charged area of London concern an annual average value of about 280,000 vehicle kilometres shifted from cars to other modes[56].

54 TTR "The Urban Transport Benchmarking Initiative", July 2006

55 TTR, "The Urban Transport Benchmarking Initiative", July 2006, page 47

56 Central London Congestion Charging, London, page 27

At urban level the scenarios are set up according to **hypotheses of investment capability by country (or group of countries) in urban areas** and the methodology has followed the subsequent steps:

i. Data collection and organization of urban transport investments by country

ii. Country classification by GDP per capita

iii. LPI and HPI scenario settings considering the identification of target investments for each scenario

iv. Allocation of target investments to the scenarios

v. Transformation of these investments into physical construction of public infrastructure

vi. Transformation of these infrastructure improvements into mobility figures (new passenger-km attracted by an improved collective urban transport offer)

vii. Calculation of the modal shift from urban car traffic (from MURE data) to the traffic taken up by public transport

viii. Energy potential calculations by scenario

The average past public transport investment expenditure per capita has been obtained by considering the annual average of five years (1997-2001) for 44 metropolitan areas in 20 EU countries[57]. The transport investment includes:

- construction of new infrastructure
- rolling stock purchase
- new equipment for existing infrastructure
- financial costs and expropriation costs

A country classification has been carried out by using a cluster analysis characterized by two main indicators:

1. The ratio between the EU GDP per capita (=100) and the per-capita GDP of the EU countries (PPP 2006 prices)
2. The population density (inhabitants/km^2)

57 From the UITP Mobility in Cities Database, 2001.

Table 8-12: Country classification by GDP per capita and population density

Luxembourg	High Density & High GDP
Liechtenstein	
Finland	Low Density & High GDP
Ireland	
Iceland	
Norway	
Sweden	
Bulgaria	Medium Density & Low GDP
Croatia	
Estonia	
Latvia	
Lithuania	
Romania	
Czech Republic	Medium Density & Medium-Low GDP
Hungary	
Slovenia	
Slovakia	
Poland	
Portugal	
Austria	Medium Density & Medium GDP
Cyprus	
France	
Greece	
Italy	
Spain	
Belgium	High Density & Medium GDP
Denmark	
The Netherland	
UK	
Germany	
Malta	

For each group of countries the APS, the EP-LPI and the EP-HPI / TP scenario targets are set up by considering:

- For the ***Autonomous Progress Scenario***, the average past public transport investment expenditure per capita has been used to define the scenario. This information was derived from the annual average of the five years (1997-

2001) in 44 metropolitan areas of 20 EU countries from the UITP Mobility in Cities Database (2001).

- For the ***EP-LPI scenario***, the weighted national average of public investment for all countries if more than the public investment of a considered country or the public investment of the country otherwise;
- For the ***EP-HPI/TP scenarios***, the Best Practices (highest investment per capita) within the considered group.

The next step was to extrapolate the annual resources available for investment - at constant prices 2005 – and then to define a specific cost for a new kilometer of metro or tram built and for the construction of a new bus line with ten new buses. The unitary costs[58] by public investment (metro/km, tram/km, new bus line) shown in the following table have been assumed.

Table 8-13: Unitary costs by public investment

Unitary Costs (€2005)	
per km of Metro	€ 160.000.000
per km of Tram	€ 12.000.000
for a new Bus Line	€ 3.900.000

Moreover, for each group of countries weighting factors have been defined assuming an increasing need of metro and bus lines to the extent that the population density at country level increases. The represent the market shares that each metro, tram and bus may take in the newly built infrastructure. These figures are modulated with the size of the urban areas.

Table 8-14: Weighting factors adopted

	Weighting factor					
	High Density & High GDP	Low Density & High GDP	Medium Density & Low GDP	Medium Density & Medium-Low GDP	Medium Density & Medium GDP	High Density & Medium GDP
Metro	0.12	0.10	0.10	0.12	0.20	0.12
Tram	0.50	0.48	0.45	0.43	0.20	0.45
Bus	0.38	0.42	0.45	0.45	0.60	0.43

58 The figures include the infrastructure, vehicle and operating costs.
Sources:
-the EDICT project (European Demonstration of Innovative City Transport), 5° FP
- Various: Web sites: Euronet.nl, Amicotreno.it, interviews

Once we had obtained the annual target investments by group of countries for each of the scenarios, we calculated the number of kilometers or new bus lines that will be built up to 2030. Starting from these data we have been able to evaluate the person-km moved from private cars to public transport.

8.2.5.2 The Interurban Level

The RTD projects concerning transport scenarios funded over the past years by the EC represent a good source of information for an assessment of interurban modal shift. They generally cover a broad time span, e.g. up to 2020, and a wide geographical scope, i.e. at least EU25[59].

The key reference scenario used for the modal shift assessment for the interurban level comes from the ASSESS[60] study, carried out for DG TREN in the context of the Mid Term Assessment of the EU Common Transport Policy CTP to 2010. The ASSESS study tries to assess the impacts of a package of measures envisaged by the EC as the key drivers for meet the target of a sustainable transport policy in Europe.

The package of measures, corresponding to the assumptions behind the simulation of the modal shifts estimates are shown in the following table.

Table 8-15: Assumptions behind modal shift at European level

Measures	
1 Harmonise clauses in commercial road transport contracts	NO
2 Driving restrictions on heavy goods vehicles on designated roads	
3 Training of professional drivers	
4 Social harmonisation of road transport	
5 Introduction of the digital tachograph	
6 First railway package: separated management of infrastructure and services, opening international services in TENs	
7 Second railway package: opening up the national and international freight market	
8 Second railway package: ensuring a high level safety for the railway network	
9 Updating the interoperability directives on high-speed and conventional railway networks (ERTMS)	
10 European Railway Agency	NO
11 Third railway package: certification of train crews and trains on the Community rail network	
12 Third railway package: gradual opening-up of international passenger services	
13 Third railway package: Quality of rail services and users' rights	NO
14 Third railway package: improving quality of the rail freight services	

59 We mention, among others, the TEN/STAC project, the ETIS BASE information system and the TRANS TOOLS project.

60 ASSESS study (2005) "Assessment of the contribution of the TEN and other transport policy measures to the midterm implementation of the White Paper on the European Transport Policy for 2010"

15	Enter the dialogue with the rail industries in the context of a voluntary agreement to reduce adverse environmental impacts	
16	Support the creation of new infrastructure, and in particular rail freight freeways	
17	Single European Sky	
18	Technical requirements in the field of civil aviation and establishing a European Aviation Safety Agency	NO
19	Air transport insurance requirements	
20	Harmonisation of airport charges	
21	Introduction of market mechanism in slot allocation procedures on Community air-ports	
22	Community framework for airport noise management	NO
23	Protection against subsidisation and unfair pricing practices in the supply of air ser-vices from third countries	NO
24	Safety of third country aircraft	NO
25	Air service agreements with third countries	NO
26	Airport capacity expansion	
27	Introduction of kerosene taxation	
28	Introduction of differential en route air navigation charges	
29	Motorways of the seas	
30	Port services liberalisation	
29	Simplify sea and inland waterway custom formalities and linking up the players in the logistic chain	
30	Ship and port facility security	NO
31	European Maritime Safety Agency	NO
32	Double-hull oil tankers Penal sanctions for ship source pollution	NO
33	Oil pollution damage compensation fund	
34	Transfer of ship register	NO
35	Training of seafarers	NO
36	Eliminating bottlenecks in inland waterways transport	
37	River Information System	
38	Greater harmonisation of boat masters' certificates	NO
39	Social legislation inland waterway transport	
40	Port state controls	NO
41	Sulphur content of marine fuels	
42	Marco Polo Programme	
43	Intermodal Loading Units and freight integrators	
44	Trans European Network projects	
45	Funding of TENs	NO
46	Tunnel safety	
72	TEN infrastructure in the candidate countries	
73	Funding of infrastructure in the New EU Member States	NO
47	European Road Safety Action programme	NO
48	Harmonisation of road safety checks and penalties	
49	"Black Spots" on TENs	NO
50	Seat and head restraints	NO
51	Tackling dangerous driving	NO
52	Technical investigations of the causes of road accidents	
53	Harmonisation of driving licensing systems	
54	Speed limitation devices	NO
55	Intelligent transport systems and *e*-Safety	NO
56	Pedestrian and cycling protection	NO
57	Infrastructure charging covering all transport modes and internalising the external costs	
58	Uniform commercial road transport fuel taxation	
59	Electronic road toll system (interoperability)	NO

60 Harmonising VAT deductions	
61 Taxation of passenger cars according to environmental criteria	
62 Taxation of energy products and exemptions for hydrogen and bio fuels	
63 Introduction of a minimum share of bio fuels consumption in road transport	
65 Compensation of air passengers Information for air passengers, assistance for persons with reduced mobility	
66 Extending protection of users' rights to other transport modes	NO
67 Intermodality for people	
68 Public service requirements and the award of public service contracts in passenger transport by rail, road and inland waterway	NO
69 Support for pioneering towns and cities (CIVITAS initiative)	NO
70 Promote the use of clean vehicles in urban public transport	
71 Promotion of good urban transport practices	NO
64 European Research on new clean car technologies and ITS application to transport	NO
74 Develop administrative capacity in the candidate countries	
75 EU external relations in the transport sector	NO
76 Galileo programme	

Not all the measures indicated in Table 8-12 have been modelled. For 32 measures, labelled in the table with “NO”, it has not been possible to consider their impacts, as the measures are mainly characterised as R&D measures or administrative/organisational measures with uncertain impacts on transport users and operators.

On the contrary, all the measures introducing taxes and charges and improving infrastructure provision and interoperability have been taken into account. In particular, due to its importance in terms of transport modal shifts, we would like to mention the implementation of the TEN-T infrastructure projects in the EU Member States. The projects are the following:

Table 8-16: The TEN-T infrastructure projects

1. High-speed train/combined transport north–south
2. High-speed train PBKAL (Paris-Brussels- Cologne-Amsterdam- London)
3. High-speed railway axis of south-west Europe
4. High-speed train east
5. Conventional rail/combined transport: Betuwe line
6. High-speed train/combined transport, France-Italy
7. Motorway axis Igoumenitsa/ Patra-Athina- Sofia-Budapest
8. Multimodal link Portugal-Spain-Central Europe
Spain-Central Europe
9. Conventional rail link Cork-Dublin-Belfast- Larne,Stranraer
10. Malpensa airport, Milan
11. Øresund fixed rail/road link between Denmark and Sweden
12. Nordic triangle rail/road
13. Ireland/United Kingdom/Benelux road link
14. West coast main line (rail)
15. Global navigation and positioning satellite system Galileo
16. Freight railway axis Sines/Algeciras-Madrid- Paris
17. Railway axis Paris- Strasbourg-Stuttgart- Wien-Bratislava
18. Rhine/Meuse-Main- Danube inland waterway axis
19. High-speed rail interoperability on the Iberian peninsula
20. Fehmarn Belt: fixed link between Germany and Denmark
21. Motorways of the sea
22. Railway axis Athina- Sofia-Budapest-Wien- Praha-Nürnberg/Dresden
23. Railway axis Gdansk- Warszawa- Brno/Bratislava-Wien
24. Railway axis Lyon/Genova-Basel- Duisburg- Rotterdam/Antwerpen
25. Motorway axis Gdansk-Brno/Bratislava- Wien
26. Railway/road axis Ireland/UK/continental Europe
27. "Rail Baltica" railway axis Warszawa-Kaunas- Riga–Tallinn
28. Eurocaprail on the Bruxelles-Luxembourg- Strasbourg railway axis
29. Railway axis on the Ionian/Adriatic intermodal corridor.
30. Inland waterways Seine-Scheldt

In order to estimate the impacts from the measures, four scenarios have been developed in the ASSESS study, according to an increasing level of ambition:

1) Null scenario (N-scenario): assumes that none of the White Paper measures has been implemented.

2) Partial implementation scenario (P-scenario): includes only measures that are assumed to be implemented before 2010. This scenario is what – under current conditions – may actually happen in the future.

3) Full implementation scenario (F-scenario): includes all White Paper measures.

4) Extended scenario (E-scenario): the extended scenario is an enhanced version of the partial and the full implementation scenario. The extended scenario includes, besides all measures implemented or planned now, a number of measures that:
   - are included in the White Paper but not included in the partial implementation scenario due to the current status of implementation;
   - are included in the White Paper and also in a weak form in the partial implementation scenario;
   - are not mentioned in the White Paper but that may be needed to achieve (some of the) objectives set in the White Paper.

In principle, all the four scenarios are developed for 2010 (the time-horizon of the White Paper). However, sometimes the implementation and the impact of measures take time. For example, some of the TEN-projects have been started within the period 2000-2010 but they will be finalised in the period 2010-2020. Also pricing for passenger road transport in the extended scenario will only be introduced from 2011 onwards. To show the impacts of these measures the scenarios are developed and evaluated for both the year 2010 and 2020.

So the resulting modal shifts in interurban/regional transport used as input in the MURE transport tool for the ***HPI Scenario*** are based on the *ASSESS Extended Scenario*. The reason lies in the fact that given the objective to provide an assessment of the energy potential savings, it makes sense to assume the upper estimates of modal shift as reference values for the assessment. The ***LPI Scenario*** has been based on the *ASSESS Full Scenario*. Unfortunately – for what concerns passenger modal shift - in this latter scenario the hypothesis are not always positive to a shift towards a more sustainable transport mode, but it foresees also an increase in private cars traffic. For this reason we decided not to consider it within the LPI scenario, while in the goods modal shift there is an increase in usage of rail and inland waterways in respect of trucks and trailers volumes decrease.

Methods of assessment

The modal shift impact assessment, namely the modal shift from cars to other transport modes, has been carried out through a set of models, of which the core model was the SCENES transport model.

The SCENES output was processed into the TREMOVE transport database, (vehicle stock, emissions, fuel consumption, government revenues), the CGE (regional welfare), the SLAM (logistics), a noise model, and the SWOV road safety model and a macro-economic model.

In details, the set of models are the following:

- SCENES, a network transport forecast model

- TREMOVE, a transport and environmental model
- A road safety model
- A noise model
- A logistics modelling tool
- CGEurope, a regional economic model
- Quantitative macro-economic analysis

The seven models have been designed in order to be as much as possible, consistent. In the following box, taken from the ASSESS description, the relationship between the models is shown in terms of variables involved.

> TREMOVE uses the same transport baseline as SCENES. CGEurope uses the cost data from SCENES and adjusts its own transport flows as much as possible. The SCENES and TREMOVE models are linked. TREMOVE uses the transport volume from SCENES, and breaks it down to further details, e.g. on vehicle costs etc.
>
> The other models use the SCENES-TREMOVE output as is, that is mainly the Access database for TREMOVE which includes the complete demand module volumes and costs, and in some cases network data from SCENES (speeds and volumes for noise and safety assessment, etc).

The geographical model scope is EU25. Model years are usually 2000, 2005, 2010 and 2020, again except where this is not possible within the scope of the model.

The ASSESS baseline scenario (2000-2020) of modal shares in the EU25 shows a growing trend for the road sector, both passenger and freight. In particular, for freight transport, the increase is about 8 percentage points (from 74.8 % in 2000, to 81.7 % in 2020).

Table 8-17: Baseline scenario 2000-2020: Modal shares for freight (tkm) and passenger transport (pkm)

Tonne-km (%)	*2000*	*2010*	*2020*
Road freight	74.8	78.7	81.7
Rail freight	18.7	15.2	12.6
Short Sea Ship	6.6	6.1	5.7
Passenger-km (%)*	*2000*	*2010*	*2020*
Car	75.7	75.8	76.6
Coach	8.2	7.3	6.1
Train	6.9	6.5	5.9
Air	5.1	6.6	7.8

* The passenger scenario does not include a small percentage for passenger/cycling

As far as passenger transport is concerned, a growing trend is expected in the air sector (from 5.1 % to 7.8 % of total passenger-kilometre), while the rail sector is forecasted to lose passengers in the order of 1 percentage point.

The implementation of the ASSESS extended scenario leads to a better performance for the rail and waterborne sectors (in the freight transport), while in the passenger transport the weight of road transport is still strong.

Table 8-18: Extended scenario 2000-2020. Modal shares freight (tkm) and passenger transport (pkm)

Tonne-km (%)	*2000*	*2010*	*2020*
Road freight	74.8	75.7	75.1
Rail freight	18.7	18.1	18.6
Short Sea Ship	6.6	6.3	6.3
Passenger-km (%)*	*2000*	*2010*	*2020*
Car	75.7	76.4	75.3
Coach	8.2	7.3	7.0
Train	6.9	6.5	7.0
Air	5.1	6.0	6.9

* The passenger scenario does not include a small percentage for passenger/cycling

It can be observed that, at EU25 level, the implementation of the ASSESS extended scenario at 2020 determines in the freight transport a modal shift from road transport by -6.6%, towards the rail sector (+6.0%) and the waterborne sector, i.e. Short Sea Shipping (+ 0.6%).

Concerning the passenger sector, the modal shift from road to other modes is lower, -1.1%, directed mainly towards rail and coaches. The decreasing weight of the air sector (- 0.9%) should also be mentioned.

The above values of modal shift, shown at an aggregated level (EU25) are broken down on a country-by-country basis for the ESD study.

8.3 Behavioural measures

8.3.1 Description of the sector/end-use

Eco-driving is a way of driving that reduces fuel consumption, greenhouse gas emissions and accident rates. Shifting gears between 2000 and 2500 r.p.m., regular checking of tyre pressure and other tips are characterising the behavioural measures taking place nowadays.

In fact, the effective use of gear shift indicators (GSI) in itself only captures part of the total reduction potential of eco-driving. On the other hand GSI can be a useful tool to assist drivers in maintaining a correct and effective fuel efficient driving style. In this way the use of GSI in combination with eco-driving is expected to increase the long-term effectiveness of eco-driving.

8.3.2 Sector-specific / use-specific data sources and modelling issues

Also in this case the autonomous progress scenario has been obtained by filling up the MURE transport database with the TREMOVE data.

8.3.3 Step 1 – Definition of energy saving options

Within the transport sector a second group of measures taken into account in simulating non-technical instruments is the one considering people behaviours. In particular, for passenger transport we envisaged the eco-driving strategy while for freight load factor increase as considered.

8.3.3.1 Eco-driving in passenger cars

Eco-driving is a term used to describe initiatives that support energy efficient use of vehicles. It is a way of driving that reduces fuel consumption and greenhouse gas emissions. Smart and safe driving techniques, in fact, can lead to significant fuel savings.

Eco-driving is a cost-effective way of reducing CO_2 emissions because it is based on measures to alter behaviour of consumers. Eco-driving has become an integral part of transport sector emissions reduction strategies in several countries. It remains, however, in the margins of transport policy development in many other countries.

Some of the key principles of Eco-Driving are:

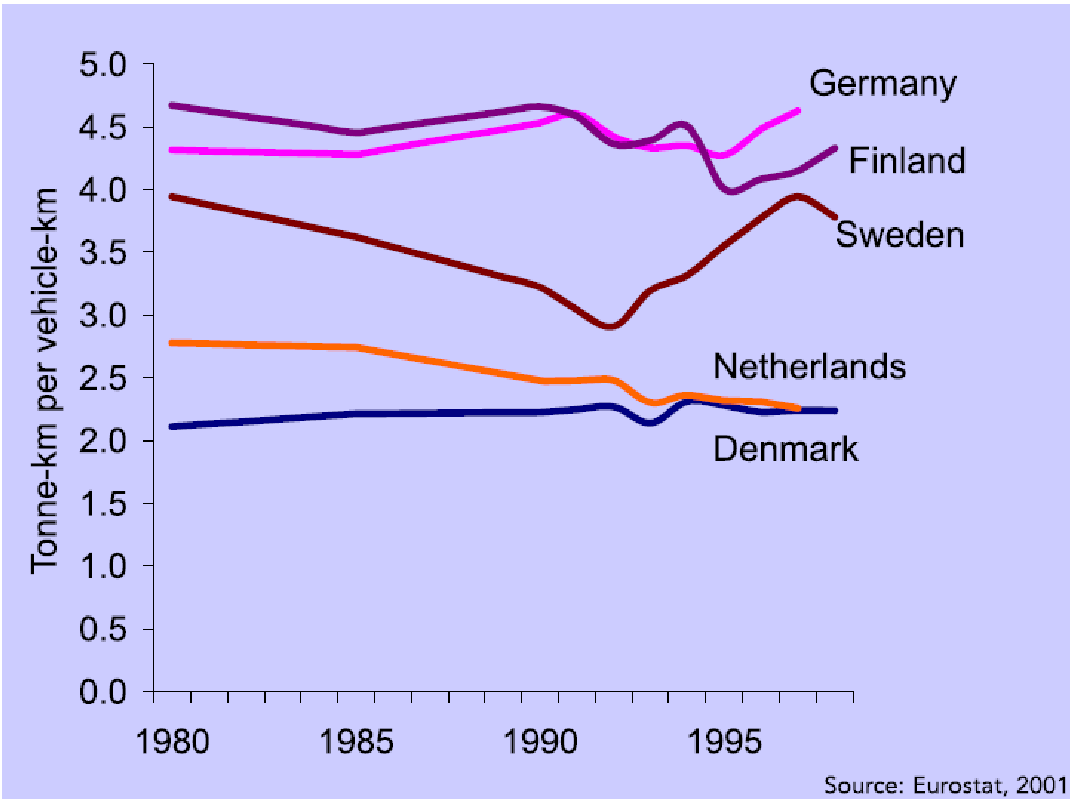
- Maintain engine speeds between 1200 – 3000 rotations per minute (rpm);
- Change to higher gears between 2000 – 2500 rpm, and drive in top gears at lower speeds – the so-called “50 in 4th gear” driving style;
- Try to anticipate more to avoid strong accelerations, decelerations, overtaking or aggressive driving;
- Driving at speed limits and avoiding high speeds;
- Add 10% to standard tyre pressure;
- Avoid using the air condition, or set at temperatures above 21°C.

8.3.3.2 Load factor[61] in freight transport

The loading efficiency of road freight transport is improving slightly in some EU Member States, but has remained relatively stable or worsened in most Member Countries.

Though data quality on load factors is poor, figures for some countries indicate they are still low. In Denmark, Germany, Spain and Portugal the load factors increased between 1980 and 1995. In the Netherlands, Finland and Sweden the load factor dropped significantly (by 10-17 %) between 1980 and 1995. Empty hauling makes up only 25 % of total truck vehicle-km in Germany and over 40 % in the Netherlands. In the United Kingdom, empty hauling declined from about 33 % to 29 % of total truck vehicle-km between 1980 and 1996.

Figure 8-4: Load factors for road of selected countries, 1980 to 1998



There are no EU-wide targets for load factors and overall freight transport efficiency. Several Member States have taken initiatives to increase the efficiency of

---

61 The load factor is the ratio of the average load to total freight capacity, in tonnes or volume. As such data are not available for the whole EU for all modes, the load factor is defined as the number of tone-km divided by the number of vehicle-km.

freight transport[62]. For example in Germany logistics and fleet management systems are used to minimise empty journeys and generally increase the efficiency of freight transport. Information and communication technologies are used in combined transport chains to facilitate the interconnection of the modes and the tracking of consignments (German Federal Ministry of Environment and Nuclear Safety, 2000).

In Finland, instead, The Environmental Guidelines of the Transport Sector set out actions for more efficient and environmentally-friendly freight transport. Projects promoting logistical efficiency to reduce transport growth (including projects to increase truck load factors) are encouraged by the Ministry of Transport. The development of logistical systems using on-board computers and geographical information systems is encouraged (Finish Ministry of Transport and Communications, 1999).

We have also to notice that transport is relatively cheap compared with other production factors. Therefore, transporters are not sufficiently stimulated to improve their efficiency. Companies prefer inefficient transport to inefficient time-management, resulting in an increasing number (more vehicle-km) and a decreasing size of shipments (TNO, 1999).

Freight transport efficiency depends to a certain extent on economic conditions. Small transporters may merge into larger transport companies, which usually use their vehicle fleets more efficiently.

8.3.4 Step 2 – Technology costs

No assumption on technology costs for behavioural changes are taken.

8.3.5 Step 3 – Definition of the four scenarios

Like the previous chapter about modal shift, also in this case we have distinguished only two scenarios beyond the Autonomous Progress: the Low and High Policy Intensity scenarios. The Technical Scenario is the same as the HPI Scenario. In fact there is no meaning to consider a “technical” scenario when talking about behavioural measures.

Energy savings that could be achieved in 2030 by the implementation of eco-driving have been estimated to be equal to 5 % in the LPI scenario and roughly 10 % in the HPI scenario.

Concerning load factors in goods transport and in particular for trucks and trailers, due to the fact that the values are almost steady, we assumed a 1% of energy sav-

---

62 European Environmental Agency – Load Factors TERM 2001.

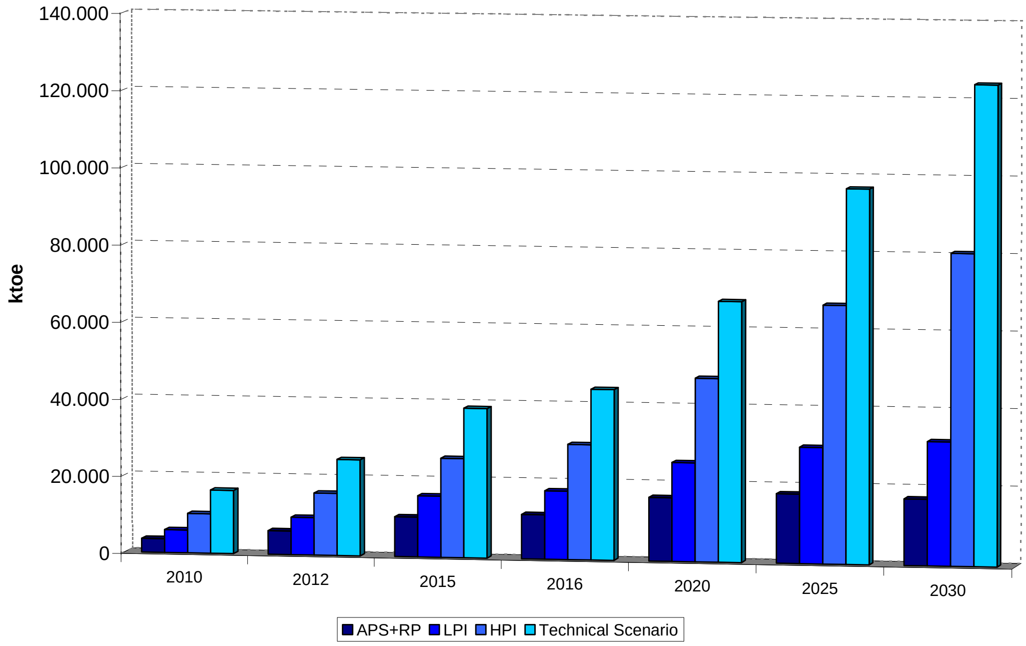
ings to be reached in 2030 for the LPI scenario and 3 % for the HPI scenario (see also section 8.1.4.

8.4 Results transport sector

8.4.1 Results technical measures

The resulting saving potentials for the transport sector are presented below. It is important to have in mind that the following histograms show the *additional saving potential*, which means that the potential is additional in comparison to the energy already saved in the Autonomous Progress Scenario. In the following the potentials of energy savings are given for the whole EU-27. Because of the high amount of data, a more detailed overview can be conducted by using the online database.

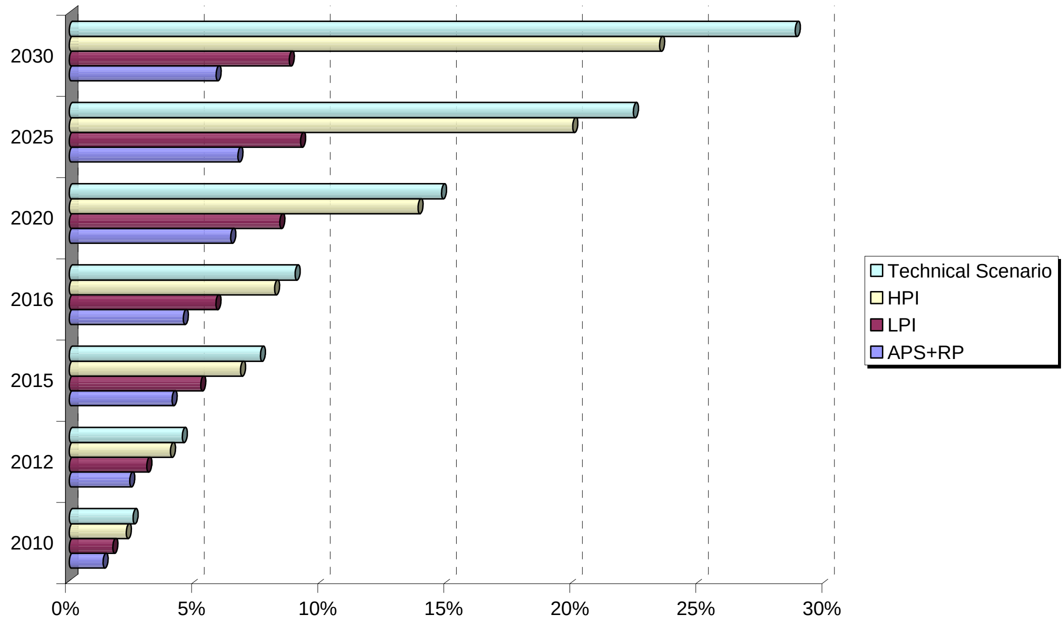
Figure 8-5: Saving Potentials for Technical Measures in passenger transport (EU-27) (ktoe)



As illustrated in Figure 8-5, the energy savings potentials coming out from the implementation of technical measures in passenger transport at EU-27 level are equal in absolute values to roughly 32 Mtoe for the LPI Scenario, 80 Mtoe for the HPI Scenario and 124 Mtoe for the Technical Scenario in 2030. The impact of recent policies (CO_2 policies for passenger cars and light duty vehicles in the pipeline) amount to 17 Mtoe in 2030.

These results as shown below (Figure 8-6) demonstrate that both the LPI and HPI potentials achievable by the realization of more efficient car engines are quite substantial by achieving a potential of 8.7 % (LPI), 23.4 % (JPI) and 28.8 % (Technical Scenario) in 2030[63]. It appears that substantial amounts of the LPI potentials are envisaged for in the recent CO_2 policies set up for cars with an aim of 130g CO_2/km in 2012/2015.

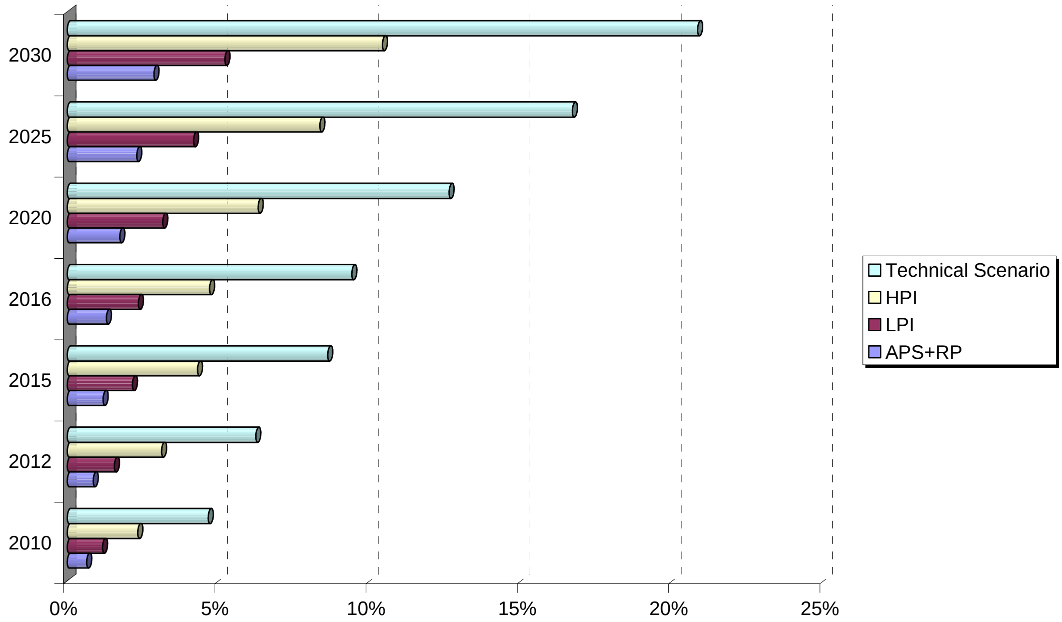
Figure 8-6: Saving Potentials for Technical Measures in passenger transport (EU-27) (%)



As illustrated in the graph below (Figure 8-7), the potential gains obtainable with technical interventions on trucks and trailers engines are quite stable during all the period considered and, in 2030, are equal to 10,7% in the LPI Scenario, 19,1% in the HPI Scenario and 29,1% in the Technical Scenario.

63 The percentage reduction refers to the Autonomous Progress Scenario for car transport.

Figure 8-7: Saving Potentials for Technical Measures in Road Freight Transport (EU-27) (%)



8.4.2 Results modal shift

The results from modal shift interventions in passenger transport both at urban and interurban level show a total potential of 13 Mtoe, 21 Mtoe and 27 Mtoe achievable respectively within the LPI, HPI and the Technical Scenario as shown in Figure 8-8. In percentage terms the maximum achievable potential is equal to 13 % in 2030 while the LPI and HPI Scenarios have a potential of 6 % and 10 % respectively.

It is worth noting that in the graphs below (Figure 8-8 and Figure 8-9) there are also potentials also for the Technical Scenario represented even if, as stated in the Modal Shift paragraphs, there is no real meaning to consider a "technical" scenario when talking about measures like modal shift. The Technical Scenario shown derives from the hypothesis that the modal shift has been implemented in parallel with the penetration of more efficient cars in terms of CO_2 emissions abatements. Hence interactions are taken into account.

Figure 8-8: Saving Potentials for Modal Shift Measures in passenger transport (EU-27) (ktoe)

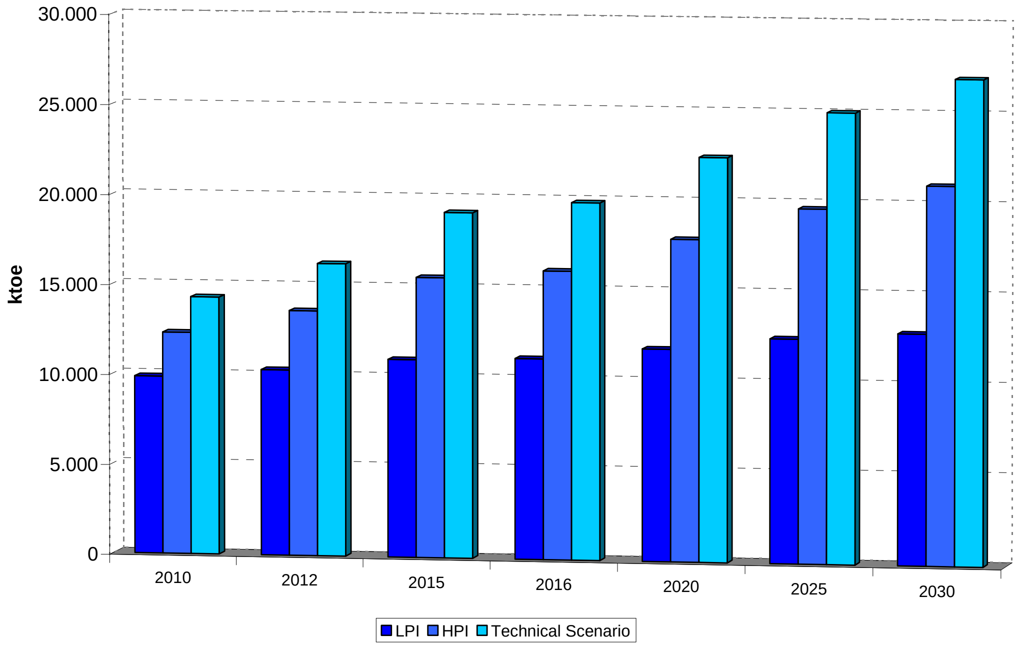
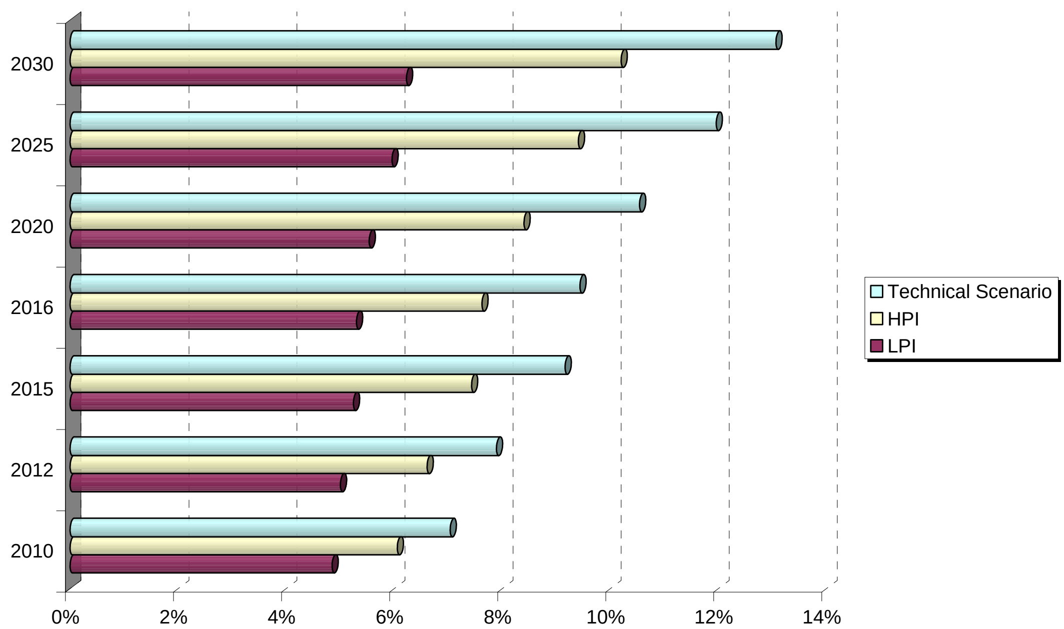
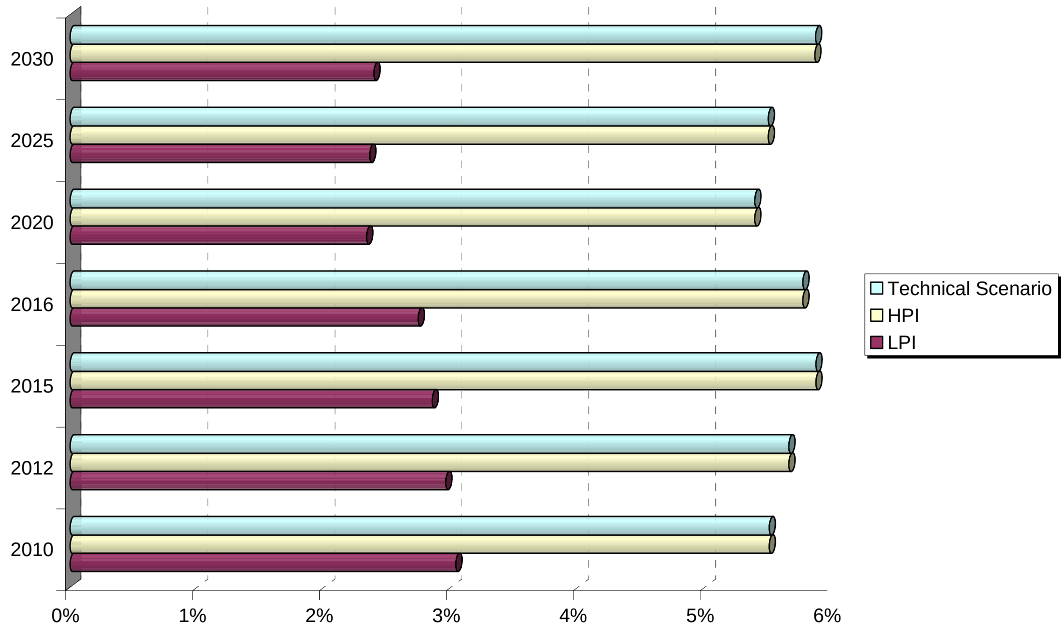


Figure 8-9: Saving Potentials for Modal Shift Measures in passenger transport (EU-27) (%)



For what concerns the good transport modal shift the achievable potentials within the LPI and HPI Scenario in absolute values are equal to 4.3 Mtoe and 10.7 Mtoe respectively, while in percentage terms the two scenarios are characterized by a potential of 2.4 % and 5.9 % correspondingly (Figure 8-10).

Figure 8-10: Saving Potential for Modal Shift Measures in goods transport (EU27) (%)



8.4.3 Results behavioural measures

The results of the behavioural measures implementation show (see Figure 8-11) a saving potential in 2030 of 9.4 Mtoe in the LPI Scenario, of 15.8 Mtoe in the HPI Scenario and 14.7 Mtoe in the Technical Scenario. The technical potential is lower than the HPI potential because this interacts with the larger potentials for technical measures which reduce the amount of energy available in the Technical Scenario.

Figure 8-11: Saving Potentials for Behavioural Measures in passenger transport (EU-27) (ktoe)

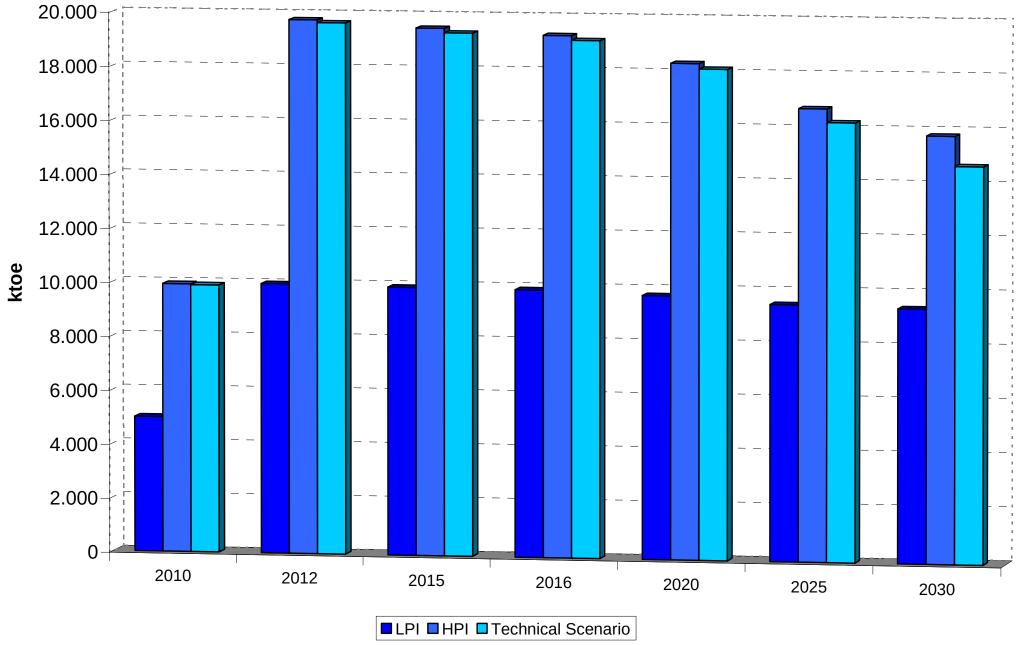
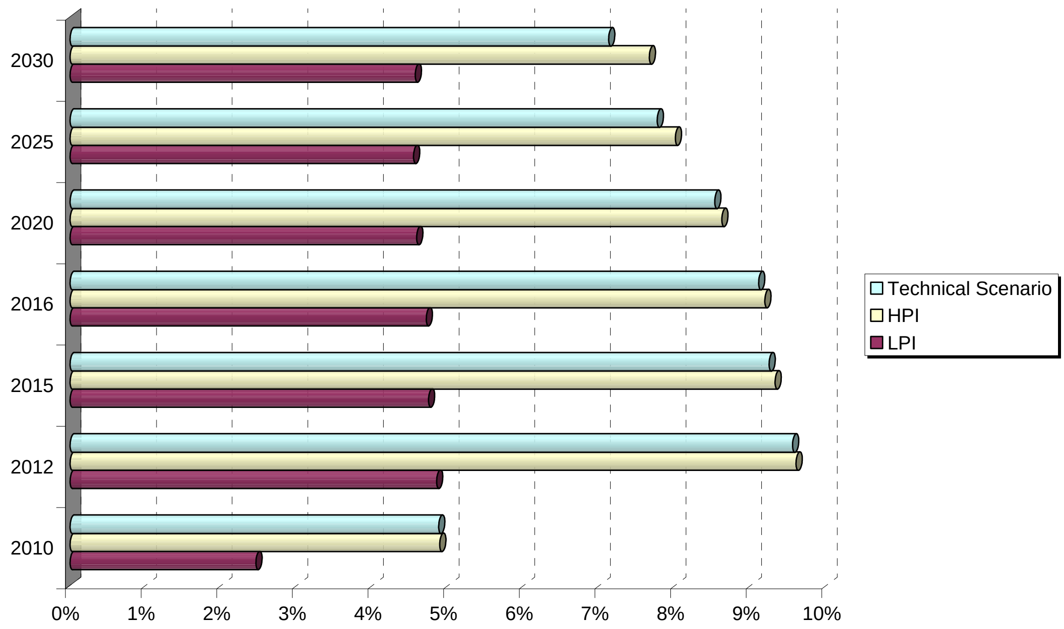


Figure 8-12 summarises the potential trends in percentage terms from 2010 up to 2030. We can see that most of the impacts build up in an early phase while in the later stages the potentials decrease due to advances on the technical side.

Figure 8-12: Saving Potentials for Behavioural Measures in passenger transport (EU-27) (%)



8.4.4 Results overall transport sector

The total saving potentials at EU-27 level within the transport sector are equal to 185 Mtoe for the Technical Scenario, 132 Mtoe for the HPI and 64 Mtoe for the low policy intensity scenario. In absolute values the main role in saving potentials achievable is played by the EU15 countries responsible of roughly 90% of the total potentials. Nevertheless it is worth noting that EU-12 countries are characterized by an stronger increase in energy savings during the considered period than the EU15 countries.

For all results at country level a more detailed overview can be performed by using the online database.

Figure 8-13: Total Saving Potentials in Transport Sector (EU-27)

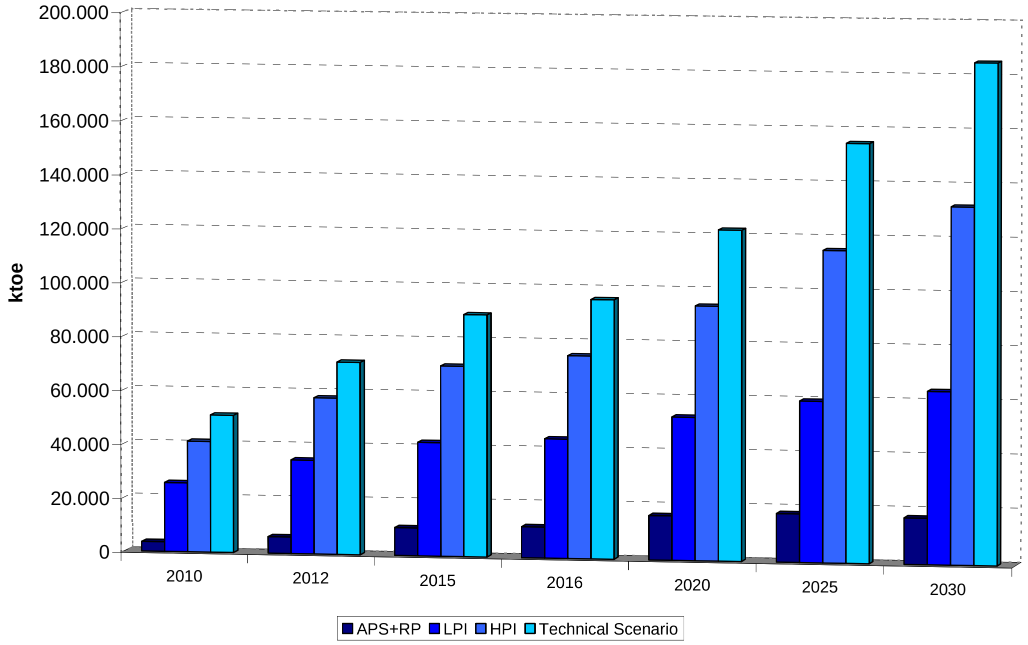
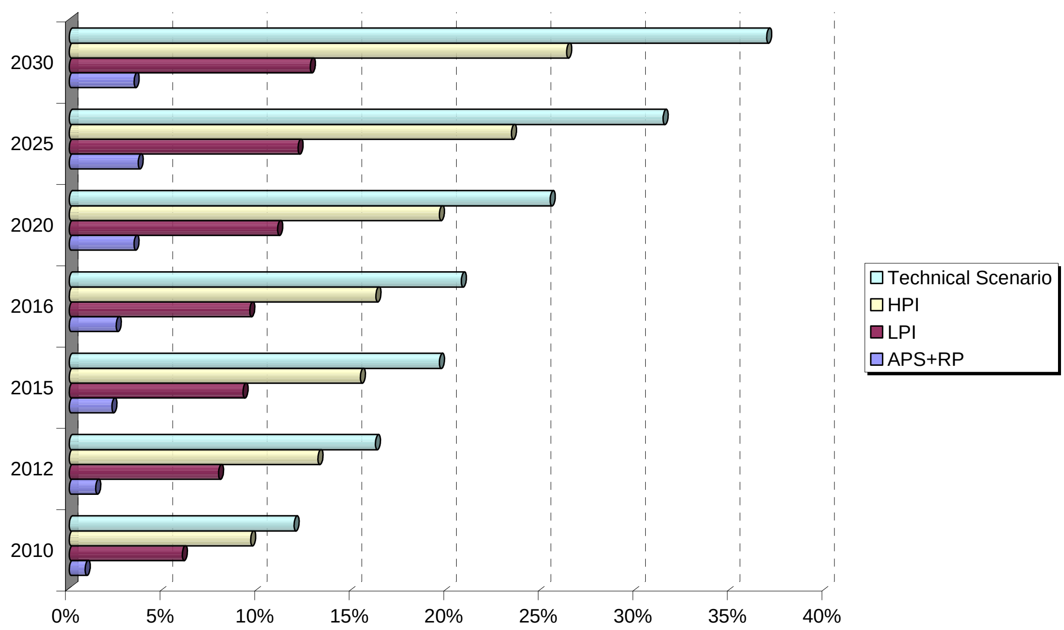


Figure 8-14: Total Saving Potentials in Transport Sector (EU-27) (%)



9 Industry

The saving potentials in the industrial sector were calculated by dividing the technological structure in three different fields:

- Process related technologies are defined to be very individual and often only found in one branch or even applied for only one production step. The technologies related to certain processes in energy intensive industries are distinctly covered in the model.
- There is a certain set of technologies, which are applied independent of the branch or the production step. They are called cross-cutting technologies (CCT) in the following and will be divided in electricity consuming CCT, which are mainly motor systems, and heat generation CCT, which are related to heat and steam generation.

The following analysis is structured according to this division of technologies and each technology field will be treated in one chapter. Also the model that had been used for the analysis of industry is adapted to this structure and is described in chapter 9.1.2.1.

9.1 Process technologies

9.1.1 Description of the sector/end-use

The structure of the part of the model that presents process technologies (see below) is implemented according to Figure 9-4. The energy consumption of the sectors implemented is directly taken from official EU energy balances. Table 9-1 shows how the distinct sectors are defined. For the illustration of "bottom-up" saving potentials in the following chapters, the sector non-metallic mineral products will be divided in glass and cement production.

Table 9-1: Sectoral coverage of the model

Sector	NACE- Code
Iron and steel	27.1, 27.2, 27.3, 27.51, 27.52
Non-ferrous metals	27.4, 27.53, 27.54
Paper and printing	21, 22
Non-metallic mineral products	26
Chemical industry	24
Food, drink and tobacco	15, 16
Engineering and other metal	28, 29, 30, 31, 32, 34, 35
Other non-classified	20, 25, 33, 37, 45,17, 18, 19,13, 14

According to Figure 9-4, the sectors can be further divided in characteristic processes. In this study, we chose the most relevant processes in terms of energy consumption (seeTable 9-2) and included production statistics and forecasts as well as the specific energy consumption for each process. As described in Figure 9-5, the implementation of these processes is necessary for the bottom-up part of the model. By considering physical production values, a direct connection to energy consumption is established. The connection between energy consumption and monetary indicators like value added is more indirect and thus less concrete. Nevertheless, the amount of data needed for the calculation increases considerably when extending the bottom-up calculations to further processes. Thus, only the processes with the highest energy consumption were included.

Table 9-2: Processes by sub-sector implemented in the model

Iron and Steel	Non-ferrous metals	Paper and Printing
Sinter	Primary Aluminum (Hall-Heroult)	Paper
Blast furnace	Secondary Aluminum	Mechanical Pulp
EAF	Aluminum Further Treatment	Chemical Pulp
Rolled steel	Primary Copper	Recovered Fibres
Coke oven	Secondary Copper	
Smelting reduction	Copper Further Treatment	
Direct reduction	Primary Zinc: Imperial Smelting	
	Zinc: Galvanizing	
Glass	**Cement**	**Chemicals**
Container glass	Clinker burning-Dry	Chlorine-Hg (mercury)
Flat glass	Clinker burning-Semidry	Chlorine-Membrane
Other glass	Clinker burning-Wet	Chlorine-Diaphragm
	Quarrying	Polypropylene (PP)
	Raw material preparation	Polyethylene (PE)
	Cement Grinding	Polyvinyl chloride (PVC)
	Lime milling	
	Gypsum milling	

As all of the processes have a certain specific energy consumption that shows, how much energy is used for a certain amount of output (e.g. energy consumption per tonne of steel), saving options exist, that can decrease the specific consumption and thus, make the process more energy efficient. In total, about 80 distinct saving options are considered and allocated to the relevant processes.

The production projections for the most relevant products are given in Figure 9-1. The products were grouped according to the following definitions (compare with Table 9-2):

- Steel: blast furnace and electric arc furnace
- Paper: paper (all types)
- Glass: flat glass, container glass and other glass
- Cement: dry cement, semi-dry cement and wet cement
- Aluminium: primary aluminium and secondary aluminium

Figure 9-1: Production projections of chosen product groups for EU27 [kt]

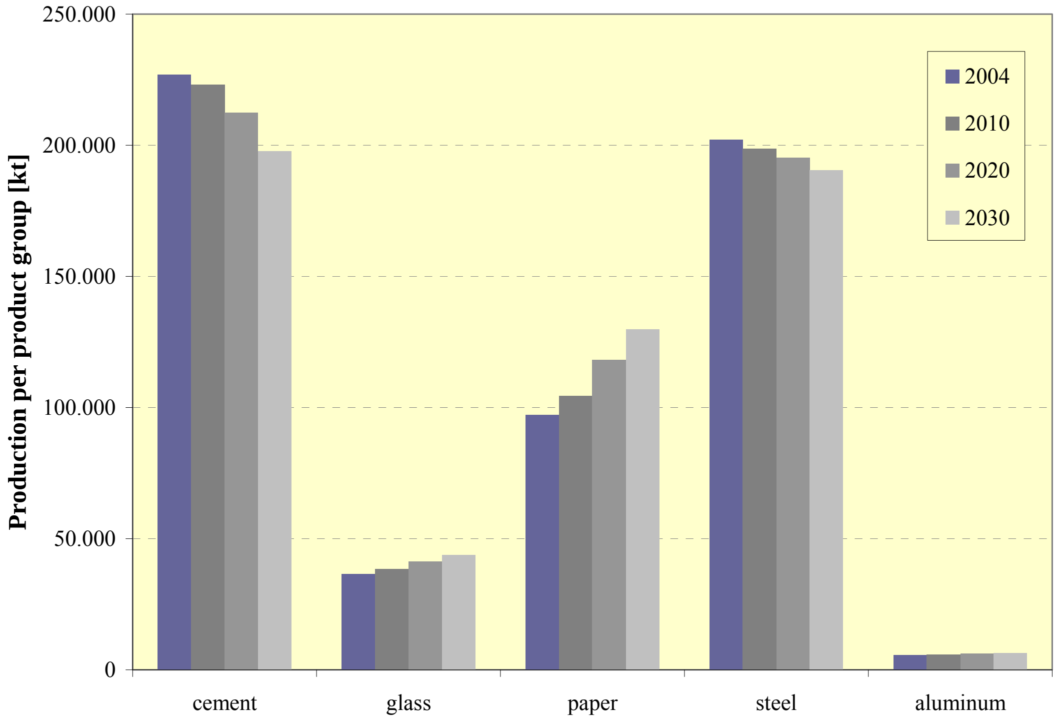


Figure 9-2: Final energy demand in EU27 industry by sector 2004 (Eurostat)

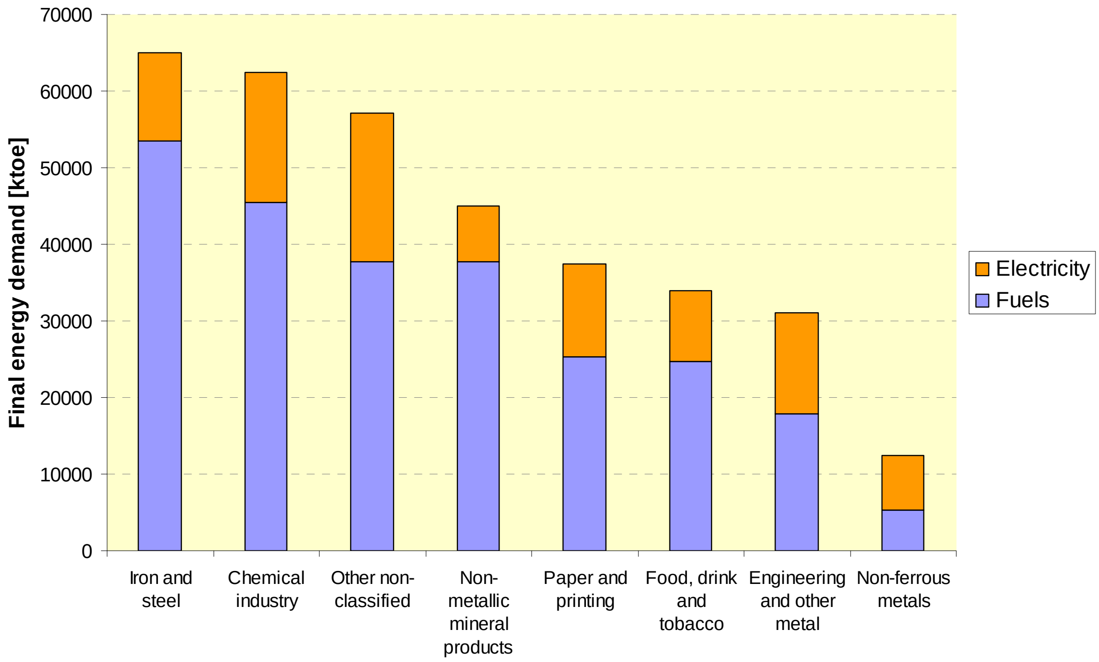
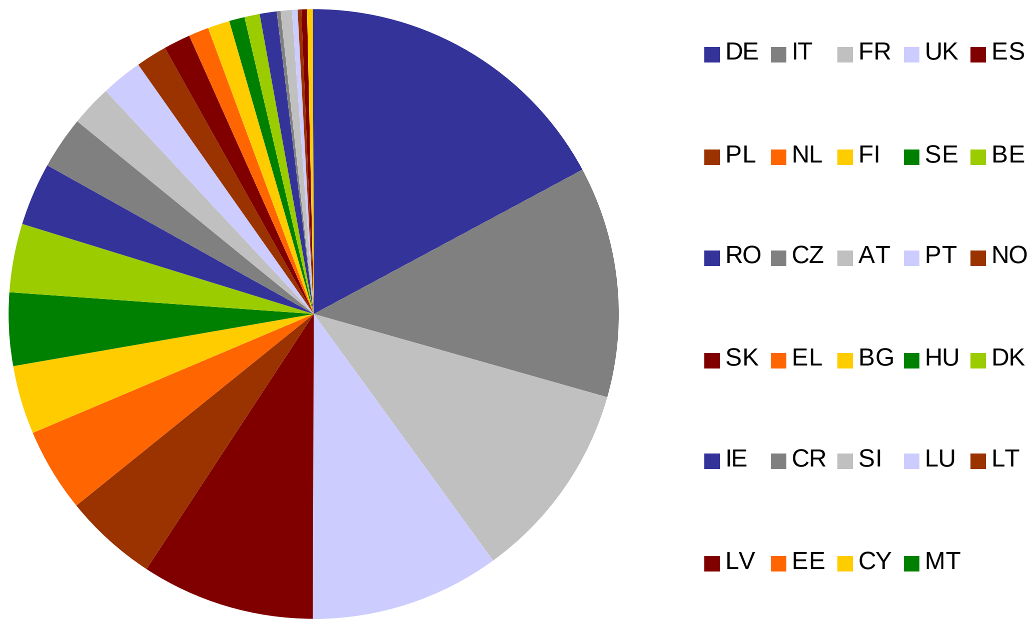


Figure 9-3: Share of total industrial energy demand by country (2004)



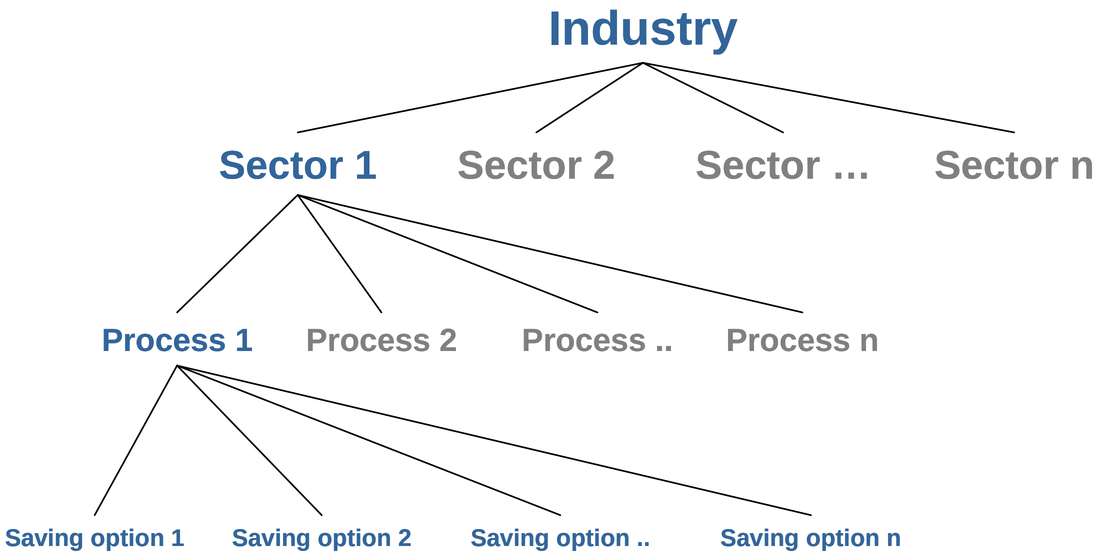
9.1.2 Sector-specific / use-specific data sources and modeling issues

9.1.2.1 Structure of the MURE-Industry model

For the assessment of saving potentials in the industrial sector the MURE-Industry model was used. It is structured according to the characteristics of the industrial sector.

First of all, this implies the division in 8 industrial sectors – to ensure, the model is compatible to Eurostat energy balances. Each of these sectors consists of several production steps, which are defined as processes. A certain activity - most commonly the annual production in metric tonnes - can be allocated to each of these processes. As for each process, also the specific energy consumption per unit of activity is given, the total amount of energy used in the process can be calculated. Given this energy demand, for all processes, options were considered that reduce the specific energy demand and, hence, increase the energy efficiency of the process.

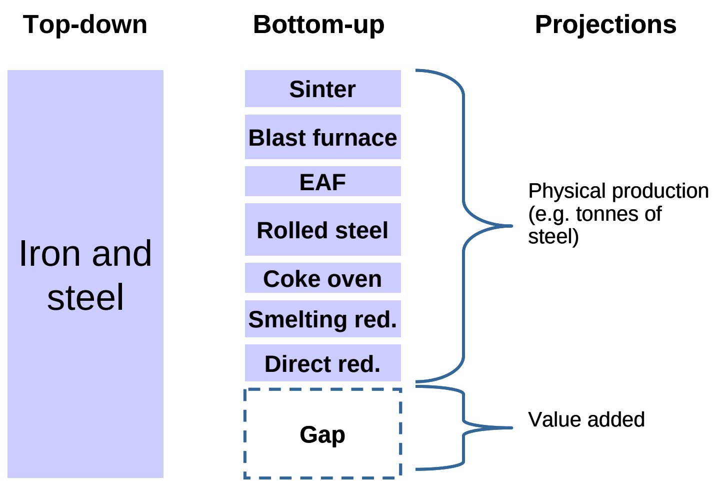
Figure 9-4: Structure of the MURE-Industry model



For the analysis of saving potentials in the industrial sector, the saving options play an essential role. For each of the saving options, information on the technical saving potential, the costs and the rate of diffusion are provided in the model.

In addition to this bottom-up information, the model contains top-down information, taken from the official Eurostat energy balances. The combination with the energy balances ensures, that no unrealistic values are included in the model and, furthermore, the whole energy demand is included in the model to complement the bottom-up technology information. Figure 9-5 shows how the bottom-up and the top-down approach are combined, using the example of the iron and steel sector. While the top-down energy demand is given in the energy balances, the bottom-up value is calculated as the sum of the energy consumption of all processes implemented for the iron and steel industry. But, as it is not possible to include all processes in the model, the bottom-up energy consumption is always lower than what is given in the energy balances. This gap is the reason why the top-down approach is also necessary.

Figure 9-5: Combination of bottom-up and top-down in the Mure-Industry model



As the objective of the model is to make projections about energy demand, projections of activity values are needed. Here, one advantage of the bottom-up approach becomes obvious: the physical production output can be taken as activity indicator, while for the "gap", for which no technical information is available, value added is taken as activity indicator.

But for forecasting the energy demand, physical indicators are much more reliable due to a variety of reasons also outlined by (Neelis et al. 2007; Schenk, Moll 2007). For this analysis, the main reason is that the specific energy consumption is much more correlated to the physical output (e.g. metric tonnes) than to the monetary output. Consequently, the monetary output (as value added) is only taken, if there was no information on the physical production available or if the process was not relevant in terms of energy consumption.

Another characteristic of energy consumption in industry is the fact that some energy using applications are only used in certain sectors, whereas others are to be found in nearly all sectors. Due to its use pattern, this second type of technology is also referred to as *cross-cutting technologies*, which are divided in heat producing and electricity demanding technologies, while the first type of technologies is named *process specific technologies* in the following.

For the following analysis of saving options and their potentials the same distinction between technologies is applied, beginning with the process specific technologies.

9.1.2.2 Sector-specific data sources

As for this bottom-up calculation approach, a huge amount of data is needed, it was necessary to make use of many different and often much specialised sources. Therefore only the most important sources will be presented. These contain databases on production statistics or energy balances as well as key publications on energy efficiency in industry.

Physical production is one main driver for energy demand and considered in our calculation on the level of the processes shown in Table 9-2. Main sources are:

- The UN database on worldwide physical production (Industry Commodity Production Statistics Database 2004) gives historical production by product and country. Often these data are slightly too disaggregated for energy efficiency purposes.
- Most of the production values in the iron and steels sector were taken from the “Steel Statistical Yearbook 2006” of the International Iron and Steel Institute. The reliability of the statistical data seems high, as the values are in accordance with other statistics.
- As all the statistical databases give only historical data, the necessary projections of production development were taken from an ongoing European research project on Adaptation and Mitigation Strategies (ADAM: http://www.adamproject.eu/). In the framework of this project, projections of production figures for energy intensive products were made in accordance with expected economic growth.

As written above, it is not possible to show all the literature sources used for the assessment of energy saving potentials in industry, but still, several key publications exist, that shall be presented here:

- A recently published report on industrial energy consumption by the International Energy Agency (IEA 2007) presents a broad overview of energy intensities and energy efficiency development over time as well as in comparison between different countries and world regions.
- For the calculation of saving potentials, it is very helpful to have information on the best practice energy consumption for distinct processes. A recent publication by Worrel et al. (2007) gives an overview of the worldwide best practice values for energy intensity in chosen industrial sectors.
- Neelis et al. (2007) give a comprehensive overview of the development of energy intensity in the Dutch energy intensive industry. Although, the focus of their study are the Netherlands, the comprehensiveness and the huge amount of information on the energy intensity of distinct products makes it a valuable source for our analysis.
- For the comparison of long-term trends, in certain industrial sectors as well as for the whole industry, the Odyssee Database (http://www.odyssee-indicators.org/) as well as IEA (2004) can be recommended.

9.1.3 Step 1 – Definition of energy saving options

Due to the heterogeneity of the industrial sector, a huge variety of different saving options is available in the different branches. This huge variety makes it impossible to consider all saving options in the model. Nevertheless, the saving options that were identified have the highest potentials and still moderate costs, so that a future application seems reasonable.

Saving potentials due to dynamics in drivers, e.g. shifts between substitutable processes towards more or less energy intensive processes are not explicitly considered as distinct saving option, still, the effects of process substitutions have an influence on the development of energy intensity and energy demand. These effects are included in the autonomous scenario for the industrial sector. **They are therefore not considered as energy saving options which are open to energy efficiency policy**. Examples of these saving potentials realised by process substitutions are:

- For the production of chlorine in the chemical industry, three main technologies can be used: the diaphragm process, the mercury process and the membrane process. Of all these, the membrane process is least energy intensive and an obvious trend, that this process continuously substitutes the mercury process, which will be forbidden in Europe by 2020, can be observed and is considered in the calculations

- The energy intensity of cement production is directly related to the clinker / cement ratio, i.e. the amount of clinker used to produce a fixed amount of cement. The more clinker substitutes, like fly ashes or granulated blast furnace slag are used, the less energy intensive is the production of cement. In our calculation, a considerable increase of clinker substitutes is considered, leading to an average clinker factor of about 71 % in 2030.

- For the production of steel, two main processes are used, the blast furnace and the electric arc furnace (some others play a minor role in Europe). Of these both, the electric arc furnace has a huge demand for electricity and thus a shift towards this process would increase electricity demand considerably while at the same time decreasing the demand for final energy. It should be noted that even in primary energy terms this process shift induces an energy saving.

- In aluminium production one can distinguish between primary and secondary aluminium. The production of primary aluminium is very energy intensive, as also there electrolysis is used. Aluminium is further also produced by recycling aluminium wastes, which is far less energy intensive. Also here, a shift towards secondary (recycled) aluminium is an important option to decrease energy demand in aluminium production.

The saving options that were distinctly considered in the modelling work are described in the following. But, as about 80 saving options are considered in the different processes, only representative examples will be shown. The following main types of saving options can be distinguished

- Heat recovery in processes where waste heat is not yet used. If the temperature level of waste heat is high enough, it is even assumed that the heat can be used do drive a turbine and thus generate electricity. This is for example the case in the blast furnace process in steel production. In other cases the waste heat can be used for preheating, e.g. scrap, which than is used in the electric arc furnace for the production of secondary aluminium. An instrument often used to fit sources of waste heat with heat demand uses, taking into account different temperature levels is the pinch analysis.
- For some processes, it was not possible to identify distinct saving options, instead a whole bundle of saving options or process improvements were considered. This bundle represents the difference between the mean energy intensity in a certain country and the best practice energy intensity for the process.
- One group of options consists in the substitution of a certain production technology by the best available technology (BAT) in terms of energy efficiency. Examples are new and improved burner types like recuperative burners, improved roller mills, improved furnaces or new catalysts.
- Besides the substitution of process technologies, in some cases it is possible to use additional technologies in order to increase the efficiency, like the improved insulation of furnaces.
- The most radical saving option, but often also the most influential is the substitution of the whole production process by an improved process. This is not to be confused with the substitution of products like discusses above which is considered to occur autonomously. Examples are the usage of oxygen as fuel in the electric arc furnace process or thin slap and strip casting in steel production.
- As not only technical saving options are considered, another group of saving options represents behavioural or management options. These options mainly address the reduction of stand-by losses by e.g. improved control systems, which are more related to actual demand.

As mentioned, to all of the processes shown in Table 9-2 saving options are allocated that increase the energy efficiency of the process.

9.1.4 Step 2 – Technology costs

In the last chapter, a short overview of the saving options considered was given. Already the types of saving options that were presented show that it is often difficult or not possible to allocate costs to the saving options, as for example it is not possible to draw an adequate system boundary. Moreover, energy efficiency is often not the main driver for the implementation of saving options related to process improvement, thus their costs can often not be allocated to the energy saved. Main driver to implement these options is perhaps a general process improvement or the reduction of costs.

Furthermore, when bundles of saving options were considered, it was not possible to allocate some kind of average costs to these bundles.

To conclude, explicit and reliable cost information is only available for saving options that are in fact distinct technologies like recuperative burners, improved furnaces or better insulation. In the case of saving options that represent a switch of processes or major changes in processes, the costs are much more difficult to asses and are subject to higher uncertainties. For this second type of saving options, costs were assessed by assessing at industry typical requirements for investment decisions, like a payback period of several years and combining this information on minimum payback time with the realisation of saving options.

9.1.5 Step 3 – Definition of the four scenarios

As for the other sectors, also in the industrial sector, four scenarios are defined. The autonomous development, which assumes no political or behavioural changes, represents the baseline development. Thus, it is assumed, that even in the autonomous scenario some saving options will be realised in companies. Two scenarios represent an economic saving potential with different policy intensities. The fourth scenario is not connected to economic decisions; it shall present a technically possible path for fostered energy efficiency development, assuming that energy saving technologies take up and diffuse through the market regardless of cost-effectiveness.

Based on the development of energy consumption in these four scenarios, we calculate three different saving potentials that represent the difference of energy demand in each scenario to the energy demand in the autonomous scenario.

Due to the structure of Industry and also the MURE-Industry model, the differentiation of the scenarios is done the following way.

For each saving option, two different diffusion rates are implemented. One is related to the autonomous development and the other to the remaining three scenarios. In order to differentiate the economic potential scenarios from the technical potential scenario, for each saving option the cost-effectiveness is calculated. Some saving options turned out to be not cost-effective under given assumptions, while others were cost-effective. Consequently, the sum of the cost-effective saving options representing the economic scenario is lower than the saving potential calculated by summing up all saving options, which represents the technical scenario.

Furthermore, two economic scenarios are distinguished, by applying two different discount rates in cost calculations, one of 8 % and another of 30 %. The high discount rate shall represent high expectations in terms of payback time in industry. The lower discount rate represents a cost-effective scenario from an economy wide viewpoint, leaving aside the high expectations about payback time.

As only restricted information is available on the costs of many saving options, the economic-potentials have to be interpreted with caution. Some saving options, that might be economic, but for which it was not possible to quantify costs, were only included in the technical potential. Thus, the two economic potentials might be too low in comparison to the technical potential; that is why they have to be interpreted as lower bound for the economic potentials.

Furthermore, it must be kept in mind that with a bottom-up approach it is never possible to consider all saving options especially in a long term time horizon. Still, our approach shall consider the most important options in terms of saving potential, although, it can always happen that new highly effective options are found that could not be foreseen at the time of this study.

Table 9-3: Overview of the definition of the four scenarios for industrial process technologies

Scenario	Definition
Autonomous scenario	Low diffusion rate
Economic scenario (low policy intensity)	High diffusion rate but taking into account only cost-effective saving options (30 % discount rate)
Economic scenario (high policy intensity)	High diffusion rate but taking into account only cost-effective saving options (8 % discount rate)
Technical scenario	High diffusion rate (maximum boundary given by stock and lifetime of technologies)

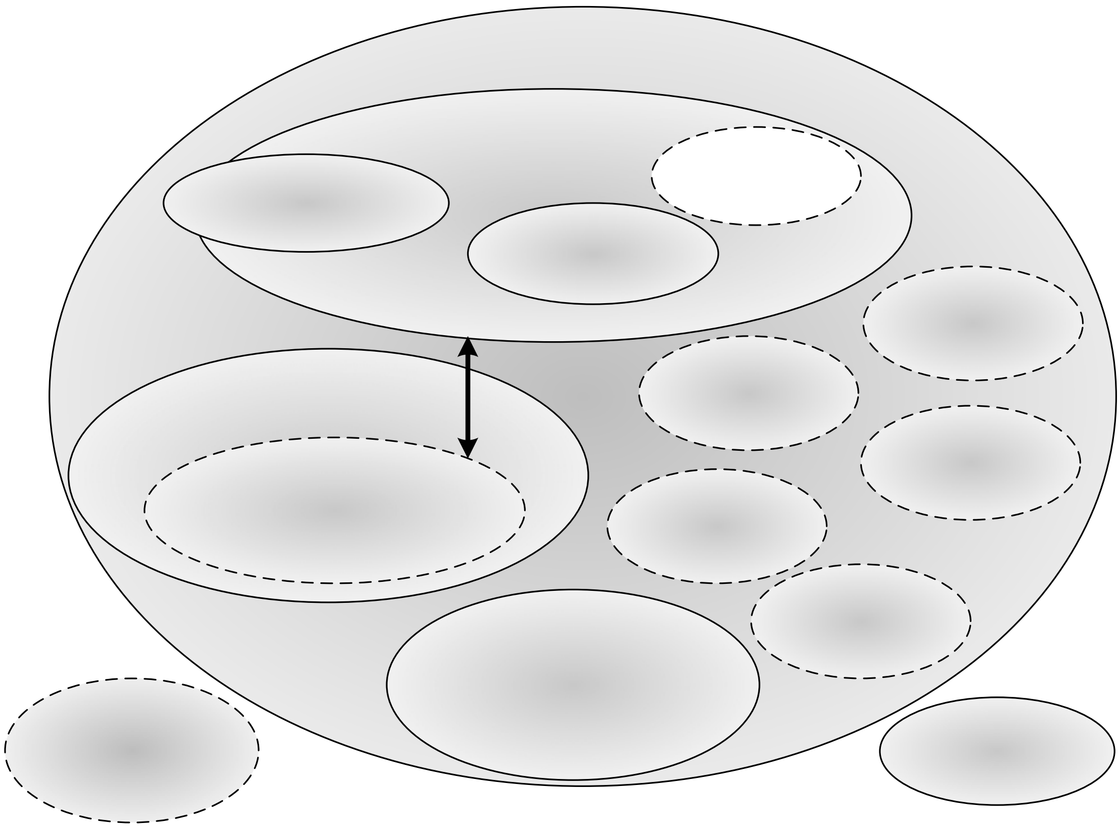
9.2 Electricity consuming cross-cutting technologies

9.2.1 Description of the sector/end-use

In contrast to the household or even the commercial sector, electricity is used for a much wider variety of purposes and appliances in the industry. Most systems are individually designed according to characteristics of production processes, which often differ between companies.

An overview of the possible uses of electricity in the industry gives Figure 9-6. The figure shows the most common applications, but still, many are not included.

Figure 9-6: Cross-cutting technologies (CCTs) in industry – system boundaries



Nevertheless, by choosing the most relevant technologies, it is possible to include a larger part of the electricity demand in the model. Depending on the country specific structure of industry, the share of CCT changes slightly, but is in average about 70 % of the total industrial electricity consumption, considering electric motors and lighting as CCT (for more details see Figure 9-7).

As electric motors make the biggest share in electricity demand, five of the six CCT are some kind of electric motor systems, thus electric motors play a central role in our assessment of efficiency potentials. In the following, the chosen technologies are described.

Pumps are the CCT with the highest share of industrial electricity demand, which is estimated to be about 12 % in Europe. Especially the paper industry has a very high share of pumps in electricity consumption, mainly used for pulp and water pumping (Sulzer Management, Winterthur 1997).

Fans are mainly used in industry for cooling, drying, suction cleaning or for the ventilation of rooms (Hoffmann, Pfitzner 1994). A huge variety of different types of fans are utilised in the industry, which all have varying efficiencies. According to Radgen (2002) they account for about 9 to 17 % of electricity demand of the industrial branches.

Compressed air is used in industry for a variety of different applications, like pneumatic drives for tools, fogging and varnishing as well as for suction and cleaning. The advantage of compressed air in comparison to the direct usage of electricity is mainly its flexibility (Fraunhofer ISI 2003). Thus, for many applications compressed air is often preferred, despite its higher electricity demand.

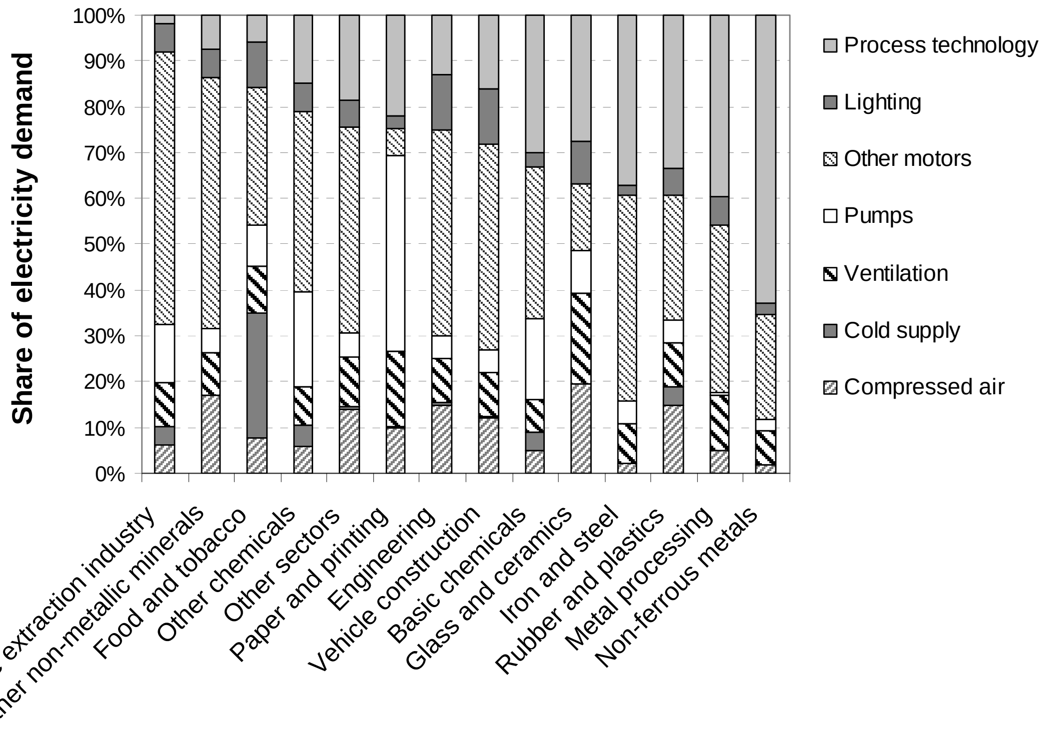
Cooling systems are not as widespread through the industrial branches as other CCT are. They are mainly used in the food sector, for cold storages and refrigerators and in the chemical sector for low temperature processes.

Other motor appliances shall represent all motor systems that are not covered by the systems described above. This group is very heterogeneous and includes for example conveyors, centrifuges, elevators or mixers.

Lighting systems in industry are either using fluorescent lamps or high intensity discharge lamps (HID), representing between 37 and 63 % of electricity demand for lighting in Europe respectively (IEA 2006). Thus industrial lighting is far more efficient than residential lighting.

To give the quantity of saving potentials and their costs not only in relative terms but also in absolute values for the industrial sector of a whole country, we needed to identify the absolute energy demand in any of the considered motor systems. Therefore we estimated the share of every motor system in the total electricity demand of each industrial sub sector (see Figure 9-7), based on a literature analysis and several expert interviews (see next literature overview).

Figure 9-7: Share of cross-cutting technologies by sector



9.2.2 Sector-specific / use-specific data sources and modelling issues

Two main groups of studies are available that assessed the saving potentials in cross-cutting technologies. The first covers the SAVE-studies, which analysed energy consumption and saving potentials for efficient electric motors in general (Almeida et al. 2001), for the usage of variable speed drives (Almeida et al. 2000) and also in ventilation systems (Radgen 2002), pump systems (ETSU et al. 2001) and compressed air systems (Radgen, Blaustein 2001).

The second group covers studies done in the framework of the European Directive on Energy using products. The studies are life cycle assessments of energy using products and they aim at assessing environmental as well as monetary impacts of these products. Furthermore, they show improvement potentials and suggest suitable political instruments. Important for the analysis of cross-cutting technologies are mainly the studies under lot 11, which cover electric motors (Almeida et al. 2007), fans (Radgen et al. 2007) and pumps (Falkner 2007).

The field of lighting is comprehensively described in IEA (IEA 2006)), covering the status quo of lighting usage, technology descriptions, saving options and according policy instruments.

9.2.3 Step 1 – Definition of energy saving options

To asses the saving potentials we related certain saving options to any of the cross-cutting technologies; for example the repair of air leakages in compressed air systems. As we included about 50 saving options in total, it is not possible to describe each of the saving options in detail; instead the following summary shall give an idea about what type of options were considered.

As shown, most of the considered cross-cutting technologies are *motor systems*. Due to the similarity of motor systems, there are several saving options that can be applied to more than one system. Examples are the usage of a motor with a higher efficiency (Almeida et al. 2007), or the direct coupling of motor and driven application, which avoids friction losses in a belt driven system.

Also the choice of high efficiency *pumps, fans* and *compressors* leads to considerable savings (Radgen et al. 2007). The optimisation of the ductwork is another often very effective saving option; this is especially the case for compressed air systems, for which only small leakages in the pipes can be responsible for huge energy losses (Radgen, Blaustein 2001 p. 49). In all systems the possibility exists to lower so called standby losses by improving control systems that are related to the real demand of an energy service. Control systems are especially interesting in combination with a variable speed drive, which is an inverter that controls the input frequency to the motor and thus also the motor’s rotation speed (Almeida et al. 2000). Variable speed drives are in particular efficient for pumps systems that are often controlled using a valve, which decreases the flow of a fluid by increasing friction in the pipe, but leaves the rotation speed of the motor constant.

For *pumps*, the possibility exists to soften the surface by coating it with glass or resin to reduce friction losses and also increase the durability, (Gudbjerg, Andersen 2007).

Lighting systems are somewhat more different to the presented motor systems. A lighting system consists of a lamp, a ballast, cables, control mechanisms and light fixture. All these components have influence on the efficiency of the whole system.

Using electronic instead of magnetic ballasts can decrease the electricity consumption by about 25 % at constant luminous efficacy (Meyer et al. 2000 p.111).

Besides technical improvement options a high saving potential can be realised using improved and demand related control systems. These can be simple like more and better located light switches and also time switches or more complicated systems including motion detectors and photometers that allow to adapt the illumination level to the actual demand (Carbon Trust 2006 p.5).

For any of the saving options we calculated saving potentials after the following methodology.

For some CCT comprehensive analysis of saving potentials exist, like the study conducted by Radgen et al. (2002; 2001) on compressed air and ventilation systems.

In these cases, the literature values were taken and slightly extended as well as updated.

In cases where no data was available, case studies on saving potentials in certain companies were used as basis for own estimates, which were done analogously to Radgen et al. (2001) using the following equation:

$$Pot_{tech, Rem, t} = Pot_{tech, Ref} * (Sh_{Applicable} - Sh_{Applied, t})$$

For each saving option a technical saving potential, $Pot_{tech, Ref, t}$, is calculated as average value from the case studies. This is corrected by the share of cases or companies in which the saving option is applicable, $Sh_{Applicable}$, and the share of companies that have already applied the option at a certain point in time, $Sh_{Applied, t}$. Result is the remaining technical saving potential at this point in time, $Pot_{tech, Rem, t}$.

The next step is to shift the viewpoint from single saving options to the whole set of saving options which can be applied to increase the total efficiency of a distinct CCT. This widening of system boundaries implies several consequences.

First of all to mention is the influence that saving options have on the potentials of other saving options. This effect can be explained using the example of a compressed air system. In this example, two saving options exist to increase the efficiency of the whole system. The first is the replacement of the motor by a high efficiency motor and the second is the repair of air leakages in the ducting system. It is assumed, that the motor replacement will lower the total energy consumption by 5 % while the repair of air leakages will contribute 10 % to the reduction of total system energy consumption. If now, it is chosen to first repair the air leakages, and thus reduce energy consumption by 10 % leading to a remaining consumption of 90 %. Now, the saving potential for the motor replacement is decreased to 5 % of the remaining 90 %, which means 4.5 % when related to the initial energy consumption of the compressed air system. This reduction of saving potential is accompanied by a reduction in the cost of saved energy.

In general it can be said, that this effect always appears, when more saving options are related to the same "energy flow" or target, only then they can influence the height of each others' potentials. This is also the reason, why this phenomenon was not discussed above in the section on process specific saving potentials. For cross-cutting technologies, we allocated about 10 saving options to each technology, while we allocated far less saving options to each of the processes in chapter 7.4. Thus, in the second case, with less saving options for each process, the interactions are also less, if not marginal.

Two main consequences can be observed that have to be considered when analysing saving potentials:

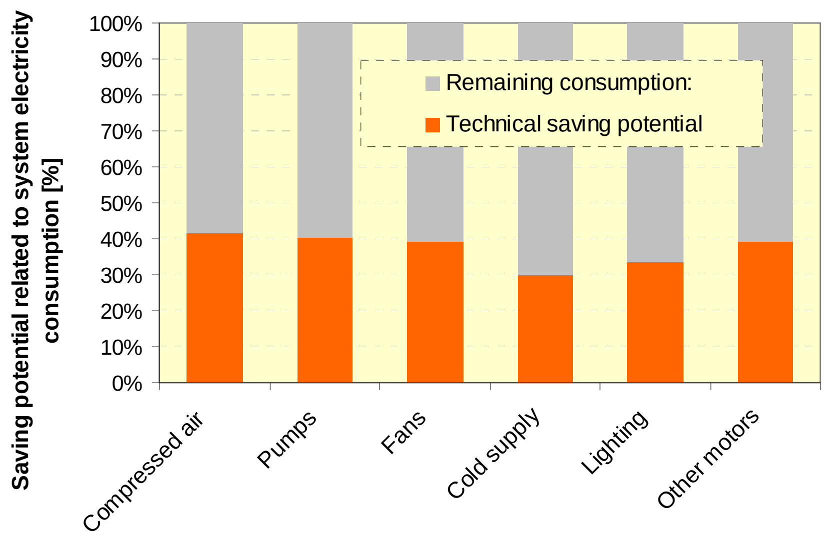
- The cumulated saving potential of many saving options is lower than the sum of all the distinct potentials

- To calculate the "corrected saving potential" assumptions on the ranking of saving options have to be made, because this ranking of saving options has a direct effect on the height and costs of every saving potential.

In our approach we decided to consider these interactions between saving potentials by ranking them from the most to the least cost-effective option. Knowing the ranking of saving options, it is possible to calculate "correction factors" to reduce the height of their potentials. This calculation method has to be kept in mind, when analysing the resulting abatement cost curves; this correction method makes already expensive options even more expansive, because the amount of saved energy (and thus saved energy costs) is lower.

Considering the given methodology and its restrictions, the resulting relative saving potentials for any of the CCT are given in Figure 9-8.

Figure 9-8: Relative long-term technical saving potential by application



9.2.4 Step 2 – Technology costs

In contrast to the assessment of costs for process technologies in chapter 9.1.4, for cross-cutting technologies it is more often possible to find or calculate cost data as the saving options concerned have a more modular structure and system boundaries are easier to draw.

Most important principle for the cost assessment is that only "premium costs" were considered. For energy efficient motors that would mean only the price difference to standard motors is relevant, not the whole motor price. In general one could say only the cost share that can directly be related to the efficiency improvement is considered. This is especially relevant the more non-energy efficiency benefits (or disadvantages) a certain technology has. Nevertheless, in many cases such a differentiation is not feasible, due to the high level of detail of the information needed.

This focus on "premium costs" has another implication on the market diffusion of all saving options that represent an alternative investment in a more efficient technology (for example high efficiency motors). As only the price premium is considered, the diffusion is directly restricted by the rate of renewal of the motor stock. Only if, for example a standard motor shall be replaced, the high efficiency motor can be installed. In the case of electric motors, a lifetime of 20 years would also be the minimum time period needed for the complete diffusion of high efficiency motors in the stock.

Besides the assessment of costs in the base year a second important assumption is the development of costs over time. The assumption of constant costs over 25 years seems relatively unrealistic and a decline of costs would be expected. Nevertheless, as the empirical basis is very thin, we used a simple model to implement cost degression; that means the standard experience curve model, described for example by the IEA (2000). It is assumed that cost reduction is directly correlated to the experience gained with a certain product. The critical variable in this concept is the learning rate, which determines the slope of the cost reductions. A doubling in cumulated experience leads to a relative decrease in costs in the height of the learning rate. In our model we assumed rather low learning rates, from 1 to 10 % depending on the potential for cost reduction of the saving options.

When constructing experience curves the relevant system for which the costs shall be analysed has to be chosen. In our study the system is as broad as possible, from the production of the product to the installation in the firms. Thus, according to Neij et al (2003) the productions as well as the market perspective are included in the calculations and the costs are related to the whole process of applying a saving technology. This represents the fact, that cost reductions are possible everywhere in the production chain and for our purpose it is not important where the cost reductions take place.

Like for the market diffusion as well for the cost development, there is not much data available on energy efficiency technologies. Most studies on cost reduction have been carried out for supply side technologies like wind or solar energy.

Nevertheless, as many of the saving technologies considered in our study are at the beginning of their market diffusion, a general tendency towards price reductions seems realistic, at least more realistic than constant prices until 2030.

As indicator for the experience often the cumulated capacity produced or installed (Neij et al. 2003) or the cumulated energy supplied are used on the supply side. Analogously on the demand side we use as indicator the cumulated energy saved by a certain saving technology, which is an approach also used by Jakob et al. (2004) for building insulations. We decided to choose the cumulated energy saved and not the cumulated installed saving potential as many of our saving technologies are organisational measures for which the learning does not stop with the implementation of the measure but continues. This effect can only be implemented by taking a wide system boundary and thus the cumulated energy saved as experience indicator.

Nevertheless, for some saving technologies the contrary is true. For example for high efficiency motors, as for most "real technologies" not much learning can be expected after having installed the motor in a company.

$$P_t = P_0 * X_t^{-E}$$

P_t Price in year t

P_0 Price in base year, $P_0(X=1) = P_t/(X_t^{-E})$

X Indicator for cumulated experience: cumulated saved energy

E Experience parameter, which determines the slope of the curve; it is directly related to the progress or learning rate: $E = \log_2(1\text{-learning rate})$

Equation 9-1: Experience curve (compare IEA 2000 p.10)

As there is only little empirical data available on the cost development of energy saving technologies, we assumed three different cases for the slope of the cost reduction curve and grouped the technologies according to their expectations for cost reductions.

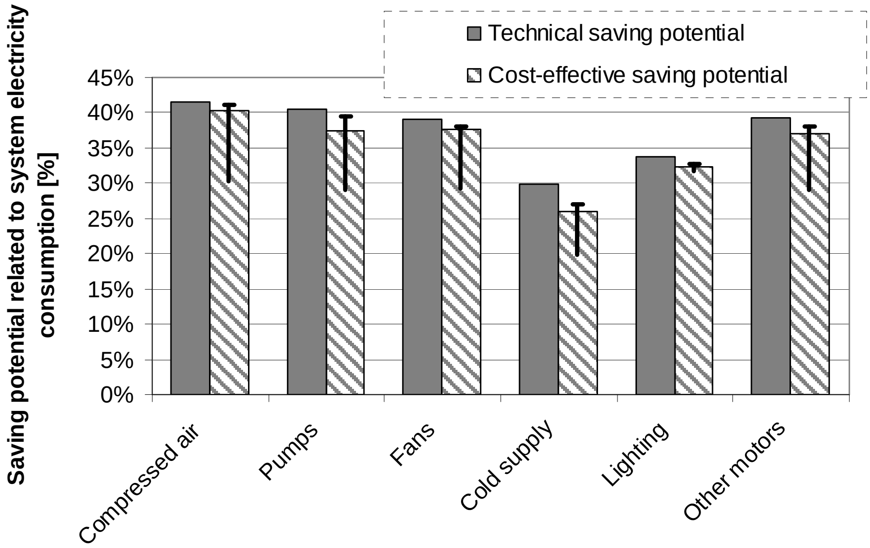
- A learning rate of 1 to 3 % is assumed for material-intensive technologies, like for example high efficiency electric motors with low possibilities for further cost reductions due to the high share of material costs.
- For material-extensive technologies and knowledge based or management saving options we assumed a learning rate of 5 to 7 %, because more possibilities exist to decrease costs by further improvements in productivity.
- The highest learning rate we assumed was 10 %, mainly for technologies that are based on microelectronics and for which stronger cost reductions have been observed in the past. Examples are control systems in general or more specific variable speed drives for electric motors. Duke et al. (1999 p.52) observed a learning rate of 11 % for electronic ballasts (1986-97, USA, market price to cumulated sales).

In general, the assumed learning rates are rather moderate and will more likely underestimate the decline in costs.

The learning rates are assumed exogenously, thus they can not be influenced by for example R&D investment. Induced learning is not considered in the model.

The resulting cost-effective saving potential can be observed in Figure 9-9. The small vertical interval lines represent different assumptions on electricity prices and discount rates.

Figure 9-9: Relative technical and cost-effective saving potential for cross-cutting technologies (2030)

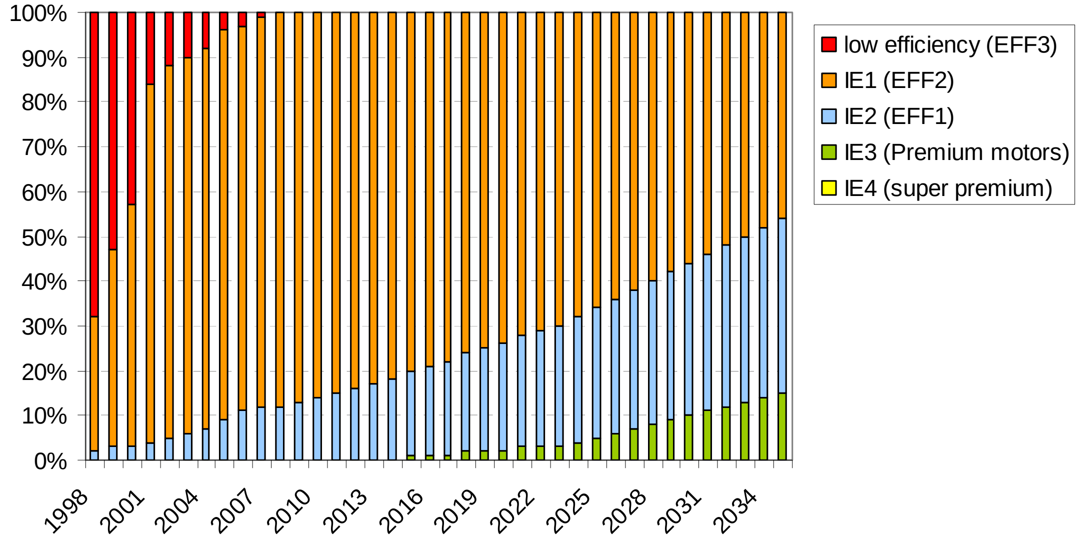


9.2.5 Step 3 – Definition of the four scenarios

The four scenarios are defined the same way as for process technologies described in chapter 9.1.5.

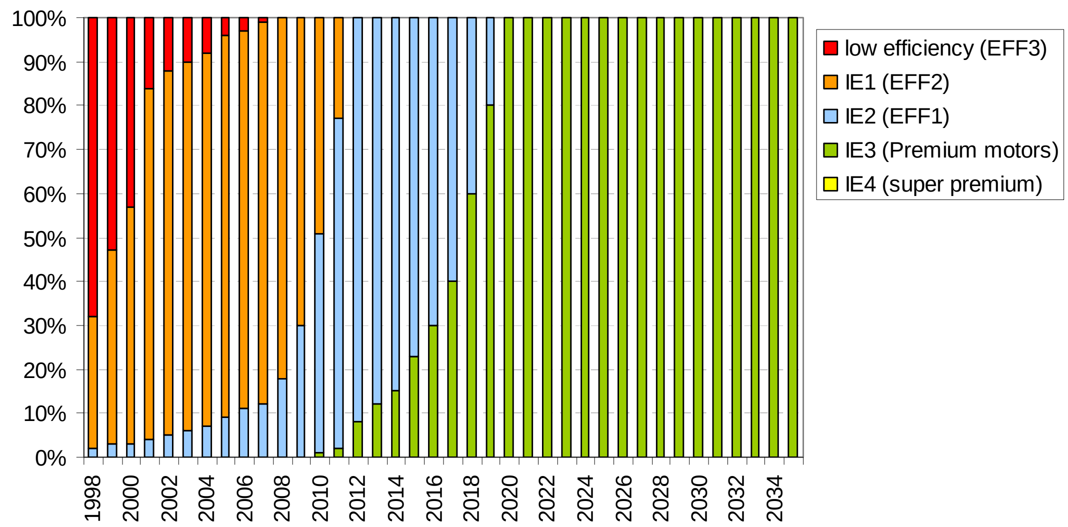
For electric motors a stock model was used, comparably to these used to determine the saving potentials in the residential sector. Two essentially different developments were assumed. In the first case, the autonomous development the labelling of electric motors is not being changed and no additional policies are to be applied. The resulting market shares are given in Figure 9-10. The type of motor efficiency class (IE1 to IE4) corresponds to the classification proposed by the International Electrotechnical Committee (IEC), with IE1 motors being the least efficient. Compared to the current labelling scheme in the EU, the new IE1 class corresponds to the current EFF2 class and IE2 has equal requirements as EFF1. Thus the IEC labelling scheme goes beyond the currently applied scheme in the EU, by establishing the more ambitious class IE3. The concept of very efficient IE4 motors is so far not well defined. Although this very efficient class is expected to exist in the future, so far no requirements in terms of efficiency values have been made. Thus, IE4 motors are not explicitly considered in the calculations.

Figure 9-10: Electric motors market share “no additional policies” (EU25; until 2005 empirical data)



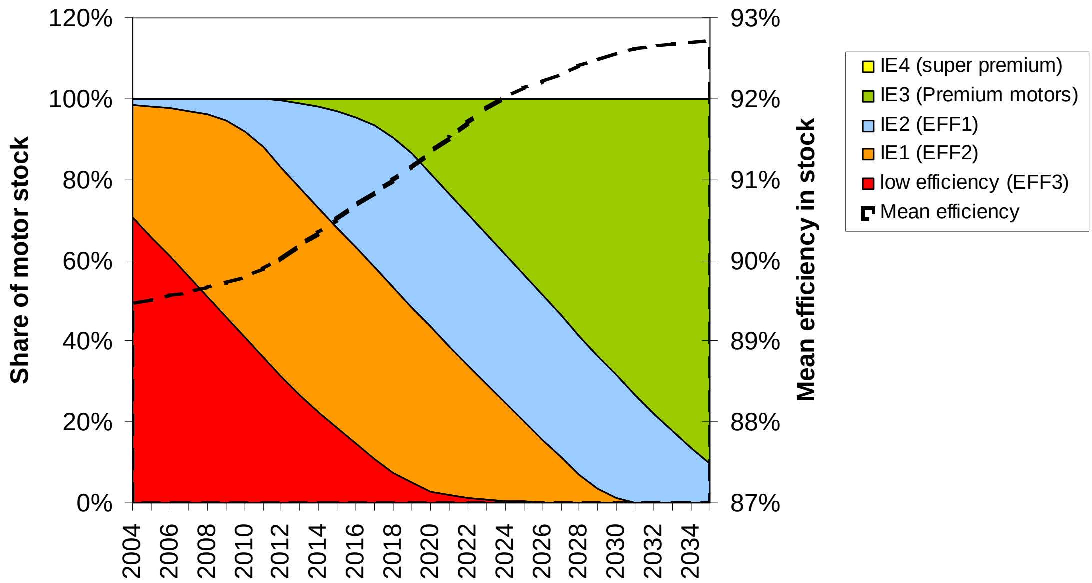
In the second case, we assumed new policies that introduced minimum energy performance standards (MEPS) for electric motors sold in the EU. It was assumed that from 2012 onwards only motors with an efficiency equivalent to EFF1 (IE2 according to international classification) are sold. By 2020 the new standard will be even stricter and IE3 motors will present the new minimum efficiency level (see Figure 9-11).

Figure 9-11: Electric motors market share “New standards” (EU25; until 2005 empirical data)



Given the above market shares the resulting motor stock can be calculated. As for the years before 1998 no data is available it is assumed that the years before have the same shares as 1998.

Figure 9-12: Resulting stock of electric motors "New standards" (EU27)



As data on the share of electric motors by efficiency class is only available for the EU as a whole it is assumed that the shares are the same for each country.

Nevertheless, using energy efficient electric motors is only one saving option of all the options described above. But given the variety and the high number of saving options only for electric motors a stock model was used. The diffusion over time of the other saving options was realized by using logistic diffusion curves, which look very similar to the diffusion of electric motors but are not connected to a market share and a product stock.

To summarise, the definition of the scenarios is done comparably to process related saving options. That means, two different diffusion rates were considered and for the economic scenarios the additional criteria of cost-effectiveness has to be fulfilled. To represent an economic low policy intensity scenario we used a 30 % discount rate while we considered an 8 % discount rate for the economic high policy intensity scenario. See also Table 9-4 for an overview of the scenario definitions.

Table 9-4: Overview of the definition of the four scenarios for industrial electricity consuming cross-cutting technologies

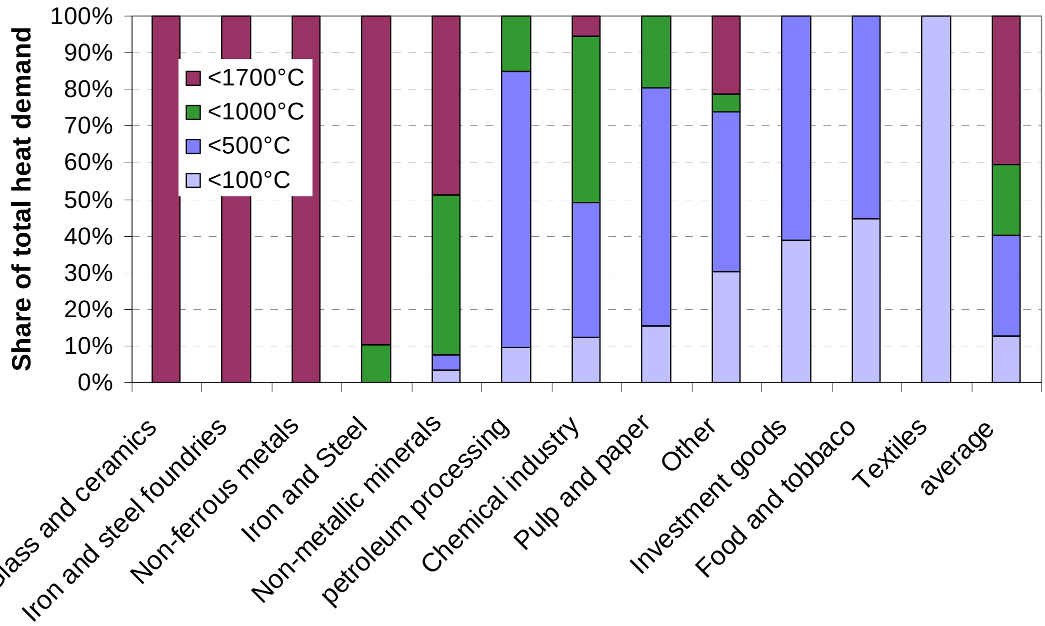
Scenario	Definition
Autonomous scenario	Low diffusion rate
Economic scenario (low policy intensity)	High diffusion rate but taking into account only cost-effective saving options (30 % discount rate)
Economic scenario (high policy intensity)	High diffusion rate but taking into account only cost-effective saving options (8 % discount rate)
Technical scenario	High diffusion rate (maximum boundary given by stock and lifetime of technologies)

9.3 Heat generation cross-cutting technologies

9.3.1 Description of the sector/end-use

Heat is used in industry for a variety of different purposes. While in some cases, heat with a temperature of less then 100°C is sufficient, other branch specific processes need temperatures far above 1000°C. While the low temperature levels can be supplied with ordinary boilers, for the high temperature processes, industrial furnaces specially designed for certain processes are necessary. Figure 9-13 shows in detail which temperature levels are needed in which industries. Although, the calculation methodology is based on a rather old study by Hofer (1994) the method used is still valid, as the main processes in industry have not changed considerably.

Figure 9-13: Heat demand by industrial sector and temperature level (own calculations based on Hofer (1994)

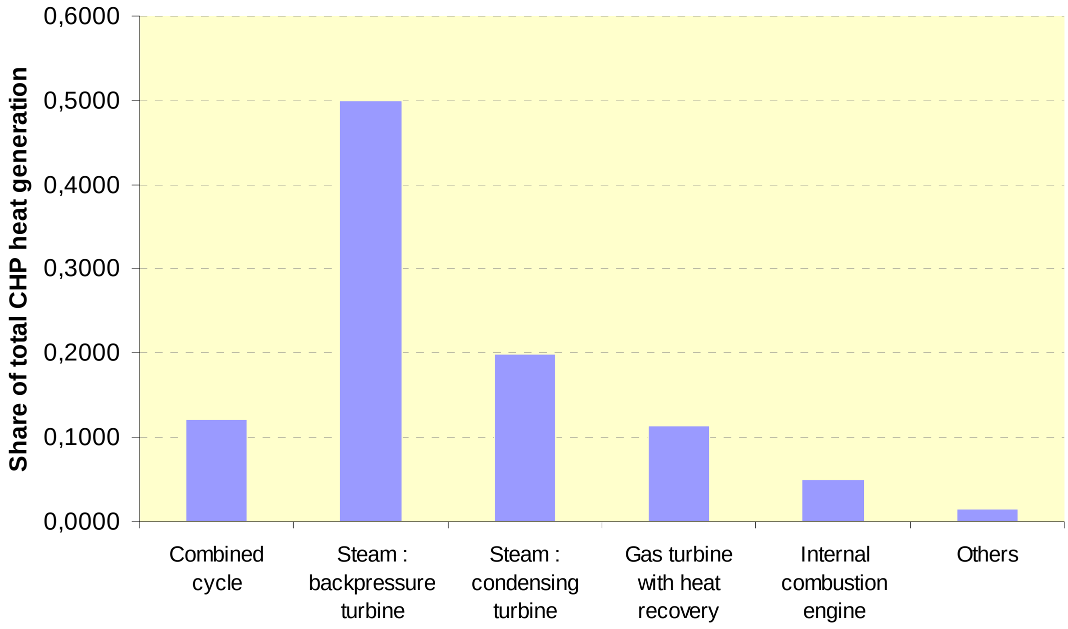


For CHP generation in Europe, a variety of different technologies are applied, which shall be presented briefly, based on the overview given by (IZT Institute for Futures Studies and Technology Assessment GmbH et al. 2002 p.44). The classical and most used CHP technology is the steam turbine, either as backpressure or condensing turbine, which allows it to use any kind of fuel as input. The disadvantage of steam turbines is the relatively low electrical efficiency of below 20 per cent. In industrial CHP, gas turbines were more common, due to their high reliability and large range of power. They account for a higher electrical efficiency but only permit gasses as fuel, traditionally natural gas. The highest electrical efficiency can be reached with combined cycle gas turbines (CCGT), which are a combination of a gas turbine, followed by a steam turbine. Their main advantage, the high efficiency of above 40 per cent, led to a tripling of electricity production in CCGT in the EU15 from 1994 to 1998 (Eurostat 2001 p. 14), while in the same period, the electricity production from steam turbines stayed constant. Also for internal combustion engines a remarkable increase in electricity generation could be observed. They are mainly applied in smaller units and for more decentralised and flexible purposes.

Figure 9-14 shows the share of heat generation of each of these technologies in total CHP generation. Unfortunately, only aggregated data for public and industrial (autoproducers) CHP heat generation was available. In industry, the share of steam turbines might be lower and the usage of gas turbines might be more extensive than shown in this figure.

All these technologies permit heat production with a maximum of around 500°C. Thus, their application is bounded by the temperature pattern of heat demand. As shown in Figure 9-13 heat below 500°C is concentrated on certain sectors, which, consequently, have the highest potential for further CHP utilization.

Figure 9-14: Heat generation by CHP technology (Danko 2005)



9.3.2 Sector-specific / use-specific data sources and modelling issues

Data sources for heat demand and heat generation technologies are provided by Eurostat (Danko 2005; Eurostat 2001). They show heat generation by country, sector and technology used. To make estimations on saving potentials the mean efficiencies by countries are essential.

Further specific information on the country specific structure of CHP technologies and also political instruments are given by several COGEN Europe studies (http://www.cogen.org/publications/reports_and_studies.htm)

9.3.3 Step 1 – Definition of energy saving options

The saving potentials in heat generation are calculated, comparable to the saving potentials in electrical cross-cutting technologies. Still, there are some necessary differences due to the characteristics of heat generation, which will be explained in detail.

The model contains eight technology groups for the generation of heat in industry, of which only boilers represent the separate heat production (SHP), all other technologies are applied for combined heat and power generation (CHP). This already shows the focus on CHP.

Technologies considered are:

- Steam backpressure turbine
- Steam condensing turbine
- Gas turbine
- Combined cycle
- Fuel cell
- Internal combustion engine
- Boiler
- Others

Main input variable for the calculations is the heat demand of industry. It is derived in the first part of the model, taking into account the development of production and value added as well as certain sector specific energy saving options and assuming an average combustion efficiency of 85 %. In the next step, the total heat demand is allocated to different temperature levels, as the possibilities and the technologies for supplying heat depend strongly on the temperature needed. For example temperatures below 100°C are mainly used for water and space heating and also in the food industry, whereas temperatures up to 500°C are needed for many different industrial processes. The usage of heat in temperature levels above 1000°C is very specialised and process specific. In these high temperature levels, industrial ovens are the source of heat production.

Two general groups of saving options in heat generation are implemented: improved diffusion of combined heat and power replacing separate generation of heat and electricity and improved efficiencies in separate as well as combined heat generation. Both will be explained in the following.

Beginning with the increased diffusion of CHP plants, which substitute separate heat and electricity generation. An autonomous and a maximum diffusion of CHP, which distinguishes between industrial sectors and CHP technologies, are exogenously included in the model. As upper threshold for the CHP diffusion it is assumed that CHP can only be applied to the share of heat demand, which has a temperature below 500°C. CHP technologies producing heat considerably above 500° are so far not available but might be in the future. One option might be the solid oxide fuel cell (SOFC) that allows for heat levels up to 900°C, which might clearly increase the potential for CHP application in the industrial sector.

The calculation of the energy savings realised by faster CHP diffusion is a methodologically crucial aspect. In this modelling approach we applied a methodology in accordance with Eurostat (Eurostat 2001) that calculates the savings by comparing the CHP system with an alternative system that might be in place, if the CHP unit would not have been built. The saving potential is defined as the difference between primary energy demand of both systems. Consequently, the choice and definition of the alternative system - the system that was replaced by the CHP plant – has considerable influence on the results. If the alternative system is a modern Combined Cycle Gas Turbine (CCGT) for electricity generation with efficiency of about 60 % and a modern boiler for heat generation having efficiency above 90 %, the savings allocated to the substitution by CHP are rather small if not negative. On the other side, if the efficiencies of the average power plant of an economy are assumed as alternative to CHP, the savings allocated to CHP are considerably higher, if not too high.

In our calculations, we assumed an alternative system that produces electricity with an efficiency of 45 % and heat with an efficiency of 85 %.

$$ES_{t,p,c} = \frac{HP_{t,p,c} - HP_{t0,p,c}}{\eta_{heat,ref}} + \frac{(HP_{t,p,c} - HP_{t0,p,c}) * \rho_{p,c}}{\eta_{el,ref}} - \frac{HP_{t,p,c} - HP_{t0,p,c}}{\eta_{heat,real,t0,p,c}}$$

With

$ES_{t,p,c}$	Energy savings in year *t*, technology *p* and country *c*
$HP_{t,p,c}$	Heat produced in year *t*, technology *p* and country *c*
$\rho_{p,c}$	Average ratio between electricity and heat production of CHP for process *p* and country *c*
$\eta_{heat, ref}$	Reference heat production divided by primary energy input
$\eta_{el, ref}$	Reference electricity production divided by primary energy input
$\eta_{heat, real, t0,p,c}$	Real heat efficiency of CHP unit in year *t*, technology *p* and country *c*

Equation 9-2: Calculation of savings due to increased CHP diffusion

The second group of energy savings considered in the model are the savings due to improvements in energy efficiency, leaving aside structural effects. In all technologies mentioned above, a potential for improvements in energy efficiency exists. Important to consider is the fact that the model works with average efficiencies of plants already operating, which also includes rather outdated technologies with low efficiencies. Thus, improvement potentials are considerably higher than they are for new plants only.

This approach is direct based on the most recent Eurostat statistics on CHP (Danko 2005). The remaining saving potential is calculated as difference between the average efficiency of a certain heat production technology in a certain country and the highest efficiency of the same technology of all countries. As the differences in average efficiencies between countries are considerable high, also the saving potentials differ a lot. In case there was no data available, the average efficiencies of either EU25 or EU15 were taken.

Although, this approach considers certain technologies for heat generation, it is not really a technology focused bottom-up approach, as it mainly works with top-down statistical mean values. This has several implications. As for the efficiency improvement, no distinct "energy efficiency technologies" were evaluated, it is not possible to allocate costs to the saving options and potentials.

Main simplifications:

- The heat temperature levels by branch are assumed to be equal in all countries and to be constant over time
- It is assumed, that at most 90 % of the heat demand below 500° can be supplied by CHP. This restriction shall display the heterogeneity of heat demand.
- Growth rates of CHP are assumed to be equal in all sectors of each country.
- In the official Eurostat statistics, which were used as basis for the calculations, the shares of CHP technologies were not given separately for public supply and autoproducers (industry). Consequently the technology shares used include also CHP technologies used in public supply

9.3.4 Step 2 – Technology costs

The economic situation of industrial CHP plants in Europe is strongly depending on the development of gas and electricity prices. Falling electricity prices after the liberalisation of the electricity markets deteriorated cost-effectiveness of CHP plants, especially, when gas prices were increasing (Horn et al. 2007 p153).

As a result of the more challenging price situation, about 60 % of companies that were running industrial CHP plants estimated their plants to be threatened by shutdown due to high costs (Horn et al. 2007 p.153)..

According to Horn et al. (2007) also the CHP law has not considerably improved the situation for CHP plants. Only in some individual cases it could be proved that the CHP law supported the establishment of new CHP plants.

The present energy prices allow for most industrial CHP plants to produce electricity with costs comparably to wholesale prices, but facing a higher uncertainty due to the fluctuant heat demand. As a result payback periods are rather long, especially in comparison to the companies' core businesses.

Consequently, without additional strong support, industrial CHP production is not expected to increase significantly.

Building on the described economic situation of CHP production, we assume for the modelling work that a CHP diffusion that goes beyond the slowly increasing autonomous trend is not economical. Thus, the economic scenarios on CHP diffusion have the same level like the autonomous diffusion scenario. Only the technical scenario experiences a much higher diffusion rate.

9.3.5 Step 3 – Definition of the four scenarios

The total saving potential in heat generation can be divided in 2 main types of efficiency improvement, as shown above. The first is the increased diffusion of CHP, meaning the substitution of separated electricity production (SEP) and SHP by CHP and the second is the improvement of mean efficiency of CHP and SHP by means of technological improvement. Both types are covered in the technical scenario.

The economic scenarios cover only the efficiency improvement, for CHP and SHP units, as it is agreed that convergence of mean efficiencies in Europe towards the best practice is cost-effective. Concerning the second type of improvement, the enhanced diffusion of CHP, this option is considered not to be cost effective - especially with regard to the last years, where without public subsidies CHP units were not built. Therefore, in the economic scenario only the autonomous market diffusion rates of CHP technologies are included, which are essentially lower than in the technical scenario.

In the autonomous scenario, even the rate of convergence of mean efficiencies in CHP and SHP between European countries is much lower.

Figure 9-15: Share of CHP in heat generation (EU27)

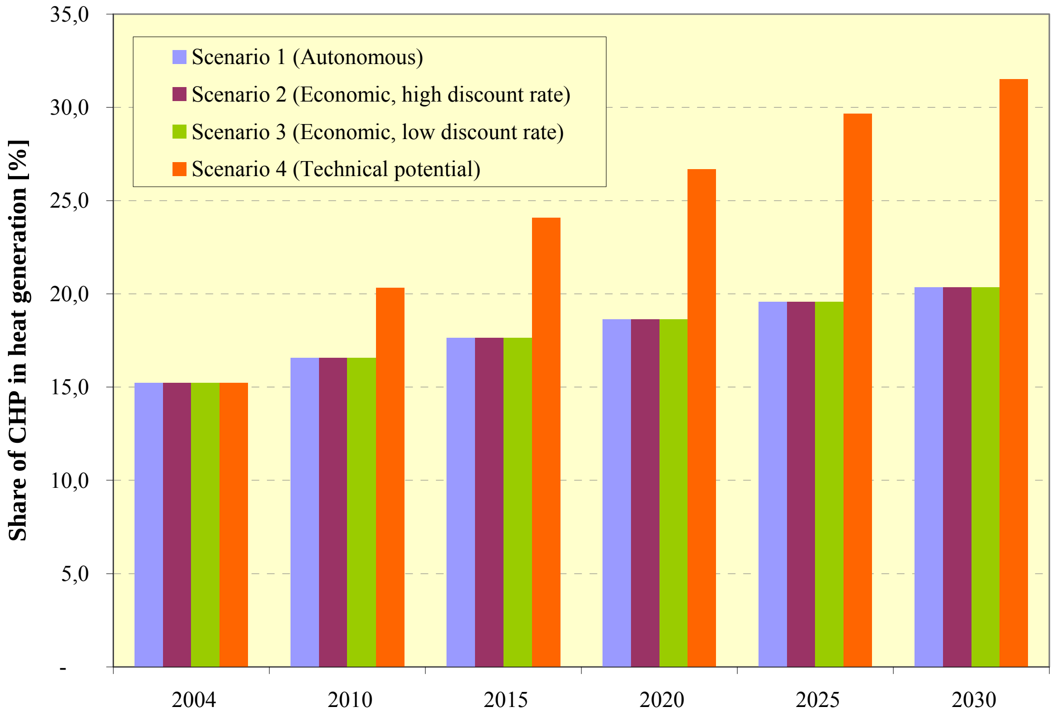


Table 9-5: Overview of the definitions of the four scenarios for heat generation cross cutting technologies

Scenario	Definition
Autonomous scenario	Low rate for CHP diffusion (extrapolation of statistical development) and low EU-wide convergence of plants' efficiency values.
Economic scenario (low policy intensity)	CHP diffusion as in the autonomous scenario; EU-wide efficiency convergence as in the technical scenario.
Economic scenario (high policy intensity)	Only one economic scenario established for heat generation technologies, because of data restrictions and due to the fact that the diffusion of CHP is non-economic under the conditions considered here.
Technical scenario	High diffusion rate of CHP (max 90% of a sector's heat consumption below 500 C to be generated in CHP plants); Fast EU-wide convergence of plants' mean efficiency values.

9.4 Results industry

9.4.1 Results process technologies

The saving of energy in certain processes means that in these processes certain products can be produced using less energy for each. Consequently, the consumption of energy per unit produced (e.g. per tonne of steel produced) decreases as energy is saved in this distinct process of production. The unit consumption is calculated by dividing the energy consumed in one year by the number of units produced in that year. This figure is often used as an indicator for the comparison of energy efficiency either over time or between countries.

The unit consumption figures given in this study do not represent single products but mostly groups of products. The example of steel will clarify this distinction. Steel can be produced using different processes of which the blast furnace process and the electric arc furnace process are separately considered in the calculation of saving potentials. Still, for the presentation of the results only one indicator is used, which is the energy consumption per tonne of steel produced. Thus, one tonne of steel shall be understood as a country specific mixture of blast furnace and electric arc furnace steel, representing the whole steel production of one country. This calculation method implies that also structural changes like e.g. the shift towards electric arc furnace steel influence the calculated unit consumption.

$$\mathrm{UC}_{\mathrm{PG,Y,C}} = \frac{\sum_{P=1}^{n} E_{P,Y,C}}{\sum_{P=1}^{n} P_{P,Y,C}}$$

$UC_{PG,Y,C}$: Unit consumption of product group PG in year Y and country C

$E_{P,Y,C}$: Energy consumption for product P in year Y and country C

$P_{P,Y,C}$: Production of product P in year Y and country C

Equation 9-3: Calculation of unit consumption

In the following the development of the resulting unit consumptions are given for the whole EU27 and for the sum of electricity and fuel input. More disaggregated results are presented the online Energy Saving Potential (ESP) database. The definition of the product groups is the following:

- Steel: blast furnace and electric arc furnace
- Paper: paper (all types)
- Glass: flat glass, container glass and other glass
- Cement: dry cement, semi-dry cement and wet cement

➢ Aluminium: primary aluminium and secondary aluminium

Figure 9-16: Energy consumption per tonne of steel produced (EU27)

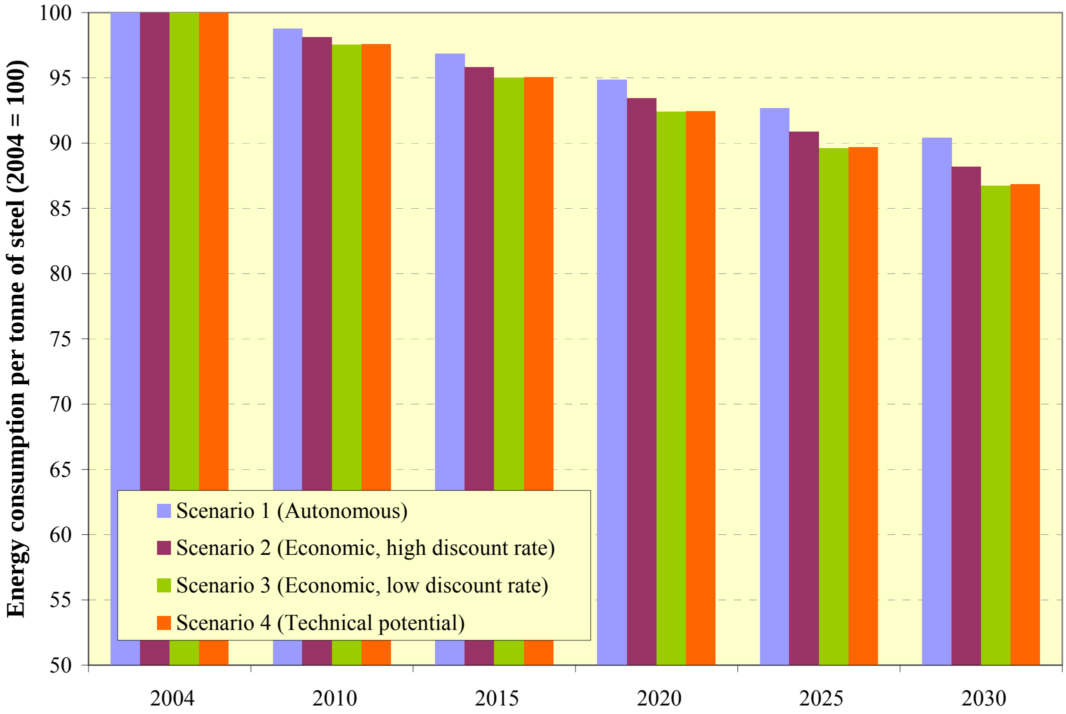


Figure 9-17: Energy consumption per tonne of paper produced (EU27)

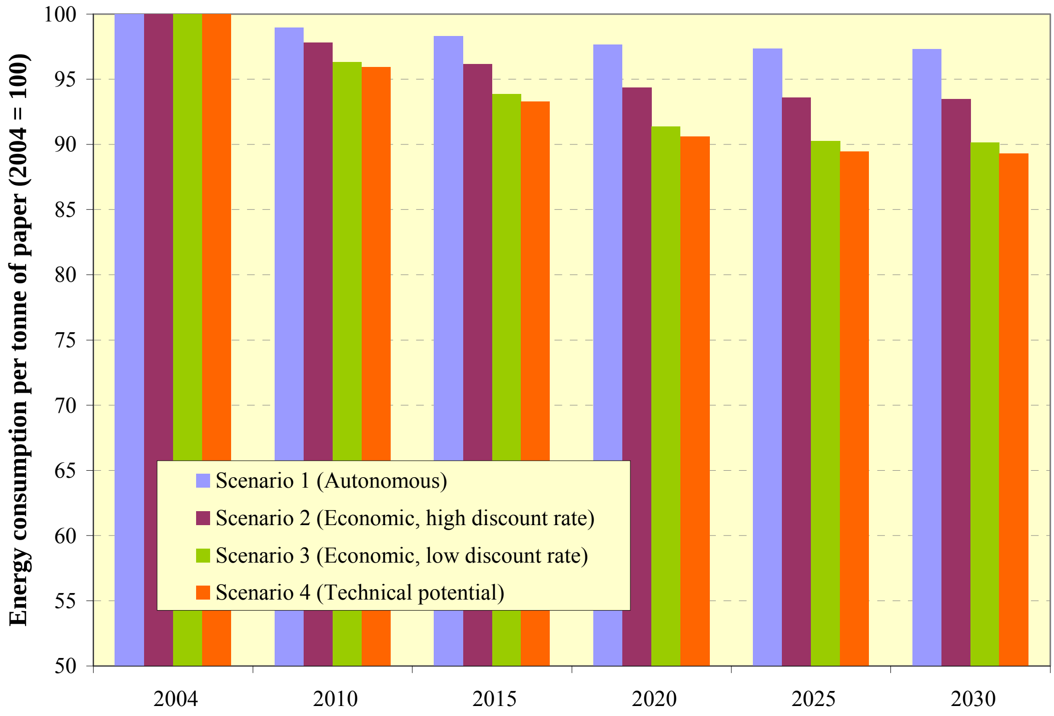


Figure 9-18: Energy consumption per tonne of glass produced (EU27)

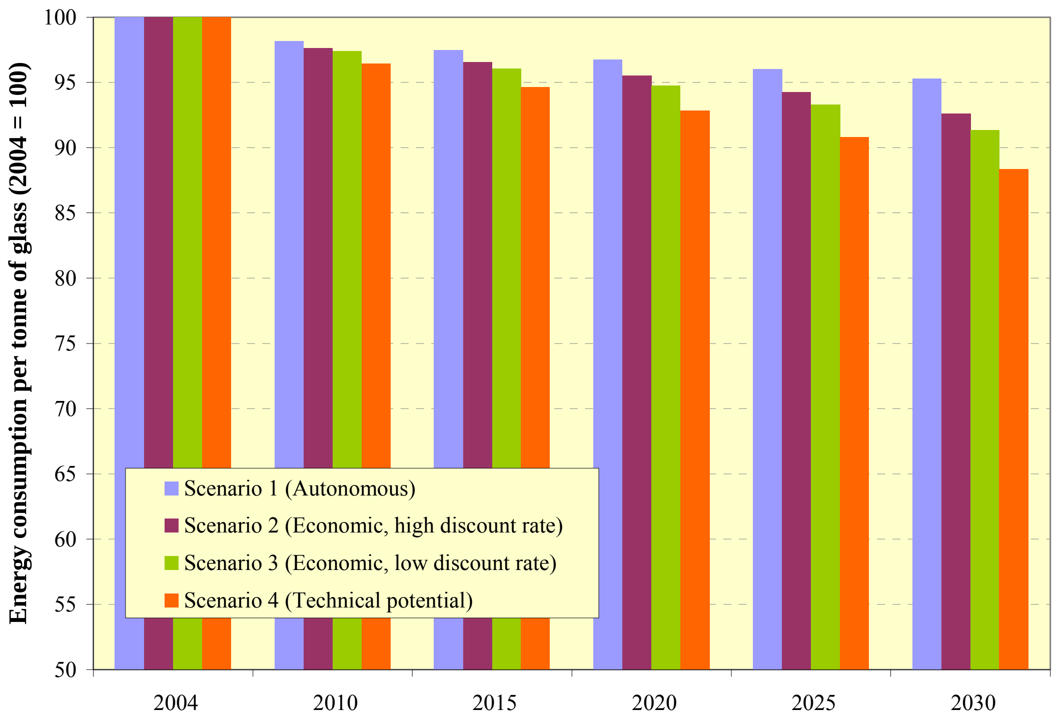


Figure 9-19: Energy consumption per tonne of cement produced (EU27)

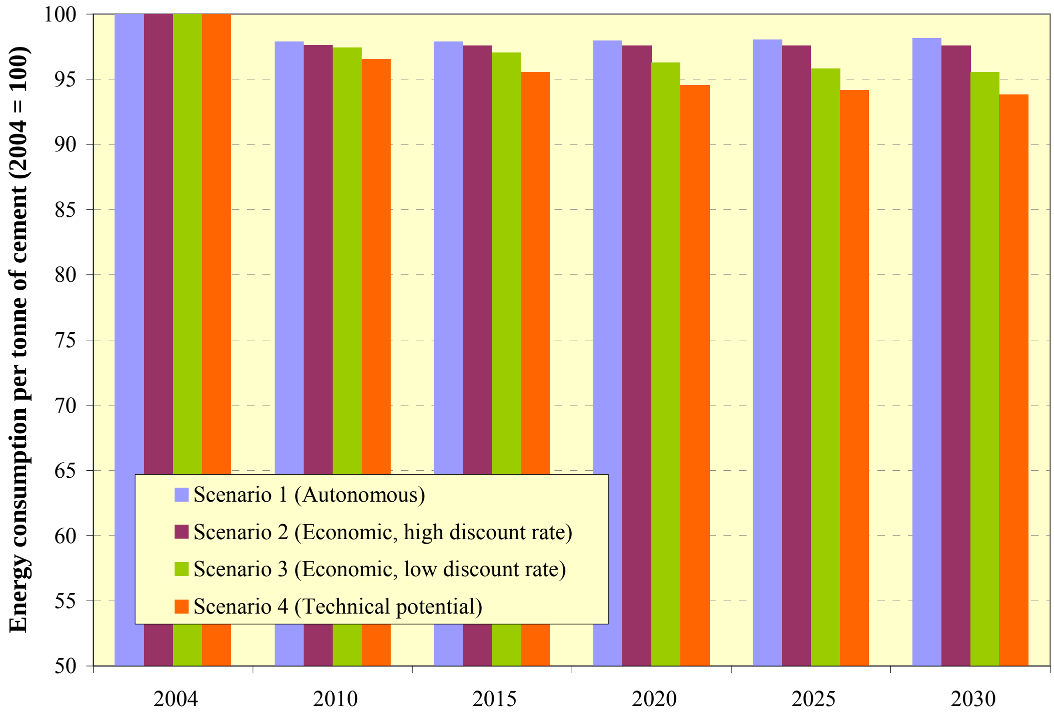
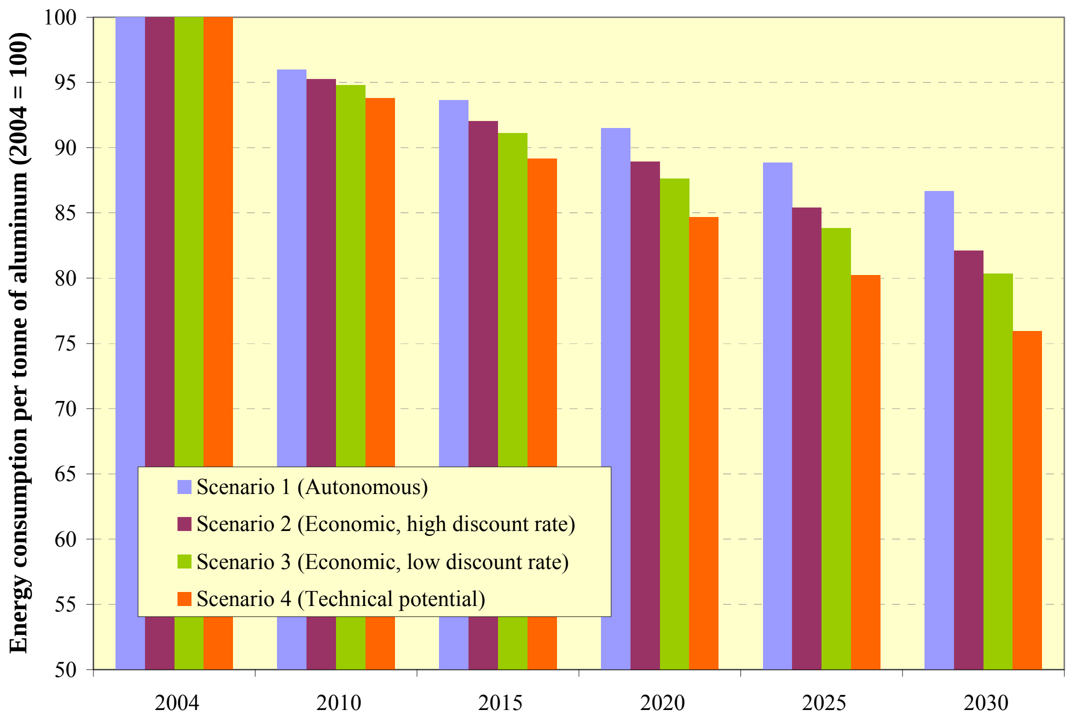


Figure 9-20: Energy consumption per tonne of aluminum produced (EU27)

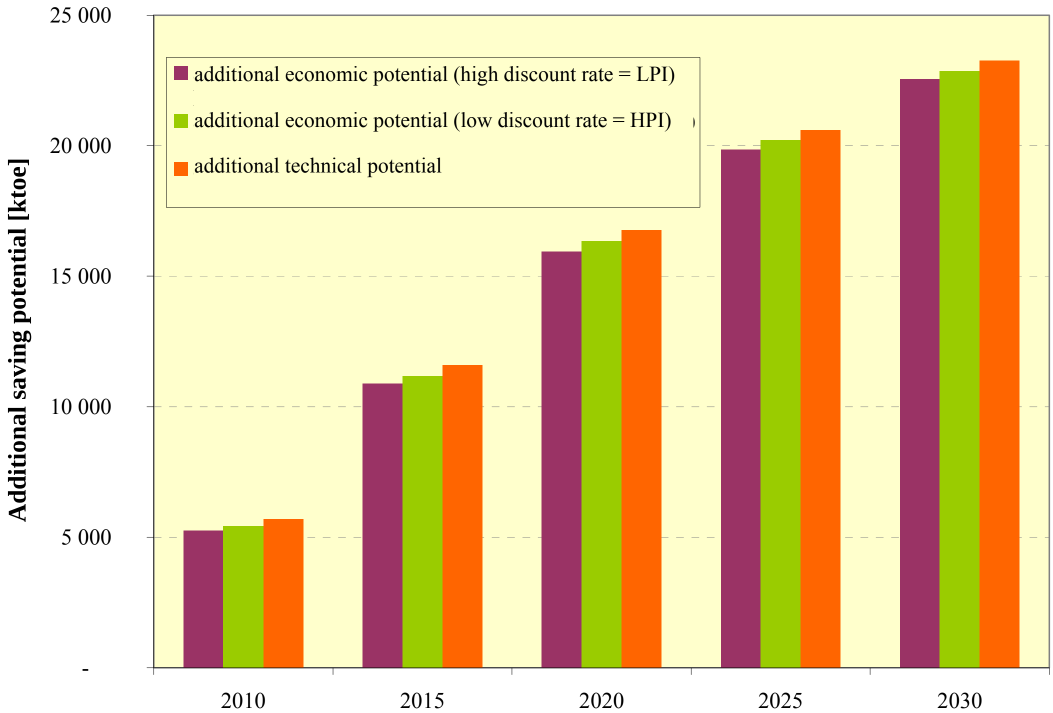


9.4.2 Results electricity consuming cross-cutting technologies

The resulting saving potentials are presented below. It is important to have in mind that the diagram shows the *additional saving potential*, which means that the potential is additional in comparison to the energy already saved in the autonomous development, which represents more or less as business as usual path. Thus the additional potential excludes these business as usual improvements and is calculated as difference between the three scenarios and the autonomous development scenario. The intention of showing additional potentials is to present only these potentials that need improved and extended policies to be realised.

Calculating the saving potentials in comparison to a frozen technology scenario would lead to considerably higher potentials.

Figure 9-21: Additional saving potential in motor and lighting systems (EU27)

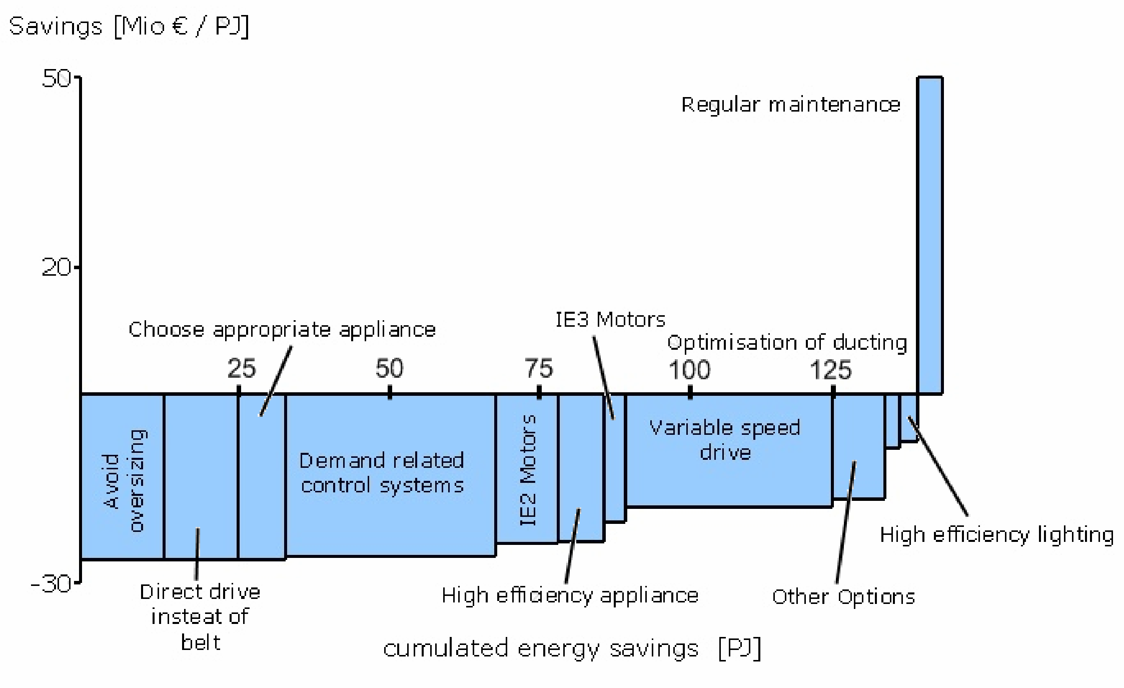


One of the main characteristics of saving options in motor and lighting systems is that the investment is in most cases cost effective and a payback time of a few years is the normal case. Consequently, the economic potentials are not much lower than the technical potential, as it can be see in Figure 9-21. The technical potential by 2030 of 14000 ktoe equals 162 TWh or 3.3 % of total industrial final energy demand (fuels and electricity).

The cost-effectiveness of these saving options can be observed more transparent in Figure 9-22, which shows groups of saving options in terms of total energy saved and specific costs for the example of Germany. As most of the options are situated below the x-axis, their costs would be negative and thus the option is cost-effective in average.

Especially for the realisation of saving options in the field of electrical cross-cutting technologies several barriers and market failures exist that prohibit the realisation of these saving options. Many of these barriers are connected to the low importance of energy consumption in the related companies. Consequently a huge part of the cost-effective saving options is not realised in the autonomous scenario. It is assumed that further policy instruments are necessary to tackle market failures in this field.

Figure 9-22: Exemplary cost curve for aggregated saving options in electrical cross cutting technologies (Germany, 2030)



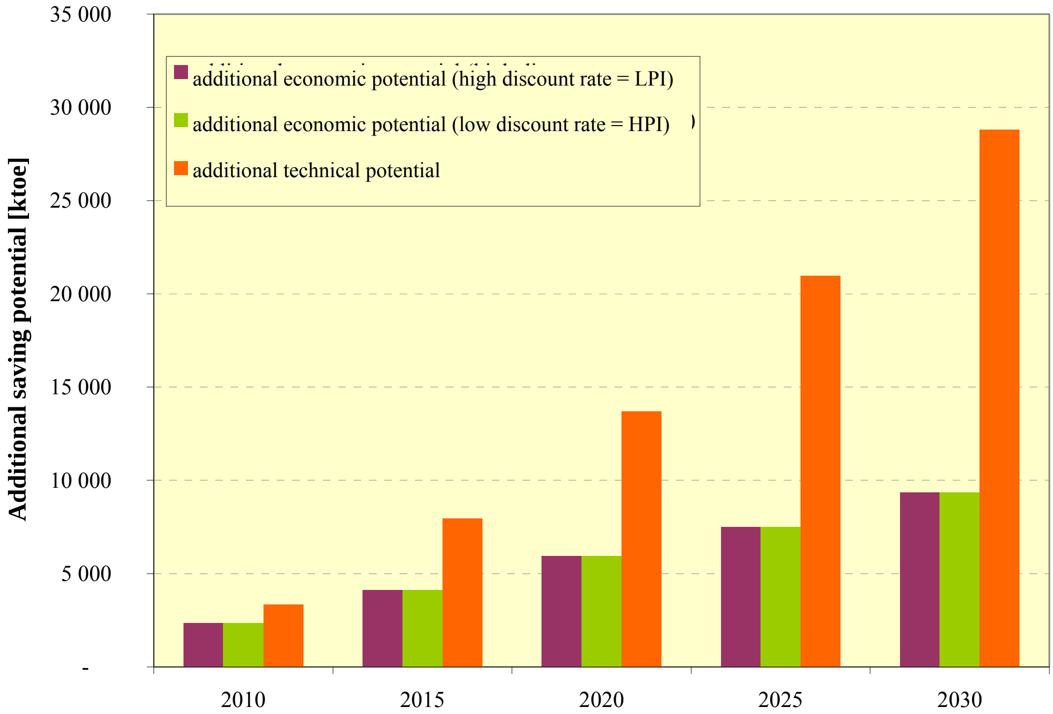
Source: compare with Fleiter (2008)

9.4.3 Results heat generation cross-cutting technologies

The saving potentials in heat generation, presented in this chapter, are the effects of two different types of saving options: the increased diffusion of CHP and the EU-wide convergence of mean efficiency values to "best practice".

As mentioned in the last chapter, for heat generation only one economic scenario has been established. The data basis had not been detailed enough to distinguish between low and high policy intensity scenarios. Consequently, the results in terms of saving potentials are equal for the two economic scenarios.

Figure 9-23: Additional saving potential in heat generation (EU27)

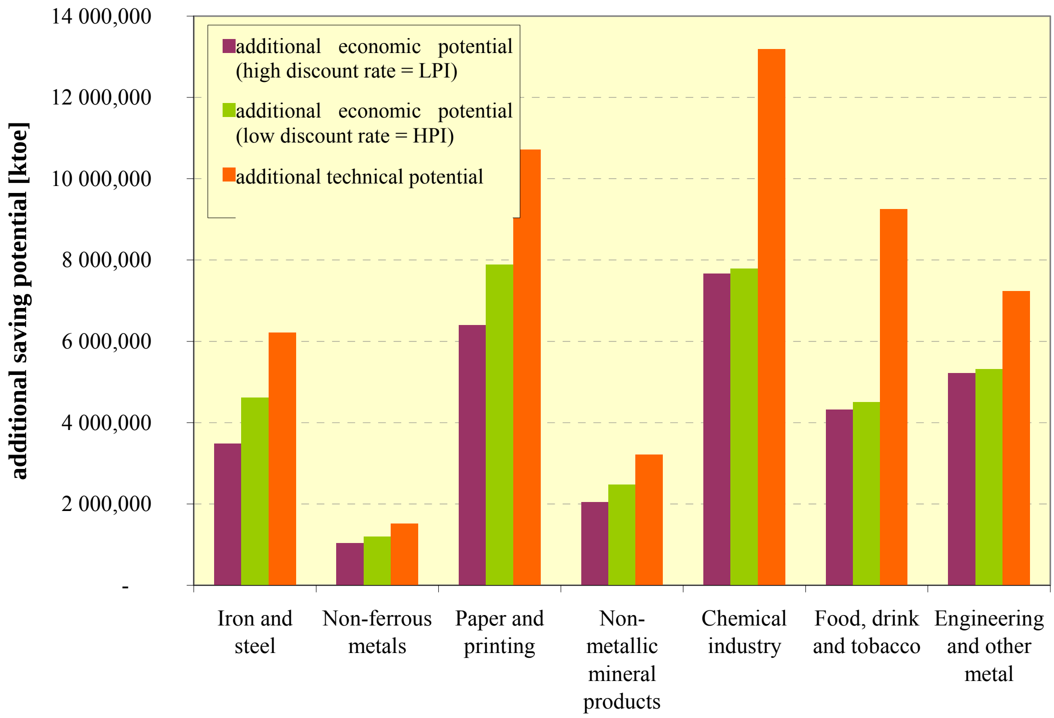


9.4.4 Results overall industrial sector

As explained in the chapters on partial results, also here it is essential to keep in mind that the diagrams below show additional saving potentials, which means that they show the difference between a chosen scenario and the autonomous scenario, which also considers a certain improvement in energy efficiency. Thus, the resulting saving potentials are interpreted as being additional to what will be realised in a business as usual development.

Due to the huge amount of data only more aggregated results are shown in this chapter. A more detailed analysis, also on the basis of specific countries, including EEA and candidate countries, can be conducted using the Energy Saving Potential database that has been developed in the framework of this project.

Figure 9-24: Additional saving potentials by sector (EU27, 2030)



The following two diagrams show the saving potentials aggregated by type of technology. The technologies are distinguished in motors and lighting (electricity consuming cross-cutting technologies), heat generation cross-cutting technologies and process specific technologies, according to the division of the foregoing chapters. Additionally, the total saving potential in industry is given, which is defined as the sum of the three distinct technology groups. The potentials in Figure 9-26 are given as share of the total projected autonomous energy demand of industry in 2030; in other words, the relative potentials are given as share of the energy demand projections in the autonomous scenario.

Even more, the category "ESD-potential in industry" shall represent a proxy for the saving potentials in sectors tackled by the ESD directive, which excludes all branches that are covered by the European emissions trading scheme (ETS). Consequently the ESD-potential is calculated as the total potential minus the potential to realise savings related to direct CO2 emissions in the sectors iron and steel, non-ferrous metals, paper and printing, non-metallic minerals and the chemical industry.

Figure 9-25: Additional saving potential by type of technology (EU27, 2030)

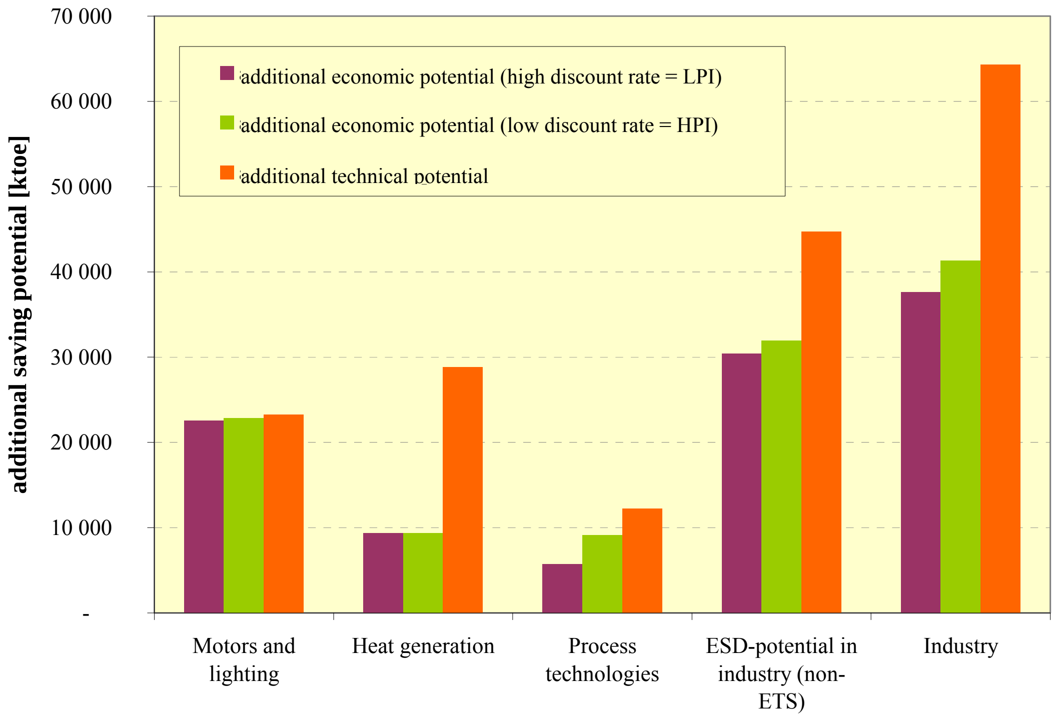
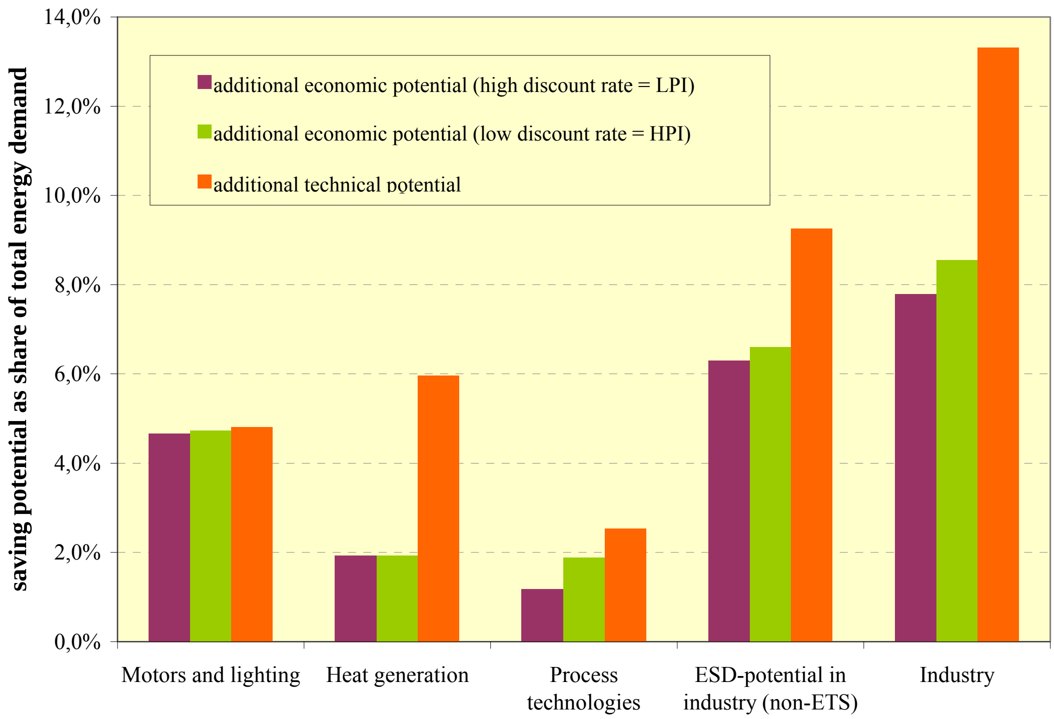


Figure 9-26: Additional saving potentials by type of technology in % (EU27, 2030)



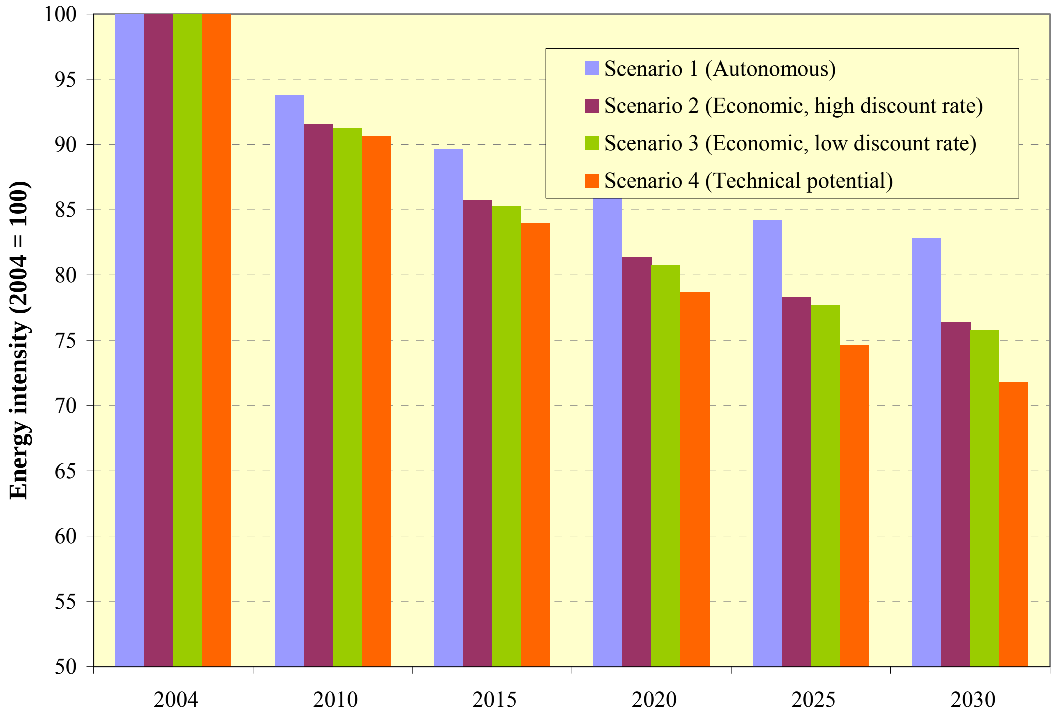
To better judge the size of the above shown saving potentials, the following explanation should help.

The additional technical saving potential in motors and lighting systems is presented to be about 4.5 % by 2030 compared to the total final energy demand in the autonomous development scenario. Because motors and lighting systems consume only electricity, saving measures aimed at these systems can only reduce electricity consumption. But only about one third (28%) of industrial final energy consumption is electricity. Taking this fact into account, the saving potential is about 16% of the total electricity consumption. Furthermore, only about 70% of industrial electricity consumption is due to motors and lighting systems. Thus, the additional saving potential is about 23 % when compared to the total electricity consumption in motors and lighting systems. It also has to be kept in mind that these 23 % are additional to an autonomous saving potential which is in this case relatively high at about 11%. Consequently, the total saving potential in motors and lighting systems is about 34 % of total electricity demand in motors and lighting systems, of course, varying between countries due to different industrial structures.

The same calculation can be made for the saving potentials in heat generation cross cutting technologies as they only refer to low temperature heat below 500°C and especially CHP is not applicable in all cases. Thus, the given additional technical saving potential of about 4.5 % is in fact above 20 % when compared to the total heat demand below 500°C and not to the total industrial final energy demand.

Following the above analysis, the remaining share of industrial final energy consumption of about 50% goes to specific processes that differ considerably between branches. For these 50 % the given additional saving potentials seem in fact low. The first explanation for this low result is a methodological one and based on the huge variety of different processes, which are difficult and time intensive to tackle in a comprehensive way in a bottom-up analysis. Thus some saving potentials might exist in some specific processes that were not taken into account in this study. The second explanation refers to the fact that these processes are mainly located in the energy intensive industries, which have very high shares of energy costs in their total costs. Consequently, the concerned companies were since long intensively looking for ways of reducing their energy consumption as it goes along with a remarkable reduction in production costs and increasing competitiveness at the same time.

Figure 9-27: Energy intensity (energy demand per value added) (EU27, Industry)



It also has to be considered that the autonomous scenario also includes savings that were realized due to dynamics in drivers, which means production shifts between different processes and products, like for instance the shift to the usage of recycled products (see chapter 9.1.3). Because the drivers are not differentiated between scenarios, they have the same effect on energy consumption in all scenarios. If drivers were differentiated between the scenarios, the gap between the autonomous and the other scenarios might be widened.

This improvement of energy intensity through structural change is exactly the same in all four scenarios and thus has the same effect on the three types of saving potentials.

Figure 9-28: Cost curve for saving options in the EU27 until 2030 (calculated with 8% discount rate, only additional saving potential)

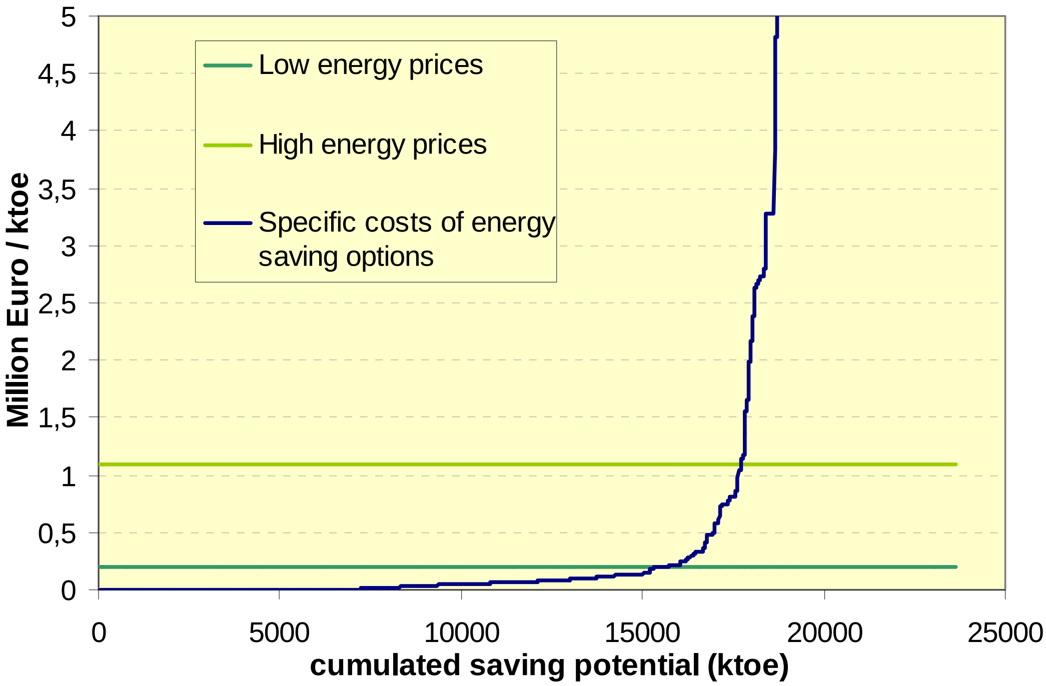
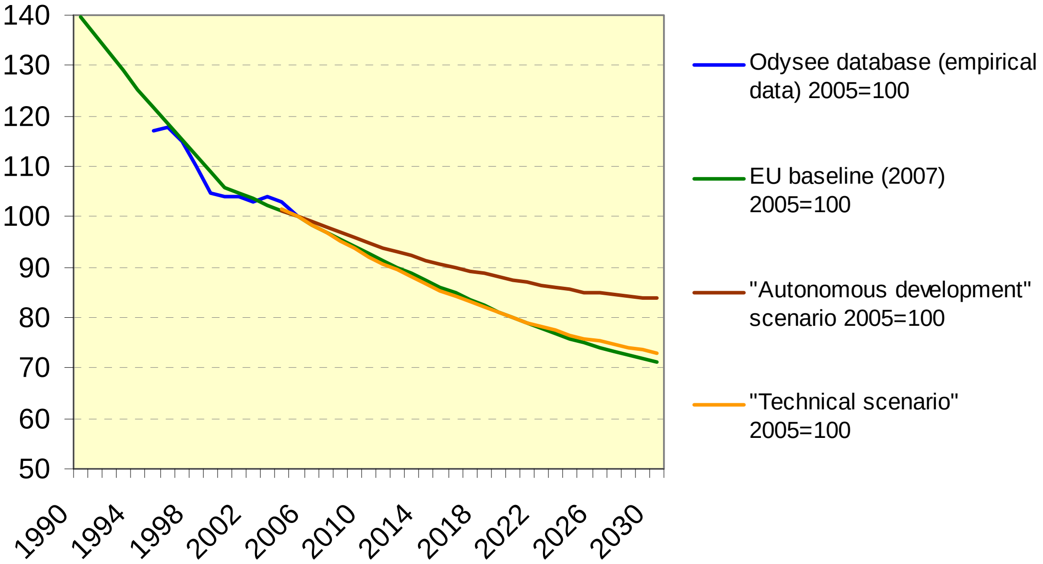


Figure 9-28 shows the marginal costs for additional (beyond autonomous) energy conservation in the EU27 industry. The curve considers the direct costs of saving options, e.g. the price premium for a more efficient electric motor. Energy costs are not incorporated in these cost figures, thus depending on the level of energy prices the cost effective saving potential is determined by the intersection point with the energy carrier price (see green lines). As this curve incorporates saving options that reduce electricity consumption as well as other energy carriers like e.g. natural gas a variety of different energy carrier price levels exists. The upper green line represents an expensive energy carrier, like electricity when bought in smaller amounts (0.11 Euro per kWh) and the lower green line represents an less expensive energy carrier, like natural gas when bought in huge amounts (5 Euro per GJ).

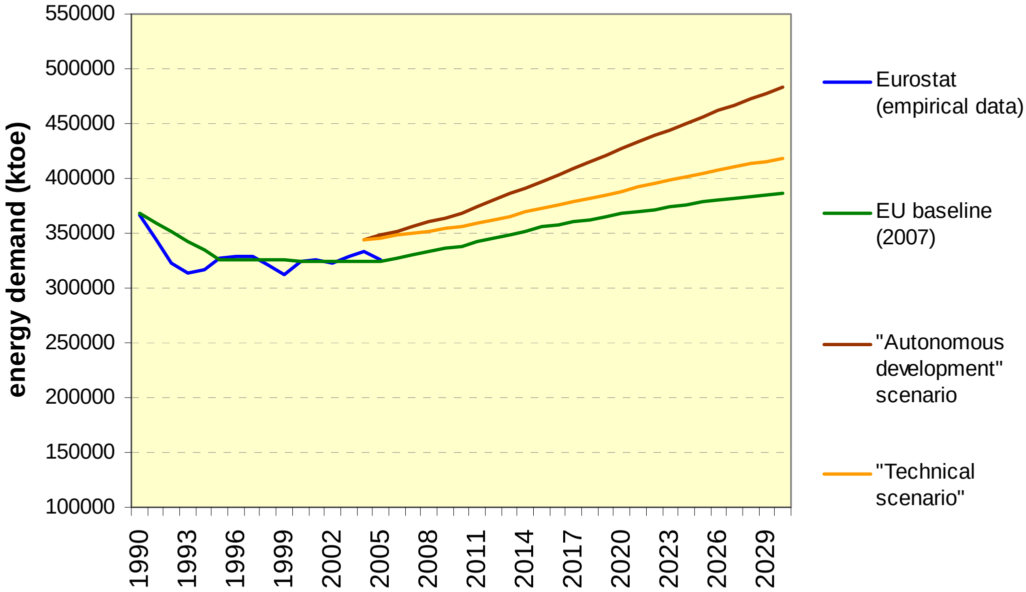
In general the curve shows a huge saving potential that can be realized cost effectively. This is the case for the whole potential beneath or in between the green energy price lines.

Figure 9-29: Comparison of industrial energy intensity development of different scenarios (Energy consumption per value added)



Comparing the energy intensity in the autonomous development scenario with the official EU baseline, it can be observed that the technical scenario is very similar to the EU baseline, while the autonomous development scenario lies considerably above (see Figure 9-29). As the value added development is considered as an exogenous variable in our modelling and taken from the EU baseline from 2007 (European Communities 2008), the similarity of the energy intensity developments indicates also comparable assumptions on the improvement of energy efficiency in our technical scenario and the EU baseline. Some explanations for this somehow astonishing result are given on the next page.

Figure 9-30: Comparison of industrial energy consumption development (ktoe)



When looking at the resulting final energy demand, it is striking that also in the technical scenario it is increasing, more or less with the same slope than in the EU baseline from 2007. In the autonomous scenario the energy demand increases even faster. The following reasons can be mentioned to explain this phenomenon.

First, the used projections on value added imply a rather strong economic growth in the industrial sector and only a very slow decrease of the share of industrial gross value added of the economy's total GDP, from 19.6 % in 2005 to 19.3 % in 2030.

Second, also the production of energy intensive products is growing in some cases (paper, aluminium, and glass) or only slightly decreasing (steel, cement) until 2030.

Unfortunately, the comparison of absolute figures between the EU baseline and our projections are difficult, due to a different energy demand in the base year 2004, which is about 3.5 % higher in our model, due to the bottom-up calculations and the fact that Eurostat figures had been preliminary when we started the modeling work. Still, the slope of both curves, the EU baseline and our autonomous scenario, are very similar, so that a downward shift of our projections to the EU baseline value in 2004 would result in a close overlapping of both curves. Consequently, our “technical saving potentials” scenario projection would be similar to the EU baseline.

Furthermore in our study we assumed that if no technological changes happened in industry, a part of the energy demand would grow directly correlated to the growth of value added (the other part related to production projections). This approach might lead to a high energy demand estimation as factors like a tendency towards higher value production which only results in higher value added but leaves output and energy demand constant, were not considered in our study, as the knowledge about these effects is rather low and would not allow a reliable quantification.

For the interpretation and usage of the calculated saving potentials in industry it has to be kept in mind that **this assessment does clearly underestimate the total saving potential**, mainly due to the following reasons.

First of all, as the concept of this study is based on a bottom-up approach, in which every single technology option had to be assessed and distinctly included in the model, it is obvious that saving options might exist that were not considered, especially when thinking of the enormous heterogeneity of energy consumption in industry. Therefore, the resulting potentials are to be interpreted as showing a possible efficiency improvement given that the assessed set of more than 150 distinct saving options will be realized. Thus the saving potential can completely be related to distinct saving options and is not an abstract estimation.

Closely related to the former point is the aspect of diminishing knowledge about technological options in the long term. Especially after 2020 new technologies might emerge, which have the potential to influence energy consumption in a revolutionary way. Technology fields with such a potential could be nanotechnology or biotechnology, but they are still conceptual and not concrete enough to be implemented in a bottom-up energy model.

As explained above, the model is structured in one part that takes into account the production of certain energy intensive industrial bulk products (e.g. steel or aluminum) and allocates distinct saving options to their production processes. Although more than 30 products are considered distinctly, they make up for about 50 percent of the industrial energy consumption and the remaining 50 percent are distributed to the countless number of remaining products and processes. For these remaining products a detailed bottom-up analysis is not possible, although there are certainly numerous potentials to raise energy efficiency. Consequently, the additional saving potential related to process technologies (see Figure 9-26) of about 2 percent would be at least 4 percent, if all processes could be considered.

Due to a lack of data, the saving potentials related to buildings in industry could not be estimated. But certainly the relative potential would be comparable to the potentials calculated for the tertiary sector.

The dynamics of production and consumption due to rising energy prices could not be considered in this study, but they might have a considerable influence on energy consumption, not in terms of technical saving options, but rather in terms of shifts towards products with lower energy intensity.

As shown in the chapter on saving potentials, in industry many potentials exist, which are related to a shift of processes towards higher energy efficiency - e.g. from wet clinker burning to dry clinker burning in the cement industry. This shift is considered for some processes in the model, only the effects are not attributed to the additional saving potential, but to the autonomous potential, because we did not calculate with several different production scenarios. Among others, this effect addresses the potentials by increased usage of clinker substitutes in cement production or the enhanced usage of recycled materials.

Furthermore, the assessment of costs is very restricted for certain types of industrial technologies, especially when these technologies are deeply integrated in the production process and when energy efficiency benefits overlap with other non-energy benefits. Thus, especially for the process technologies, the economic potentials have to be interpreted cautiously.

Especially the projection of the autonomous development is rather difficult to define and has to be interpreted more in the sense of an assumption. Over the last decade energy intensity reduction in EU15 industry had been about 1% annually, which lies in between the autonomous and the technical scenario calculated in our study.

10 Tertiary sector

10.1 Heat uses in the tertiary sector

10.1.1 Description of the sector/end-use

As seen above, enormous potentials exist in the residential sector and energy savings are also possible in the non-residential building sector. But, the situation of non-residential buildings regarding distribution of building ages and types in the base year is not transparent. There are mixed use buildings together with residential buildings, e.g. bars.

The stock of buildings is defined as educational, health care, shopping and leisure as well as office buildings. The division of the buildings is due to Itard et al. (2007) for following countries: France, Germany, Netherlands, Italy, Spain and United Kingdom. In order to characterize the building stock of the other countries EURIMA, Ecofys report (2005b) was used. In the report, the building stock differs between small and large non-residential buildings depending on the space of buildings which can be larger or smaller than 1.000m^2 for each climate zone.

The path of the analysis follows the residential sector, cp. the part about residential buildings. Deviations from the approach used for residential buildings are explained below.

10.1.2 Sector-specific / use-specific data sources and modelling issues

Sector-specific data sources

The used data sources are described below, in order to calculate the current and projected building stock of the non-residential buildings. Two main sources are taken into account, and additionally national statistics have been added to the databases.

In order to cover the current building stock and their distribution of age and type, following data sources are used:

- Itard et al. (2007) from TU Delft and associated partners, like IWU in Darmstadt analysed the current situation of non-residential buildings for seven European Union Member States and Switzerland. This report distinguishes between the health care buildings, educational buildings, shopping and leisure and office buildings. Furthermore, assumptions for the sizes of the buildings are made, which are taken into account, in order to define small or large non-residential buildings and to make a characterisation of the building age.
- Furthermore, Kemna et al. (2007) published values of floor area for EU25. The authors give an overview about the total floor area, but do not differenti-

ate by size or age of the buildings. But, in order to calculate projections of the total floor area it was useful to take these values into account.

- Additionally, “Cost-effective Climate Protection in the EU-Building stock” from EURIMA, Ecofys (2005b) presents an overview of the distribution of small and large non-residential buildings for the whole EU.
- Finally, diverse data on the national level complete the database on buildings in the tertiary sector. The data on the development of cost calculations in the residential sector has been used in order to calculate costs of refurbishment and for new buildings. .

Representation of the European non-residential building stock

In this context only varieties compared to the residential building part are mentioned. All other parts have already been described before.

Building age and type

Aggregated and current data about buildings in the tertiary sector are not often available. In order to define the character of the building stock in the tertiary sector, based on the results and assumptions from Itard et al. (2007) and EURIMA the structure of the existing building stock in 2004 was defined and distinguished between old and intermediate buildings. These two main construction periods have already been described in the residential part.

All in all, the data about construction periods between each country varies only between each climate zone (cold, moderate and warm) and Germany, Spain, France, Italy, Netherlands and United Kingdom per size of building (smaller and larger than 1.000 m^2). Table 10-1 shows assumptions for the existing building stock in 2004.

Table 10-1: Non-residential building stock 2004 overview in %

	Old (< 1975)	IM (1976-2004)	Share of small buildings	Share of large buildings
Cold Climate Zone	66	34	65	35
Moderate Climate Zone	70	30	65	35
Warm Climate Zone	51	49	65	35
Germany	64	36	52	48
Spain	61	39	53	47
France	66	34	58	42
Italy	71	29	48	52
Netherlands	59	41	65	35
United Kingdom	60	40	55	45

Source: WI calculations based on Itard et al. (2007); EURIMA, Ecofys (2005b)

As already mentioned, the buildings differ between small and large. Small buildings refer to smaller than 1.000 m^2 and larger to more than 1.000 m^2.

These two types belong to two typical non-residential buildings. Detailed dimensions of the buildings are shown in Table 10-2 and are due to internal data from Wuppertal Institute and show the typical sizes of each building component.

Table 10-2: Average surface components of non-residential buildings in m^2

Building components of the residential building types in m^2							
	Dwelling space	Ceiling height	Standard component surfaces				
Building type			Roof	Facade	Floor	Windows E/W
Small non-res. building	700	2.5	367	755	367	185
Large non-res. building	1800	2.5	1.500	2.100	1.500	250

Source: WI calculations based on Wuppertal Institute 2000, 2001; IWU 2005

Due to regional differences in each country, it could be observed that in some countries the amount of old tertiary buildings is higher than of intermediate buildings. EURIMA reports that two third in the cold climate zone are old buildings, whereas 70% in moderate climate countries are built before 1975. Except in warm climate countries it is supposed that half of the buildings are built after 1975. A more detailed view on some countries is possible referring to Itard et al.. It is possible to distinguish country specific for some countries like Germany, France, Italy, Spain, the Netherlands and United Kingdom, cp. Table 10-1.

Floor area of non-residential buildings

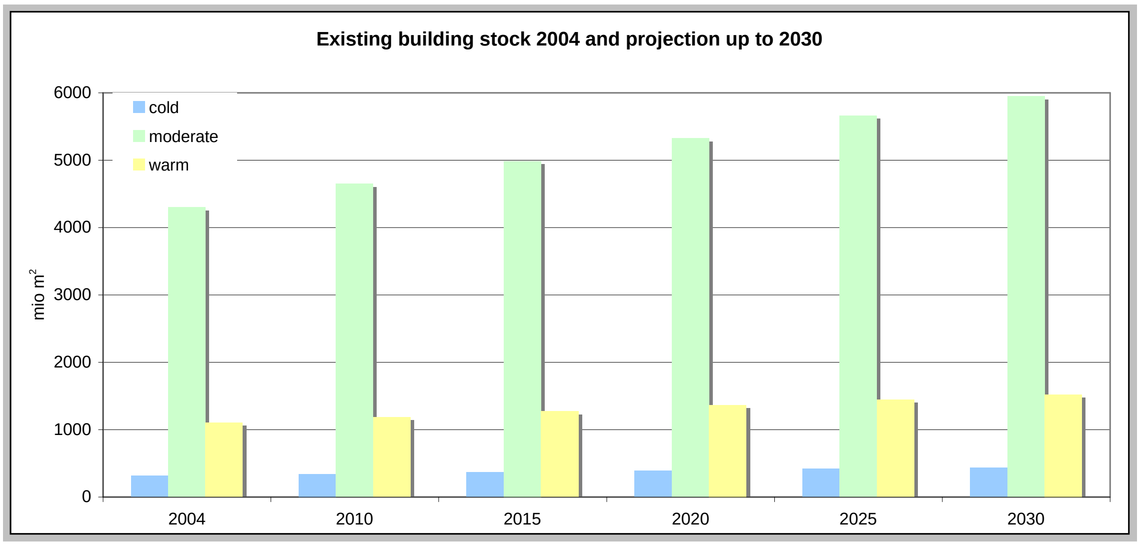
It is assumed that the floor area of tertiary buildings will increase in each climate zone until 2030. Figure 10-1 shows the projection of floor area for cold, moderate and warm climate zone.

As a result of further economic growth the total amount of buildings will increase about 38% (cp. current PRIMES values of the development of GDP in each country until 2030). The development of the gross domestic product is used to trigger the development of the housing market in the tertiary sector.

Even in the cold climate zone it will grow up to 40% from the base year 2004, with a total amount of 310 million m^2 up to 440 million m^2 in 2030. Whereas the floor area of moderate zone will rise from a total of 4.300 million m^2 up to nearly 6.000 million m^2 in 2030 and in the warm climate zone from 1.100 million m^2 up to 1.500 million m^2.

At the same time, a demolition rate of about 0.045% is supposed in the non-residential sector, whereas this value accounts only 0.03% in the residential sector due to BBR (2006) where this demolition rate is assumed. Due to Kemna et al. a more ambitious demolition rate is supposed for the tertiary sector. It is highlighted that due to image reasons the breakdown of old existing buildings, not already refurbished, and refurbishment is more aspired than in the domestic housing market.

Figure 10-1: Building stock in the tertiary sector 2004 and projection up to 2030



Source: WI calculations based on Kemna et al. (2007), BBR (2006); PRIMES

10.1.3 Step 1 – Definition of energy saving options

Technical potential / U-values

In order to characterize the specific energy consumption per building, the same energy consumption values as in the residential building part have been taken for the model calculation. Specific values have already been described there, cp. technical potential, and should not repeated again.

Climate Zones

The distribution of tertiary buildings per climate zone has already been shown in Figure 7-3. It is assumed that more than three-quarter accounts to moderate climate zone, small as well as large non-residential buildings. 19% belong to cold climate zone and 5% to warm climate zone.

Climatic conditions have already been described, cp. Step 1- Definition of energy saving options. In this chapter, climate zones are specified according to the relation between energy consumption and climatic conditions.

10.1.4 Step 2 – Technology costs

A further step is to calculate the cost effectiveness of refurbishment and new built buildings, in order to reduce emissions of dwellings. This approach has already been characterized for residential buildings, cp. part residential buildings and has been applied to non-residential buildings, too.

10.1.5 Step 3 – Definition of the four scenarios

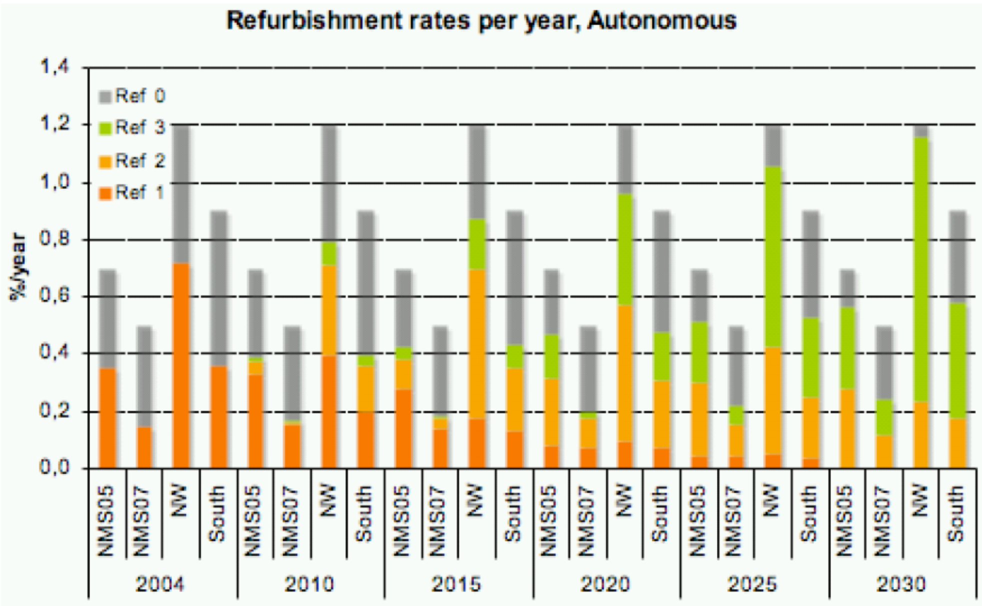
The definition of the four scenarios, autonomous, two policy scenarios (LPI, HPI) and technical potential, is applied to the tertiary building sector, too. Nevertheless, it is assumed that the refurbishment rates even in all four scenarios are more sophisticated than in the residential sector. Kemna et al. (2007) already explained, that the amount of refurbishment is 50% higher in the non-residential sector than in the residential sector, whereas the penetration rate of new building codes is synonym to new buildings in the residential building part and is therefore not part of the description of the four scenarios.

But, due to economic reasons, it is still assumed that the development will not be identical for each region, North-Western Europe, Southern Europe, New Member States 2005 and New Member States 2007 plus Croatia. Therefore, following figures show penetration rates of each scenario for refurbishment and new buildings. Furthermore, the different scenarios will be described to point out the differences between each scenario.

Autonomous scenario

It considers that technology diffusion is only driven in an autonomous way and takes into account the development of demography, refurbishment and demolition rates of buildings and includes impacts of policies. These policies are in force before 2004. Figure 10-2 shows the penetration rates per year for four regions.

Figure 10-2: Rates of refurbishment rate per year, Autonomous Progress Scenario



Source: WI calculations based on ISI (2007); WI (2000)

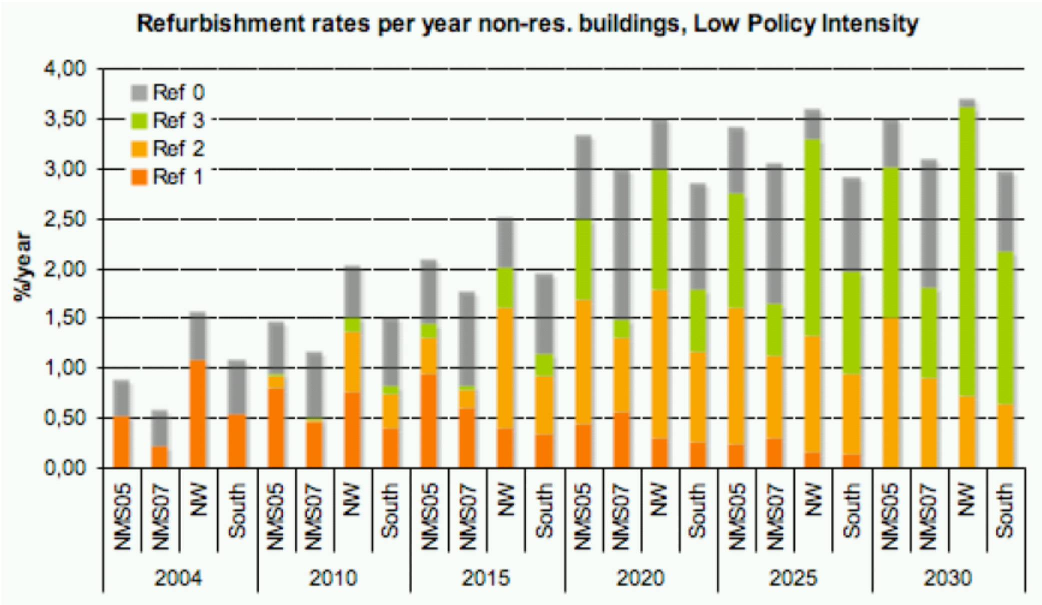
Policy Scenarios

Within these scenarios the introduction of new policies is envisaged and thus, the market will continue transforming. Therefore, two different intensities of policy influence are envisaged. The first policy scenario is the Low Policy Intensity Scenario.

Low Policy Intensity Scenario (LPI)

It is defined by low policy intensities and by considering an additional technology diffusion of BAT beyond autonomous diffusion only to a realistic level driven by increases in market energy prices and comparatively low level energy efficiency policy measures as in the past in many EU countries. In this case consumer decisions will be motivated by cost-effectiveness criteria based on usual market conditions.

Figure 10-3: Rates of refurbishment rate per year, Low Policy Intensity Scenario

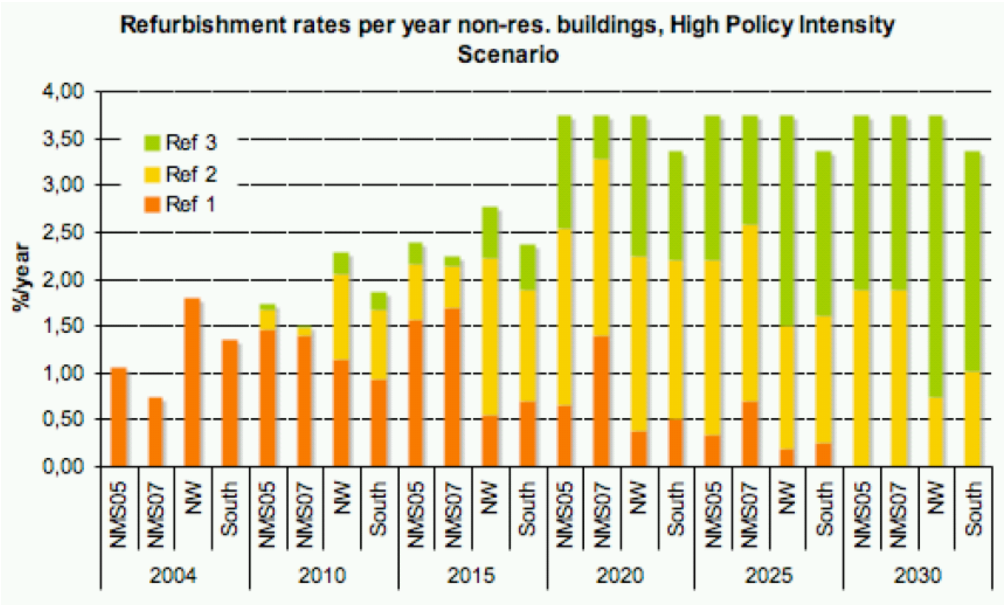


Source: WI calculations based on ISI (2007); WI (2000)

High Policy Intensity Scenario (HPI)

This scenario describes the additional technology diffusion of best energy saving technologies (BAT) to the maximum possible, from an economic viewpoint. It considers cost effectiveness from a country perspective, given the fact that one can assume in such a case a high policy intensity which reduces transaction costs for the consumer by suitable measures.

Figure 10-4: Rates of refurbishment rate per year, High Policy Intensity Scenario

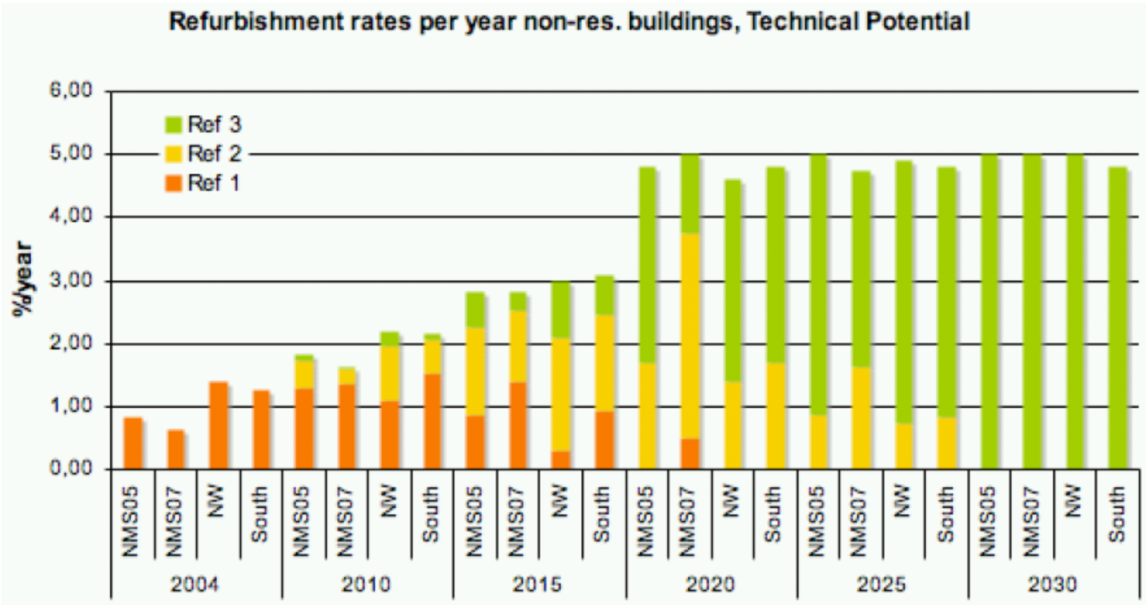


Source: WI calculations

Technical Potential Scenario

This scenario considers a full technology diffusion of BAT to the maximum possible. The maximum, in this context, corresponds to technical limits. It shows how much more energy could hypothetically be saved by the year 2015, if all investments in end-use technology, buildings etc were moved to BAT during renovation cycles or in case of new installations between nowadays and 2015. This is a hypothetical maximum that will never be reached in practice.

Figure 10-5: Rates of refurbishment rate per year, Technical Potential



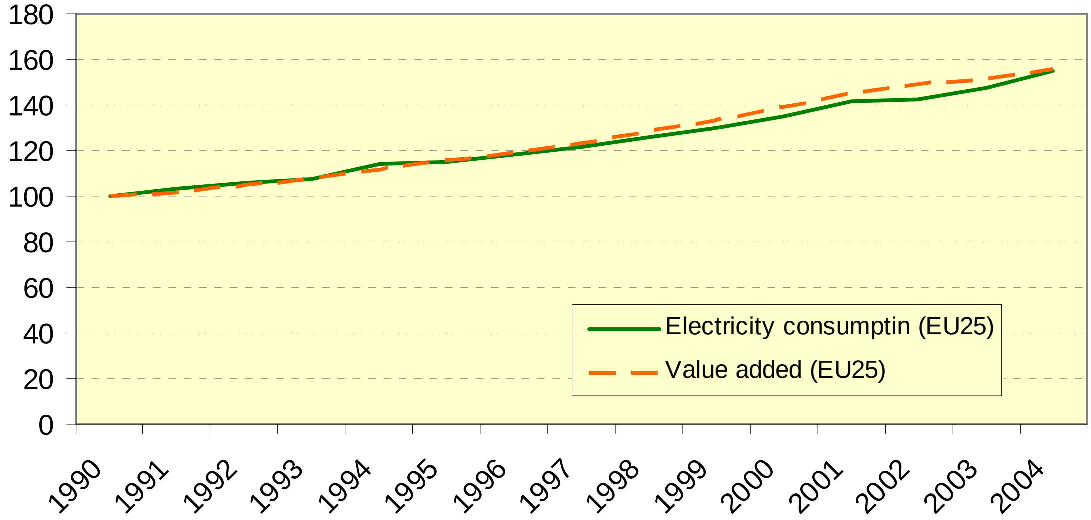
Source: WI calculations

10.2 Electricity uses in the tertiary sector

10.2.1 Description of the sector/end-use

With 2.8% annual growth in the period between 1992 and 2002, the tertiary sector had been growing more rapidly than the overall economy and thus gained in share of total GDP (ADEME 2005).While final energy consumption grew slightly slower than value added, electricity consumption showed comparable growth rates than value added. In the period from 1990 to 2004, both, electricity demand and value added in the tertiary sector increased by about 60 % on the EU25 level. Although the figures for the EU25 aggregate indicate a strong correlation between value added and electricity demand development, this correlation can not be observed for most individual member states, as shown in Figure 10-7.

Figure 10-6: Development of electricity demand and value added in the tertiary sector



Source: Odyssee Database

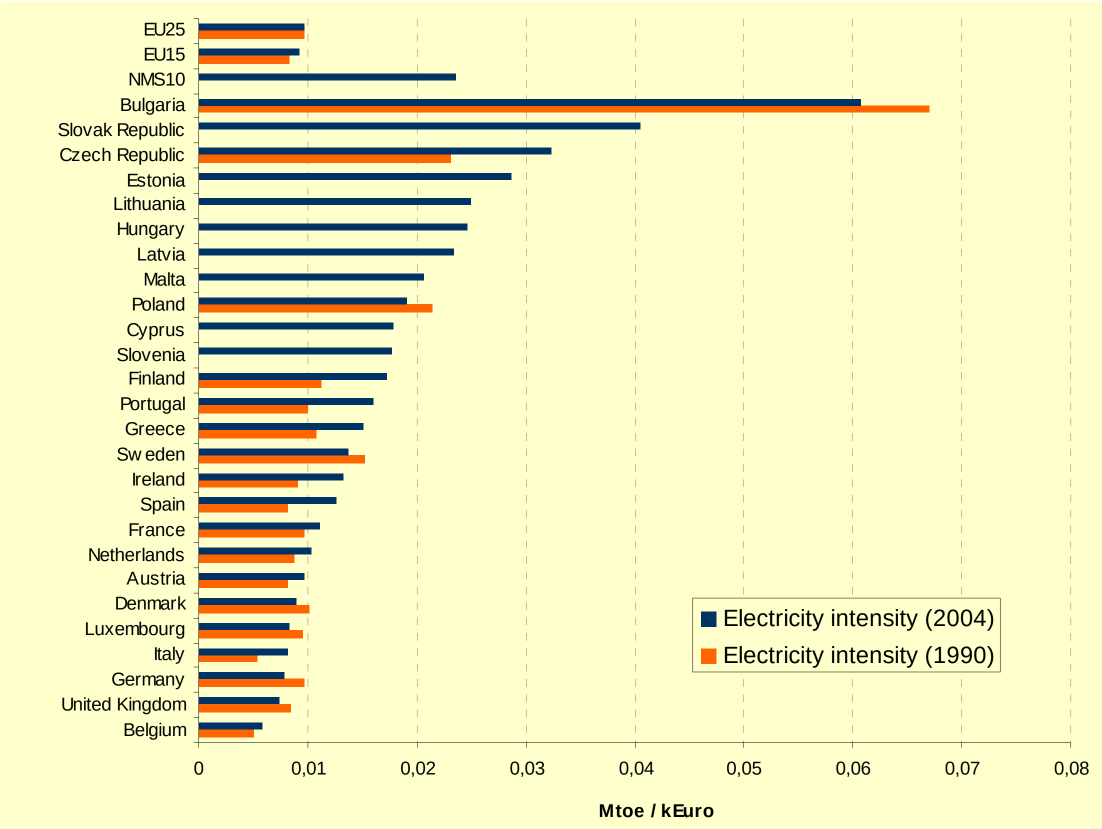
When comparing the electricity intensity of the tertiary sector between 1990 and 2004 by country, two main characteristics can be observed (Figure 10-7).

First, as mentioned above, the country specific development does not indicate a clear trend. Some countries showed increasing electricity intensity, while it fell in others. Some of the EU15 countries that show the highest growth rates in electricity intensity are the southern countries, Spain, Italy, Greece and Portugal that also experienced immense growth rates in installed air conditioning systems and cooled floor area, as described further below. However, this does not explain the raise in countries like Ireland and Finland, where a strong economic growth might be driving the trend (ADEME 2005 p.95).Only on the EU25 level electricity intensity stayed more or less constant, which can be regarded as coincidence.

Second, electricity intensity is considerably higher in new member states than in the EU15. The 11 countries with the highest electricity intensities are new member states.

However, this country comparison has to be regarded with caution, as it does not take into account the different levels of purchasing power.

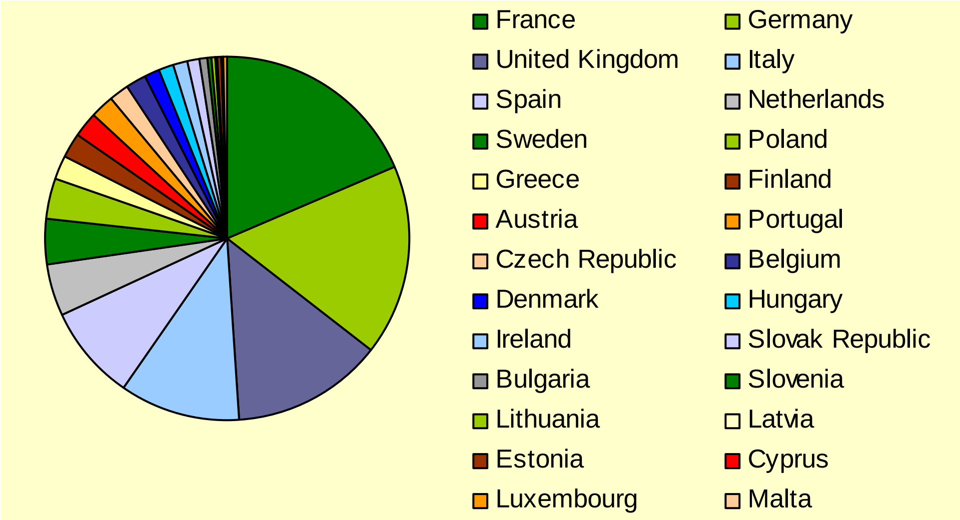
Figure 10-7: Electricity intensity of value added by country in the tertiary sector (Electricity demand per value added)



Source: Odyssee Database

When looking at the division of absolute electricity demand in the tertiary sector by country it is remarkable that only three countries, France, Germany and UK, are responsible for more than 50 % of electricity consumption (Figure 10-8).

Figure 10-8: Electricity demand in the tertiary sector by country



Source: Odyssee Database

To get a deeper understanding of the technological structure of electricity demand in the tertiary sector, the following paragraphs focus on the distinct appliances and technologies which are responsible for the main part of electricity demand. These are:

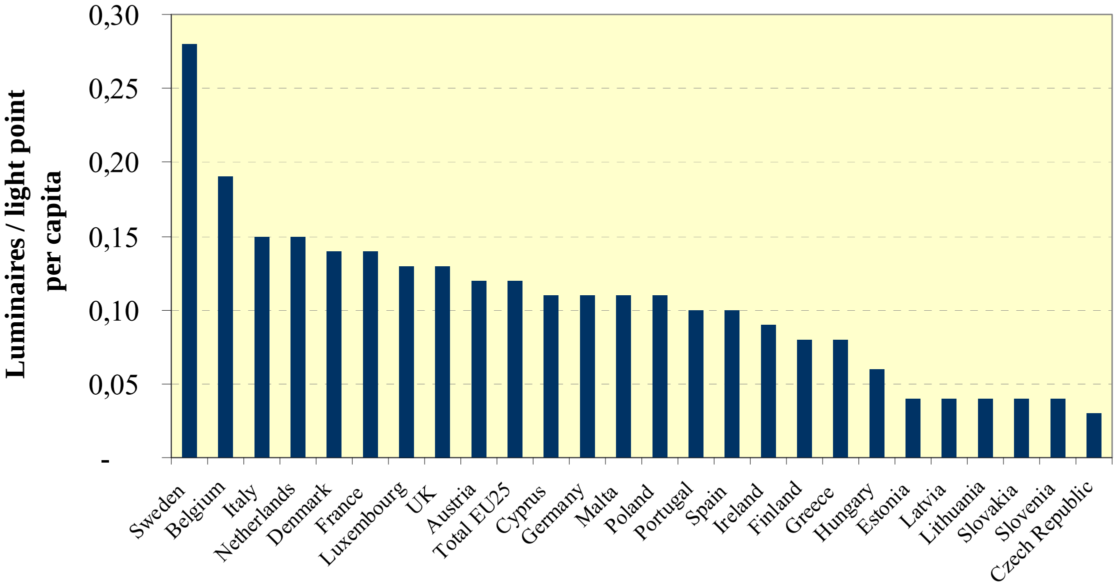
- Street lighting
- Office lighting
- Ventilation
- Air conditioning
- Commercial refrigeration and freezing
- Office equipment (computers, monitors, copying and printing)
- Servers
- Miscellaneous motor appliances (that are not covered in the other categories)

The short introduction to these technologies will also focus on how the total electricity demand of these appliances has been estimated.

A huge share of tertiary sector's electricity demand is consumed by *lighting* technologies. A general lighting system consists of three main parts, lamp, luminaire and ballast. The lamp is the actual light source that emits light. The luminaire is the apparatus in which the lamp is fixed. Depending on the local necessities it transforms, distributes or filters the light. For discharge lamps (like fluorescent lamps), a ballast is needed to limit the current of the lamp. In the tertiary sector, two main applications for lighting are observed, street lighting and office lighting (in a wider sense), which are both considered in this study.

Street lighting accounts for about 6 % of the electricity consumption of the tertiary sector in Europe. This value varies between 3 and 12 % from country to country, depending on the density of light points and the lamp technologies used.

Figure 10-9: Light points for street lighting per capita distinguished by country



Source (Van Tichelen et al. 2007)

In **office lighting** mainly linear fluorescent lamps are to be found. While their efficacy is higher than for incandescent lamps or even compact fluorescent lamps, it is lower than for high intensity discharge lamps, which are often found in street lighting or in industry. Our definition of office lighting is coherent with the definition of the EuP report (Tichelen Van et al. 2007b), who considered lighting equipment for office work areas that are functionally comparable, which excludes other types of lighting that are also found in office buildings like lighting for toilets or reception desks. Considering this definition, the energy demand calculated for office lighting represents about 12 % of the tertiary sector's electricity demand in 2004 in the EU27. Consequently, the electricity demand for all lighting applications is slightly higher.

The definition of **ventilation** systems is done according to the EuP report on Fans in non-residential buildings (Radgen et al. 2007). This means only fans above 125 W are considered in order to exclude residential fans and fans for appliances like computer ventilation. Even more fans incorporated in air handling units that also deliver cold or heat, are not considered. Still, there might be a certain overlapping between the different applications, when for example a fan is sold to an OEM who incorporates it into an air conditioning unit.

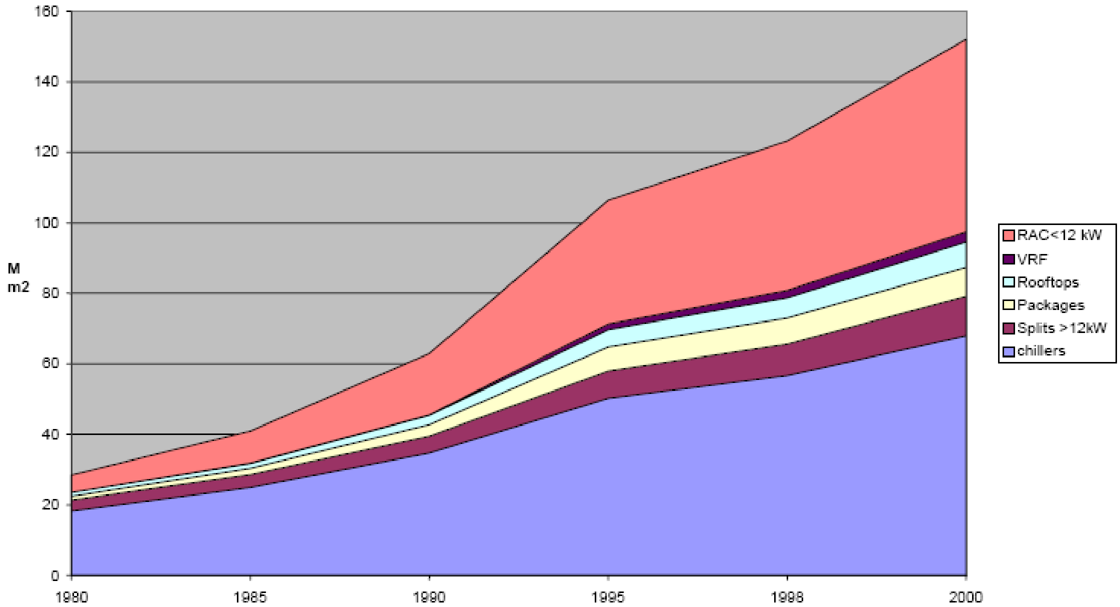
Because the scope of the EuP study on fans, which covers also buildings in the industrial sector (all non-residential buildings) the figures have to be corrected by the share of fans which are used in the industry sector.

Thus, the electricity consumption of fans in the tertiary sector as given by Radgen et al. (2007) is first corrected by the share of fans used in air conditioning systems and then corrected by the share of fans used in industry.

The usage of fans is also directly related to the installation of **air conditioning** systems, which have increased in number extensively over the last decades. Figure 10-10 shows how the floor area equipped with air conditioning systems increased to about 400 % from 1980 to 2000. In air conditioning two types of systems can be distinguished: room air conditioners (RAC) and central air conditioners (CAC). The former can be bought as separate products and are mainly found in the residential sector, while the latter, CAC, are characterised by a central refrigerating unit and are generally bigger in size. CACs are mostly found in tertiary sector buildings or huge apartment buildings.

As a result of the remarkable increase in cooled floor area since the 1980s, CACs accounted for about 10 % of electricity consumption of the tertiary sector in 2004.

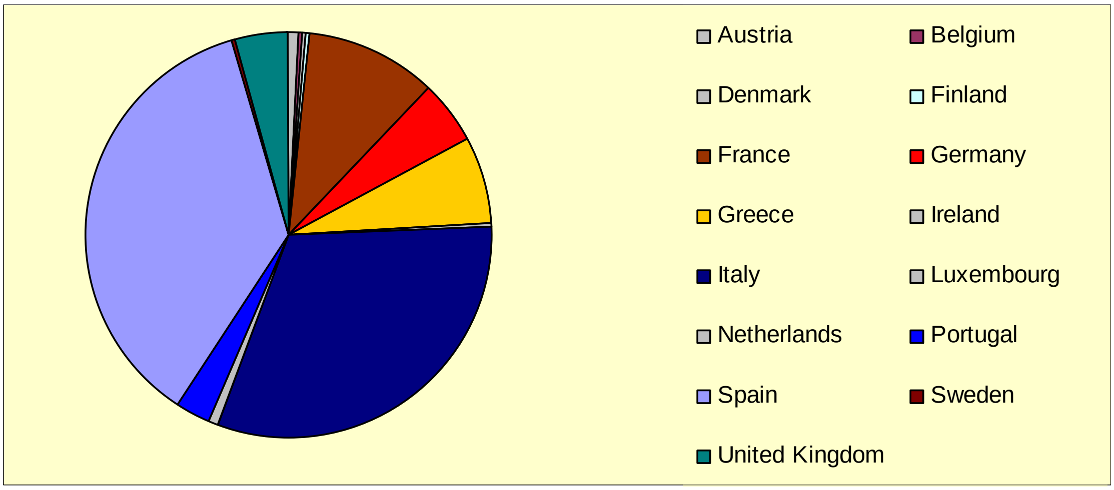
Figure 10-10: Total floor area provided by type of air conditioning system in the EU15 tertiary and industrial sector



Source: Adnot et al. (2003)

When shifting the focus from the EU15 perspective to single member states, significant differences between countries become obvious (see Figure 10-11). While the northern countries contribute only marginally to the air conditioners' electricity consumption, the Mediterranean member states are responsible for about 80% of total electricity consumption in CAC systems, according to Adnot et al. (2003 V2 p.62). Especially noteworthy are the immense shares of Italy and Spain, who account together for about 75 %.

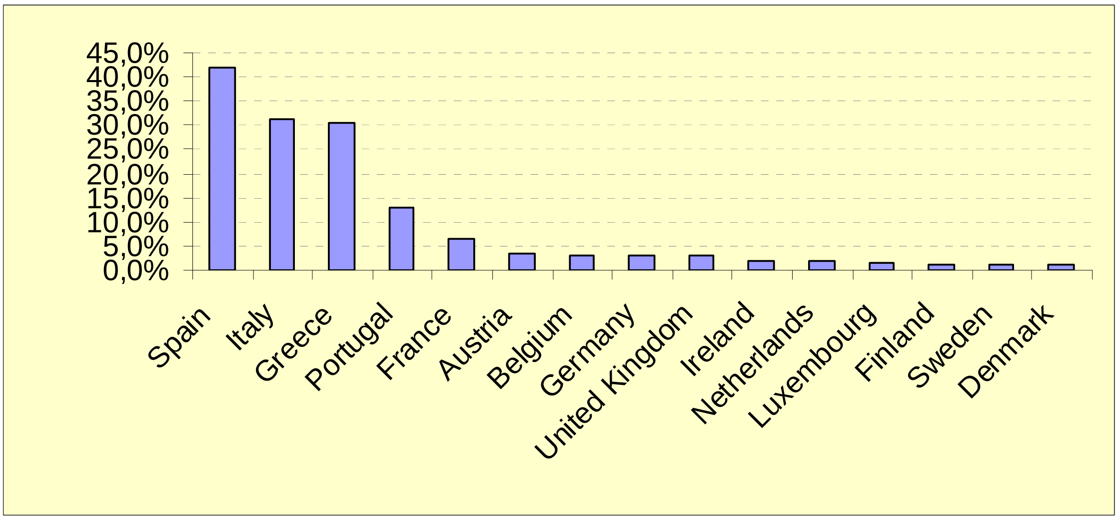
Figure 10-11: Share of EU15 electricity consumption by central air conditioning systems (2004)



Source: Adnot et al. (2003)

When looking at the electricity consumption for air conditioning systems as share of tertiary sector's total electricity consumption the difference between southern and northern EU member states becomes even more obvious (see Figure 10-12). While this share is below 5% in the central European countries and marginal in the Scandinavian countries, it goes up to 40% in Spain, 30% in Italy and Greece and 12% in Portugal.

Figure 10-12: Air conditioning electricity consumption as share of total tertiary sector consumption (2004)



Source: own calculations based on Adnot et al. (2003)

Other important electricity consuming applications are **commercial refrigerators and freezers**. This term covers a large variety of products that are utilised in different locations like supermarkets, restaurants hotels or cafés.

According to the EuP study by Monier et al. (2007) three general types of refrigeration and freezing appliances can be distinguished. These are remote (1) or plug-in (2) refrigerated display cabinets and cold vending machines (3). The first two appliances are mainly distinguished due to the location of the refrigerant compressors. In the case of remote cabinets one refrigerant compressor can even be used for several cabinets. As it is the case for plug-in display cabinets, also for cold vending machines, the whole refrigeration equipment is located directly within the frame of the machine.

Based on this general classification, they focus on the five concrete appliances, which were found to be most representative for the three types (see Table 10-3). These appliances together are responsible for about 10 % of tertiary sector's electricity demand.

Table 10-3: Commercial refrigerators' and freezers' energy consumption in the EU25

Appliance	EU-25 stock electricity consumption in 2006 (TWh)	Number of equipment	Share of total tertiary el consumption
Remote open vertical chilled multi deck cabinets	37,04	1.312.630	5,5%
Remote open horizontal frozen island	5,11	172.117	0,8%
Plug in one door beverage cooler	16,25	6.323.941	2,4%
Plug in horizontal ice-cream freezer	4,45	2.709.285	0,7%
Spiral cold vending machine	2,98	1.092.956	0,4%
TOTAL	**65,83**	**11.610.930**	**9,8%**

Source: Calculations based on Monier et al. (2007) and Odyssee database

Also for office equipment, a large variety of products can be found and it is not possible to consider each of them distinctly. Still, the most relevant products in terms of electricity consumption are considered. In detail, these are **laptops and desktop computers, monitors** (LCD and CRT) as well as different imaging appliances like printers and copiers. In the last years a constant replacement of CRT (Cathode ray tube) by LCD (liquid crystal displays) monitors could be observed as well as an increasing market diffusion of laptops. This trend is assumed in the EuP study to lead to the total phase out of CRTs by 2013 (TCO Development, Swedish Environmental Institute 2007).

The **printers and copiers** mostly used in offices are photoelectrical, which account for more than 90 % of electricity consumption of all printers in offices. Thus, inkjet printers play a minor role in terms of energy consumption, not in terms of units sold. In total, the electricity consumption of copiers and printers is marginal in comparison to the electricity demand of the tertiary sector and accounts for about 1 %.

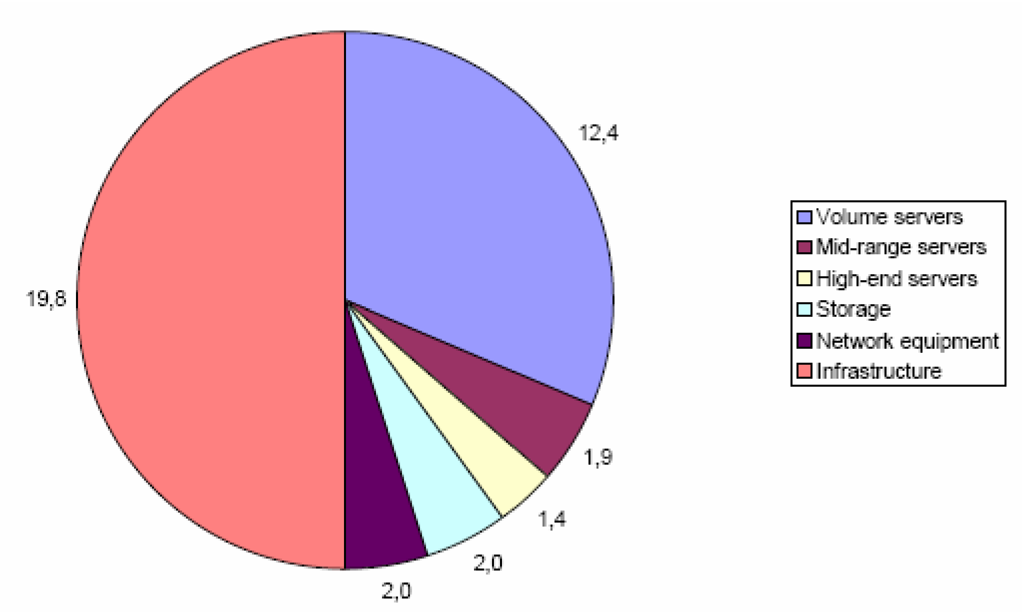
Table 10-4: Electricity consumption of office equipment

Appliance	Annual electricity consumption per product (KWh)	EU stock 2005	Total annual electricity consumption (GWh)	Share of EU27 tertiary sector electricity demand
Desktop	194	44000000	8536	1,3%
Laptop	98	36500000	3577	0,5%
LCD	86	20500000	1763	0,3%
CRT	189	24000000	4536	0,7%
Total computer		**125000000**	**18412**	**2,7%**
Copiers	257	6351000	1633,47	0,2%
Printers	134	38414000	5148,01	0,8%
Total imaging		**44765000**	**6781,48**	**1,0%**
Total		**169765000**	**25193,48**	**3,7%**

Source: Calculations based on (Fraunhofer Institute for Reliability and Microintegration (IZM) 2008; TCO Development, Swedish Environmental Institute 2007) and Odyssee database

The raising demand of the ITC society for servers and data centers affects also significantly the electricity demand. According to Schäppi et al. (2007) data centers in the EU15 consumed about 37 TWh in 2006 and their electricity demand for 2010 is expected to nearly reach 70 TWh, if no action is taken, which is a doubling in 4 years. It is estimated that about half of a data canter's electricity consumption is due to server infrastructure like cooling and lighting. To avoid overlapping, only the other half, which is directly consumed by **servers**, is considered in our analysis, as lighting and air conditioning is already covered by other end-uses. Based on the above mentioned analysis by Schäppi et al., we estimated that 2.1 % of tertiary sectors electricity consumption in the EU27 is due to servers.

Figure 10-13: Electricity consumption in data centers (EU27 total: 39.6 TWh in 2006)



Source: (Schäppi et al. 2007)

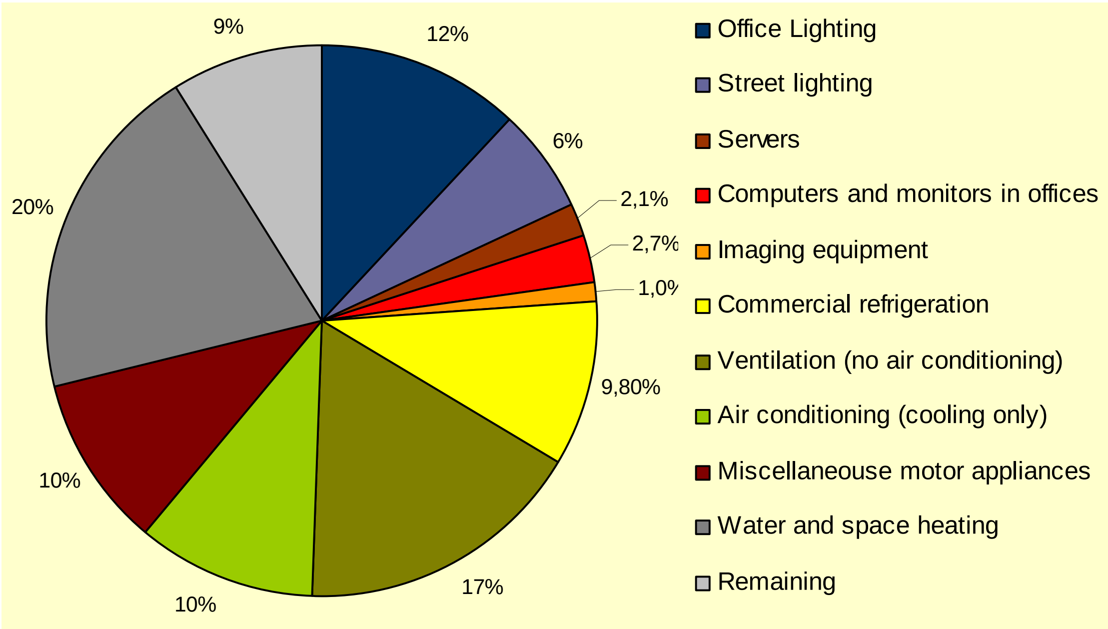
Although, the most important electric motor appliances, i.e. fans, were already considered still a huge number of appliances exists that can not be analysed in such a level of detail. Therefore, these appliances are aggregated to one bundle of "**other motor appliances**", which is composed lifts, conveyors, pumps, compressed air systems etc.

In contrast to industry, where a lot of larger motors are to be found, in the tertiary sector most of the electricity consumption by electric motors is due to small sized motors with a rated power below 10 kW. Bertoldi et al. (2007 p.43) give a total electricity consumption of miscellaneous motor appliances, which equals 10 % of the electricity consumption in the tertiary sector. This figure will also be used for our calculations.

Another main electricity use in the tertiary sector is hot water and space heating, which is covered in the chapter on building heating demand in the tertiary sector.

All the electricity consuming appliances that are not mentioned so far account in total for less than 10 % of electricity demand in the tertiary sector. Due to their heterogeneity and the lack of available data they will not be analysed in detail. Appliances in this category are cooking, small office equipment like faxes and non-office building lighting, to mention just a few.

Figure 10-14: Resulting shares of tertiary electricity consumption by appliance (EU27, 2004)



A summary of the above analysis is illustrated in Figure 10-14. The figure shows that the bottom-up analysis is able to explain 91 % of the electricity consumption in the tertiary sector. The shares of space heating and hot water and miscellaneous motor appliances were the only ones that are not calculated based on stock figures but taken from Bertoldi et al. (2007 p.43), who's calculations are based on (ECCP working group on energy efficiency in end-use equipment and industrial processes 2001). The value of 17% for ventilation seems rather high, especially in comparison to other studies like the one mentioned above by Bertoldi. This is even more the case, when it is taken into account that the ventilation consumption is already lowered by the overlapping with air conditioning systems. The figures on lighting might slightly underestimate the consumption, as we focused on most common lamp and luminaire types only.

We also tried to segment the electricity consumption country wise to allow for country specific characteristics in technology structure. However, in most cases it was not possible to derive country specific data for the distinct appliances from the mentioned literature. In these cases country specific values were assumed to equal EU averages. Only for street lighting, air conditioning and partly computers country specific values could be derived and were used in our analysis.

Table 10-5: Overview on the results and methodology of bottom-up electricity demand calculations

Appliance	Share in tertiary el consumption 2004 (EU27)	Calculation and data source
Office lighting	12.0 %	Based on estimated stock data of linear fluorescent lamps for office lighting (Tichelen Van et al. 2007b)
Street lighting	6.0 %	Based on light points and estimated stock of lamps (Tichelen Van et al. 2007a)
Computers and monitors	2.7 %	Based on estimated stock data for laptops, desktop computers, CRT and LCD monitors (TCO Development, Swedish Environmental Institute 2007)
Imaging equipment	1.0 %	Based on estimated stock data for 5 most common types of copiers and printers (Fraunhofer Institute for Reliability and Microintegration (IZM) 2008); could be 50% higher due to use pattern uncertainty
Servers	2.1 %	Based on estimated stock data for different types of servers (Schäppi et al. 2007)
Commercial refrigeration and freezing	9.8 %	Based on estimated stock data for 5 most common types of commercial refrigeration units (Monier et al. 2007)
Ventilation	17.0 %	Based on stock data by Radgen et al. (2007) corrected by overlappings with fans in industry and in air-conditioning systems
(Central) Air conditioning	10.4 %	Based on forecasts from 2003 about the stock of central air conditioning systems (Adnot et al. 2003)
Miscellaneous motor appliances	10 %	Not based on stock data, more uncertain estimation from Bertoldi et al. (2007)
Hot water and space heating	20 %	Not based on stock data, more uncertain estimation from Bertoldi et al. (2007)
Remaining	9.0 %	Calculated as residual. Covers cooking, small office equipment like faxes and non-office building lighting, etc.

10.2.2 Sector-specific / use-specific data sources and modelling issues

10.2.2.1 Sector specific methodology

The evaluation of saving potentials in the tertiary sector is mainly based on bottom-up calculations, which consider stocks of certain appliances, appliance specific energy consumption and also appliance specific improvement / saving options. The figures used are mainly derived from the product studies conducted in the framework of the EU Directive on eco-design requirements for energy using products (EuP Directive). As it is the aim of the EuP Directive to tackle energy consumption of products, studies were conducted for all main products. While many of those studies are finalised in late 2007 or the beginning of 2008 others were not finalised when our project ended and we had to use preliminary or older data sources.

The main consequences of relying on EuP studies are the following.

- Most up to date data
- Very comprehensive analyses
- Mainly focus on technical / product related saving potentials leading to an underestimation of behavioural potentials.
- The time horizon is 2020 and thus extrapolations until 2030 are necessary
- As the scenarios concentrate on cost-effective saving measures it became difficult to estimate a "technical" saving potential that could also consider very expensive options

10.2.2.2 Sector-specific data sources

In the case of street lighting, two main studies present a comprehensive overview of the current stock of technologies in use and possible options for energy savings. The first is the study in the framework of the EU Directive on eco-design requirements for energy using products (EuP) and the second is a report from a European project called E-Street, which aims at supporting intelligent street lighting in Europe (Van Tichelen et al. 2007; Walraven, As 2006).

Also for office lighting the EuP study has to be mentioned as most recent and most comprehensive source (Tichelen Van et al. 2007b). A general broad overview of global energy consumption, saving potentials and measures in the field of lighting presents IEA (2006)

For servers no EuP studies have been conducted so far. Three main studies were used as basis for the analysis. Koolmey (2007) estimated the US and the global energy consumption of servers and his methodology can be found in some of the later studies. The study by Schäppi et al. (2007) focuses on the situation in the European

Union, while Ficher (2007) gives insights into the situation in Germany and compares different legislative frameworks in different regions. A comprehensive overview of energy saving options in data centers is given by Greenberg et al. (2006), while Europe Economics et al. (2007) assessed saving options related to the labelling of servers.

For the part on commercial refrigerators and freezers the EuP study gives a very detailed and comprehensive overview (Monier et al. 2007).

Also for Ventilation systems the related EuP report had been used as main source (Radgen et al. 2007).

As the EuP study on air conditioning systems covers only residential appliances, the so-called room air conditioners, an older study had to be used to cover the central air conditioners, which are mainly used in the tertiary sector. Adnot et al. (2003) provide a comprehensive overview about electricity consumption in central air conditioning systems in the EU15 and assess also possibilities to improve energy efficiency. Noteworthy also that they provide lots of country specific data, although a little out-dated by now.

The EuP report by Almeida et al. (2007) on electric motors was used as the basis for cost and saving potential figures concerning savings in electric motor systems.

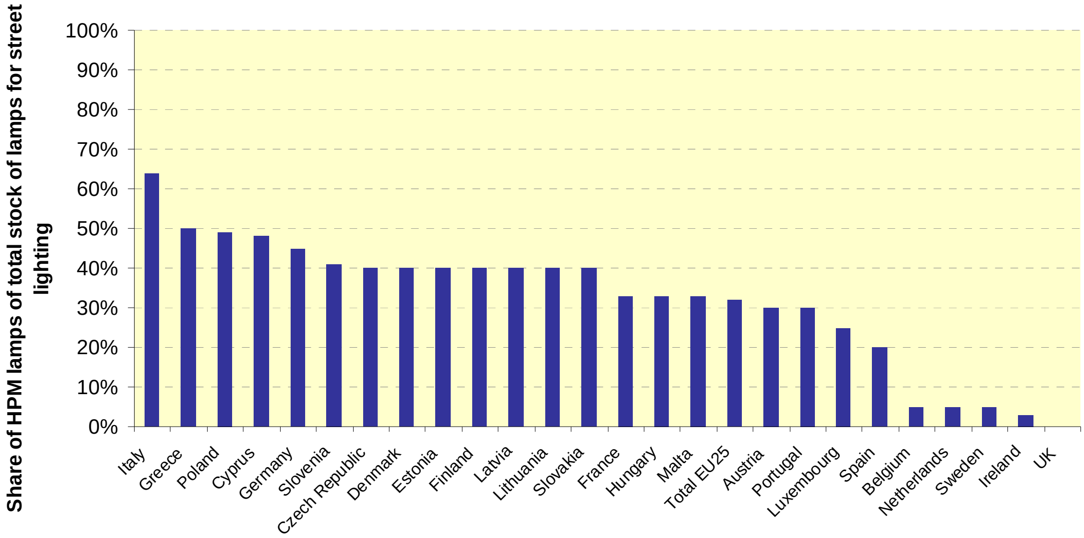
As general data source for energy consumption in the tertiary sector also the Odyssee database has to be mentioned. Unfortunately, certain information is still missing for the new member states, e.g. the floor area.

10.2.3 Step 1 – Definition of energy saving options

The considered energy saving options for **street lighting** are mainly derived from the related EuP study. They propose a list of 13 distinct saving options in total. The most important options are the phase out of high pressure mercury lamps (HPM) being replaced by efficient high pressure sodium lamps (HPS) and the replacement of ferromagnetic ballasts by electric ballasts.

While the share of HPM lamps in all lamps used for street lighting is about 31 % in the EU25, it differs strongly between countries (see Figure 10-9). According to Van Tichelen et al. (2007) HPM lamps are not used for street lighting in the UK, while they represent above 60 % of all lamps for street lighting in Italy. Consequently, also the saving potential, resulting from the replacement of HPM lamps differs highly by country.

Figure 10-15: Share of high pressure mercury lamps (HPM) in total lamp stock (2005)



Source: (Van Tichelen et al. 2007)

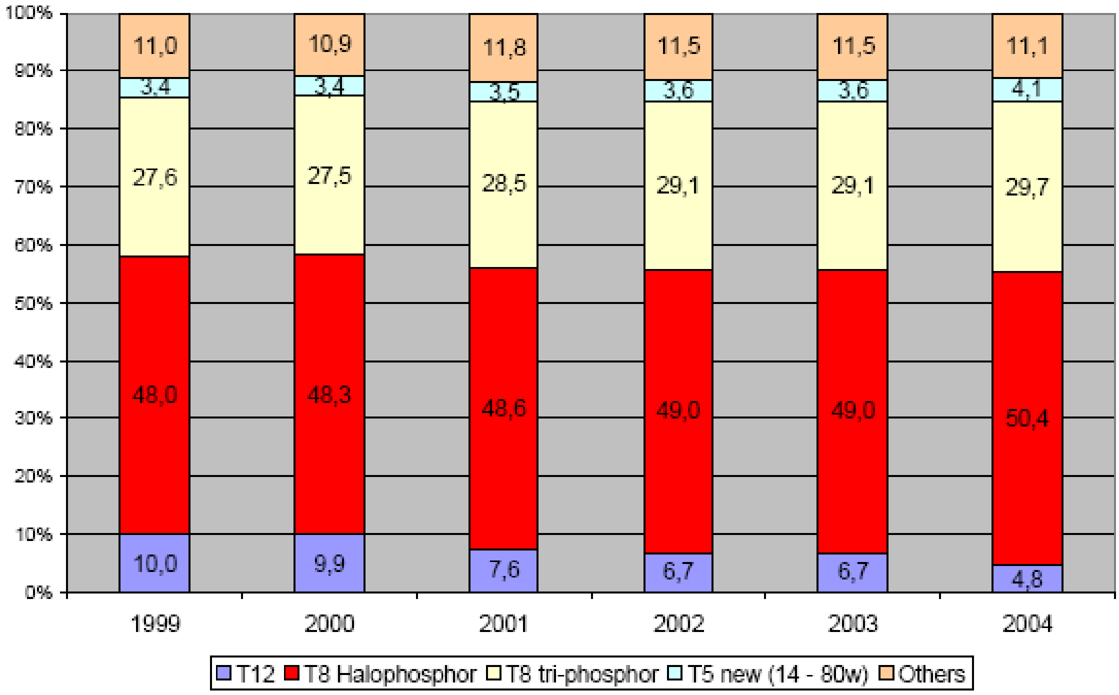
The phase-out of ferromagnetic ballasts being replaced by electronic ballasts, which have a higher efficacy and allow for dimming, is another very important saving option. The dimming option is especially interesting to overcome the technological lock-in of already built street lights. Improved luminaires with constant wattage do not decrease energy consumption but increase brightness at the light point. To lower electricity consumption either the number of light points or the wattage per light point has to be reduced. With dimmable ballasts the refitted lights can be dimmed resulting in lower energy consumption with constant lumen output.

Van Tichelen et al. (2007) calculate a total saving potential of 21 % (compared to BAU) until 2020, assuming that several political instruments are enforced by 2010, including minimum standards and technology bans.

The replacement of HPM lamps is bound to the replacement of luminaires, which have a lifetime of about 30 years. Therefore, the total potential for HPM replacement needs at least 30 years to be realised. Taking these restrictions into account, a total saving potential of 41 % could be realised until 2040.

For **office lighting,** mostly linear fluorescent lamps (LFL) are used (IEA 2006 p.211). Figure 10-16 shows different types of LFLs, which also have different efficacies (efficacy = lumens emitted per watt of power consumed). T12 lamps are known to have the lowest efficacies, while T5 lamps have the best efficacies (~105 lm/W) of all available fluorescent lamp types. T8 lamps are further divided in the less efficient halophosphor LFLs and the more efficient tri-phoshpor LFLs, reaching efficacies up to 95 lm/W (IEA 2006 p.117). Although a constant slight tendency towards higher efficacy lamps can be observed, the rise of the market share of T5 and T8 tri-phosphor LFLs is still slow. Consequently, fostering the penetration of these most efficient LFL types is an important saving option in the field of office lighting.

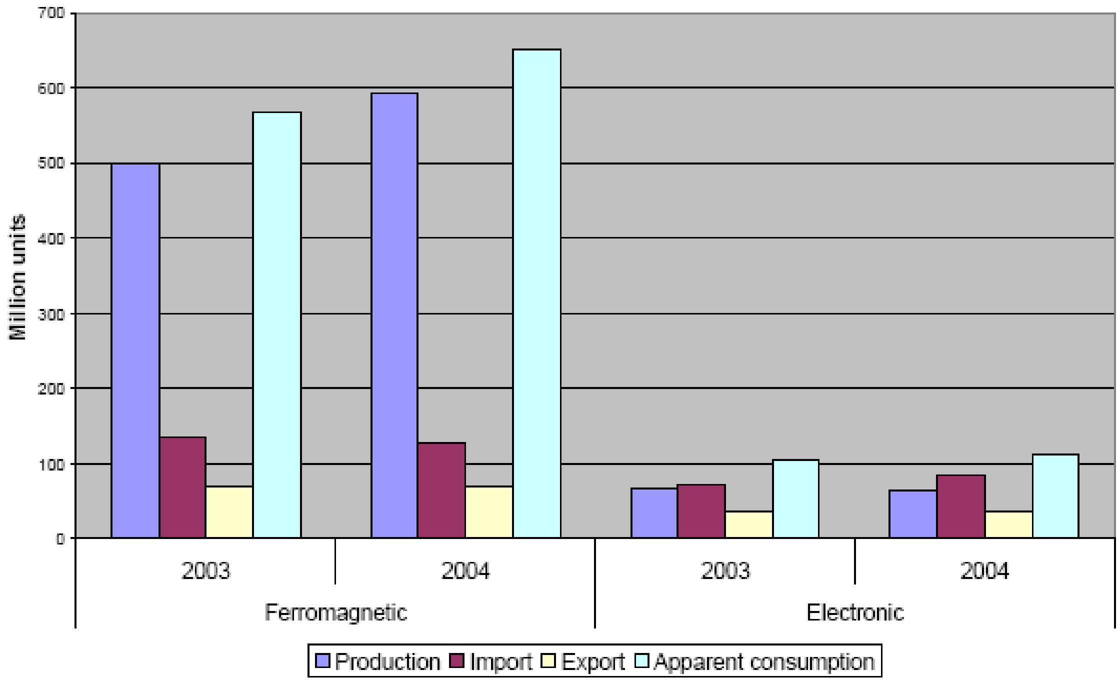
Figure 10-16: Development of market shares of different types of linear fluorescent lamps (EU25)



Source: (Tichelen Van et al. 2007b)

As already mentioned for the case of street lighting, also in office lighting ballasts are used as a "gear" to start and control fluorescent lamps. Because the efficiency of the available ballasts differs significantly, the replacement of the traditionally used ferro-magnetic ballasts by high efficient electronic ballasts would realise a huge electricity saving potential. Market data from 2004 indicate still low market shares for electronic ballasts (Figure 10-17).

Figure 10-17: Market data for ballasts for fluorescent lamps in the EU25



Source: EuP study(Tichelen Van et al. 2007b) based on figures from Eurostat

Also for office lighting, the EuP study (Tichelen Van et al. 2007b) gives the most comprehensive analysis of saving options and potentials. Therefore it is used as main source in our analysis.

They calculated a "best available technology" (BAT) scenario including the following saving options.

- Increased luminaire maintenance factor (LMF)
- Increased optic luminaire efficiency
- All office luminaires are equipped with dimmable electronic ballasts, which are much more efficient than traditionally used ferromagnetic ballasts.
- Usage of high efficiency T5 fluorescent lamps

Taking all these saving options into account, the resulting total energy consumption in 2020 is 31% lower in the BAT-scenario than it is in the business-as-usual (BAU) scenario. Still, as it is assumed that the measures are implemented in 2010 and the average lifetime of a luminaire is 20 years, by 2020 only 50% of the total saving potential are realised. Consequently, until 2030 a total saving potential of 62% is technically achievable due to Tichelen et al.(2007b). This on the first sight seemingly high saving potential is also in line with the achieved energy savings observed in 17 case studies presented in IEA (2006 p.148).

Main component in **ventilation** systems is the *fan*, which can be divided in three main components, the motor, the transmission and the fan itself, which all can be subject to improvement measures. The related improvement options are shown in Table 10-6.

Table 10-6: Options for efficiency improvements for fans

	base case	measure for improvement
fan	Forward curved centrifugal (η=60 %)	Aerofoil bladed centrifugal (η=80 %)
	tube axial	vane axial
	Axial (η=75 %)	Axial with guide vanes (η=83 %)
trans-mission	V-belt	Raw-edged belt (drive efficiency up to 98 %)
	V-/raw-edged belt	coupling drive (with speed control)
	V-/raw-edged belt	fan directly mounted on motor shaft
motor	induction motor (squirrel cage)	inclusion of more active material
	induction motor (squirrel cage)	permanent magnet motor
	induction motor (squirrel cage)	switch reluctance motor
	induction motor (squirrel cage)	electronically commutated (EC) motor (efficiency up to 80 % for smaller motors)

Source: (Radgen et al. 2007p.149)

By improving the aerodynamic profile of the fan considerable efficiency increases can be achieved. The least efficient fans with ladder strip impellers have efficiencies around 40%, the best forward curved bladed centrifugal fans achieve up to 60% and aerofoil bladed fans can achieve a static efficiency of about 88%.

The availability of significant energy saving potentials is also underlined by the finding of Radgen et al. (2007) that efficiencies divert strongly between different fans within the same product classes. Within some product classes, the static efficiency fluctuates from 20% to 70% between different fans.

The aggregated efficiency improvements they calculated are less based on distinct component improvements but more general on market shifts to best practice products, achieved my minimum energy performance standards (MEPS).

However, it shall be mentioned that the EuP study focuses on the product “fan” and not on the whole ventilation system. Thus considerable saving potentials related to system improvements are not covered in this analysis.

Adnot et al. (Adnot et al. 2003) calculated 15 scenarios on electricity consumption by **central air conditioning** (CAC) systems in Europe. The scenario with the lowest electricity consumption by 2020 assumed the implementation of US legislation on energy consumption of CAC, which is combination of MEPS and building codes, in Europe. Single improvement options are:

- Replacing constant flow by variable flow systems could save up to 80% depending on the local use pattern. By allowing for variable flow the flow rate can adapt to real load conditions as well as reduce efficiency losses due to oversized components
- Air Side Free Cooling offers a huge saving potential at low costs, but unfortunately above all in colder climates.
- Decrease pressure drop at air handling units, like filters or heat exchangers etc.
- Improve duct system quality (low pressure drop connection pieces, leakage tests..)
- Improvement of system components, like efficient motors, compressors and fans

In the case of **commercial refrigerators** and freezers the technology specific saving options, which are considered in the related EuP study (Monier et al. 2007) were used in our analysis.

For remote refrigerated display cabinets the following options shall be mentioned, that reduce the electricity consumption either by using more efficient components or by limiting heat losses:

- ECM (electronically commutated motor) evaporator fans
- Liquid suction heat exchanger for remote units only
- Addition of a glass door or glass lid for open cases

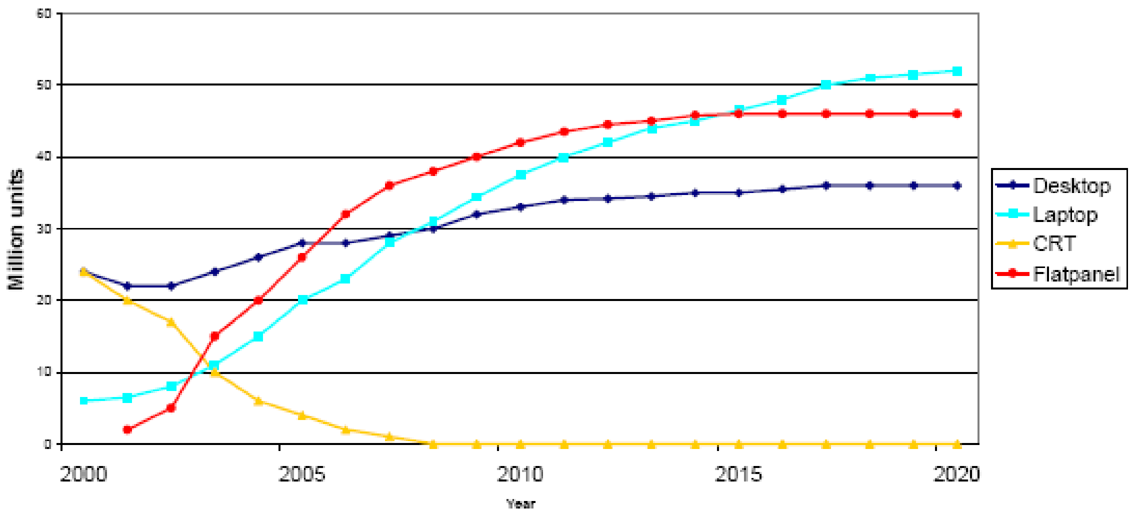
For plug-in units these additional options are considered:

- Increasing heat exchangers' surface
- Improved insulation by using argon instead of air in glass doors and in general thicker insulation
- Usage of high efficiency and modulated compressors (variable speed drive)
- High efficient lighting (T5 fluorescent lamps or LEDs) reduce direct as well as indirect electricity consumption by emitting less heat.
- Lighting controls have the same effect
- Anti-sweat heaters control

Most effective of these options are the addition of a glass door or glass lid where the case had been open before. This option can reduce the appliances' electricity consumption by up to 50%. Other effective options are variable speed drives for compressors, the increasing of heat exchangers' surface and ECM fans at evaporator and condenser.

Two main saving options in the field of **computers and monitors** are the replacement of CRT monitors by LCD monitors and the usage of laptops instead of desktop PCs (TCO Development, Swedish Environmental Institute 2007 p.210-214). Both decrease electricity consumption considerably, but due to the methodology of our study, are not counted as saving option. These two developments are regarded as exogenous technology drivers and thus do not change in the different scenarios.

Figure 10-18: Apparent consumption of office equipment appliances in the EU (from 2007 Prognosis)



Source: (TCO Development, Swedish Environmental Institute 2007)

Other energy saving options for PCs and laptops are:

- multi core processor
- adaptive intensity processor use (adaptive clock frequency)
- design of power supply
- design and selection of hard drive (flash, hybrid hard drive)

For LCD monitors these two main saving options can be mentioned:

- LED backlight usage
- design of power supply

It should be noted that about one half of the efficiency improvement in the assessed policy case is due to the implementation of power management while another third of the improvement is realised by high efficiency power supplies (TCO Development, Swedish Environmental Institute 2007 p.253).

For **imaging equipment** (printers and copiers) the network standby phase and especially the transition phase (heating) to use phase are responsible for huge parts of the appliances' electricity consumption, of course depending on the actual use pattern.

Consequently, energy efficiency measures considered in the EuP study (Fraunhofer Institute for Reliability and Microintegration (IZM) 2008) on imaging equipment address these issues:

- Reduce high ready mode power consumption in the transition phase between jobs
- Reduce duration of transition phases into network standby
- Reduce high network standby of always online products
- Reduce the still considerably high off-mode losses

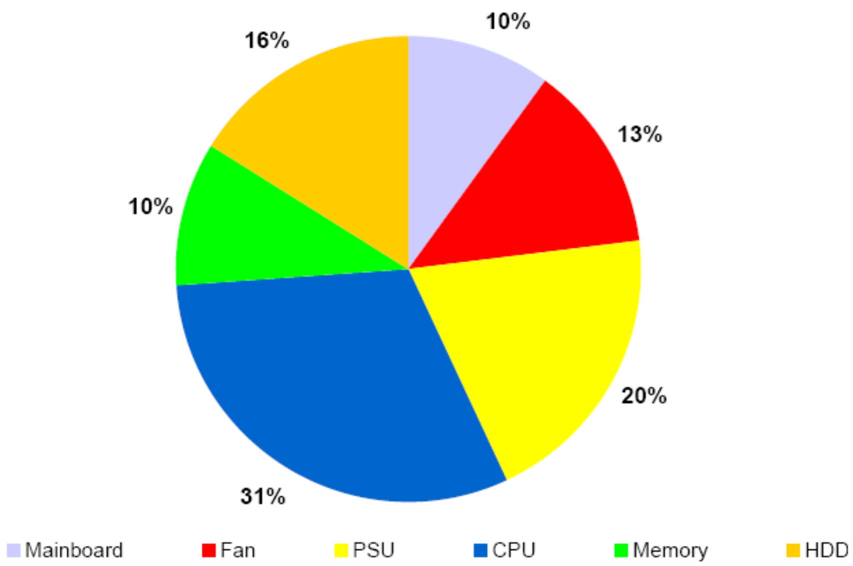
Schäppi et al. (2007) calculate a possible reduction of **servers'** electricity consumption by 50 % by 2011 compared to a business as usual development, but do not show with which saving options and measures this saving potential could be realized. Also Europe Economics et al. (2007) mention a saving potential of above 50 % for standard volume servers, which account for about 80% of all servers' electricity consumption. According to them the most important energy saving options are:

- Usage of quad core processors, which, in comparison to dual core technology, offer a 35% higher computing power at 20% lower electricity consumption. 8 core processors are already expected in 2008 and it is assumed that they have the same energy efficiency effects and further core multiplications are possible in the future.
- The saving potential of power management options accounts for about 15-20% of servers' electricity consumption, but depends strongly on the specific use pattern. As this option reduces the energy consumption of the processor, it overlaps with the option of using multi-core processors.
- It is expected that the efficiency of power supply units (PSU) can be improved by 50%, especially by improving part load operation.
- A saving option to decrease the energy consumption of hard drive disks is the replacement by solid state drives, which are expected to enter the market in 2008, but high costs are still counteracting a fast diffusion. Solid

state drives are expected to use about 4 times less energy than conventional drives.

For the analysis we assumed that servers' electricity consumption is structured as illustrated in Figure 10-19.

Figure 10-19: Typical electricity consumption in standard volume servers



Source: (Europe Economics et al. 2007 p.39)

As energy efficient servers account for lower heat losses they also reduce the energy demand for cooling. This effect is not directly considered in our approach, as the cooling demand is covered in the assessment of air-conditioning appliances. Thus, energy savings by increased efficiency in servers could be even higher than outlined here.

Saving options considered for the bundle of **other electric motor systems** mainly tackle electricity consumption of the motor itself and less system optimisation effects, as a large variety of different systems is covered by this aggregate.

The following distinct saving options are considered:

- Usage of high efficiency motors (IE2 or even better IE3 motors)
- Variable speed drives
- Improved demand related control systems
- Direct coupling of motor and application instead of V-belt
- Avoidance of oversizing

10.2.4 Step 2 – Technology costs

The saving options for street lighting are all considered to be cost-effective, as the average life cycle costs in the policy case scenario are about 30% lower than in the business as usual scenario calculated by Van Tichelen et al. (2007).

Also in office lighting, the aggregated life cycle costs in the BAT scenario were about 10% lower than they were in the BAU scenario (Tichelen Van et al. 2007b). Thus, the whole bundle of saving options considered in office lighting can be regarded as cost-effective.

For energy saving measures for *fans* Radgen et al. (2007 p.182) found that they are cost-effective in average. It was not possible to give concrete costs for certain saving options; instead they showed how much the price of improved fans could increase to be still cost-effective.

In the case of *commercial refrigeration* the EuP study provides very detailed cost information that makes it possible to explicitly model the cost-effectiveness of several distinct saving options, as done for the industrial cross-cutting technologies.

A good example that cost-effectiveness is not always the main goal for realising saving options is the replacement of desktop PCs by laptops, which is a saving option with a huge impact on energy consumption. The purchase price of laptops are so much higher that even the lower electricity consumption can't compensate for that and finally life cycle costs are significantly lower for the less energy efficient desktop PCs(TCO Development, Swedish Environmental Institute 2007 p.217). Still, laptops replace desktop PCs more and more. However, as discussed above, the replacement of desktop PCs by laptops is not considered as a distinct saving option in our analysis, as it is implemented as a technology driver that can not be addressed by policies.

The remaining options in the field of computers and monitors are on average cost-effective.

To summarise the discussion on costs, it can be concluded that for most of the appliances energy consumption dominates the life cycle costs and thus, measures that increase energy efficiency are often cost-effective. The same effect has been found for cross-cutting technologies in the industry chapter, where often more efficient solutions would also be cost-effective but still they are not applied in many cases.

10.2.5 Step 3 – Definition of the four scenarios

As most of the data on saving options is based on the findings of the EuP product studies, the structure of these studies is reflected in our scenario building. In general the approach shall be similar to the one followed for industrial electricity consuming cross-cutting technologies, still certain differences could not be avoided.

The EuP reports aim at showing possible improvement options for certain energy using products and in a final chapter presenting and comparing the impact of different policy options in terms of costs, energy and resource consumption. The fact that the reports aim at finding the policy option with the lowest life cycle costs (LLCC) leads to an underestimation of the technical scenario, as very costly options are not considered.

Furthermore, as the cost data is only in the least cases given per saving option, for most appliances only aggregated information on cost-effectiveness is available. This makes it difficult to follow the methodology laid out in the industry chapter, which distinguishes the scenarios by considering only cost-effective options for the policy scenarios (HPI and LPI), taking into account a lower discount rate for the LPI scenario than for the HPI scenario, while in the technical scenario all options are considered, no matter at what costs they would be available. As a consequence of the aggregated cost data the potentials in the three scenarios will seem very similar and in fact represent one policy scenario, which can be regarded as a collection of most likely scenarios from the EuP reports.

10.3 Results tertiary sector

10.3.1 Results heat uses in the tertiary sector

Figure 10-20 shows the unitary energy demand trend (kWh/m2) for heating uses in the public and collective buildings of the tertiary sector. The same data broken down by building size (small ≤ 1000 m2 and large ≥ 1000 m2) and building age (existing = all the building stock at the year 2004, new the future buildings built after the year 2004) are shown in Table 10-7.

With respect the starting year, the energy efficiency improvement is of the 26% for the autonomous progress scenario, of the 40%for the Low Policy Intensity scenario, of the 54% for he High Policy Intensity one and finally of the 67% for the Technical scenario.

Figure 10-20: Heating demand in the tertiary sector (offices and public buildings) – EU27 kWh/m2

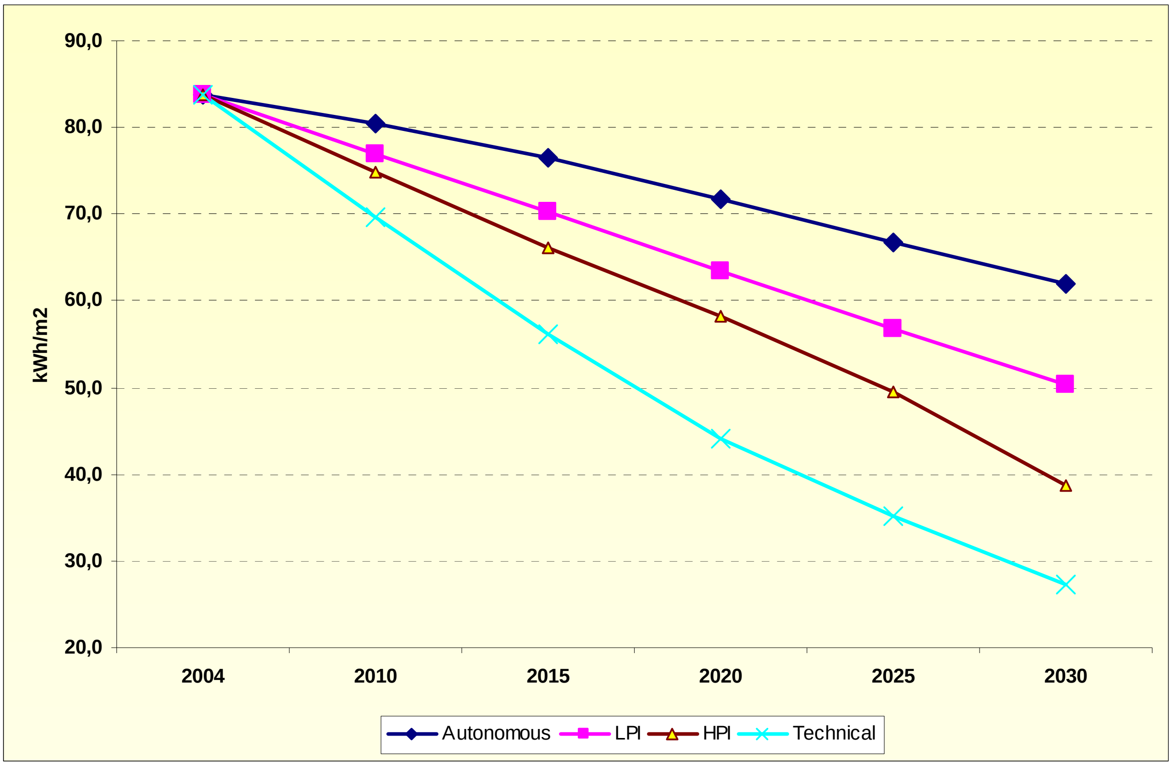


Table 10-7: Heating demand in the tertiary sector (offices and public buildings) – EU27 kWh/m2

Overall

	2004	2010	2015	2020	2025	2030
Autonomous	83,7	80,5	76,5	71,8	66,7	61,9
LPI	83,7	76,9	70,3	63,5	56,8	50,2
HPI	83,7	74,9	66,2	58,1	49,5	38,8
Technical	83,7	69,6	56,1	44,2	35,1	27,3

Small Buildings all ages ≤ 1000 m2

	2004	2010	2015	2020	2025	2030
Autonomous	96,8	93,3	88,7	83,1	77,0	71,3
LPI	96,8	89,2	81,5	73,3	65,5	57,6
HPI	96,8	86,7	76,6	67,1	56,8	44,2
Technical	96,8	80,3	64,4	50,5	39,9	30,7

Large Buildings all ages ≥ 1000 m2

	2004	2010	2015	2020	2025	2030
Autonomous	62,4	59,7	56,7	53,4	49,9	46,6
LPI	62,4	57,1	52,2	47,4	42,6	38,2
HPI	62,4	55,6	49,3	43,5	37,7	29,9
Technical	62,4	52,2	42,6	33,8	27,3	21,6

Existing buildings all sizes, up to 2004

	2004	2010	2015	2020	2025	2030
Autonomous	83,7	80,3	77,0	73,7	70,4	67,2
LPI	83,7	76,4	69,9	63,3	56,8	50,4
HPI	83,7	74,1	65,6	57,1	48,8	40,4
Technical	83,7	71,2	60,4	49,6	38,9	28,2

New buildings all sizes, from 2004

	2004	2010	2015	2020	2025	2030
Autonomous	0,0	82,0	73,9	65,5	57,8	52,2
LPI	0,0	82,0	73,2	64,7	57,8	51,5
HPI	0,0	82,0	69,0	61,3	51,5	35,7
Technical	0,0	53,0	33,7	25,6	25,6	25,6

The energy efficiency potentials achievable in the service sector from both the building refurbishment interventions and the application of the new building codes are shown in Figure 10-21 and in Table 10-8. From Table 10-8 it is possible to see that the energy savings achievable in the EU27 countries in the year 2030 from this type of interventions start from 15,8 Mtoe for the LPI scenario, corresponding to a relative gain of 22,8%, arrive to 26,9 Mtoe in the HPI scenario (38,9%) and target to 39,7 Mtoe in the technical scenario 57,2%).

Finally Table 10-9 (ktoe) and Table 10-10 (%) provide the break down of these savings by building age. In the LPI scenario the energy efficiency improvement is practically totally entrusted to the refurbishment interventions of the existing building stock. In the HPI scenario as well as in the technical one, the savings provided by a more strict implementation of the building codes provide up to the 20% of the total savings. For what concerns the building size the small buildings contribute for the 30-33% to the overall savings and the large ones for the remaining 70-67%. This percentage practically doesn’t change along the scenario steps and by scenario type (actually the building share by size is kept constant along the scenario steps).

Figure 10-21: Energy Efficiency potentials from the heating uses in the tertiary sector (offices and public buildings) – EU27 ktoe

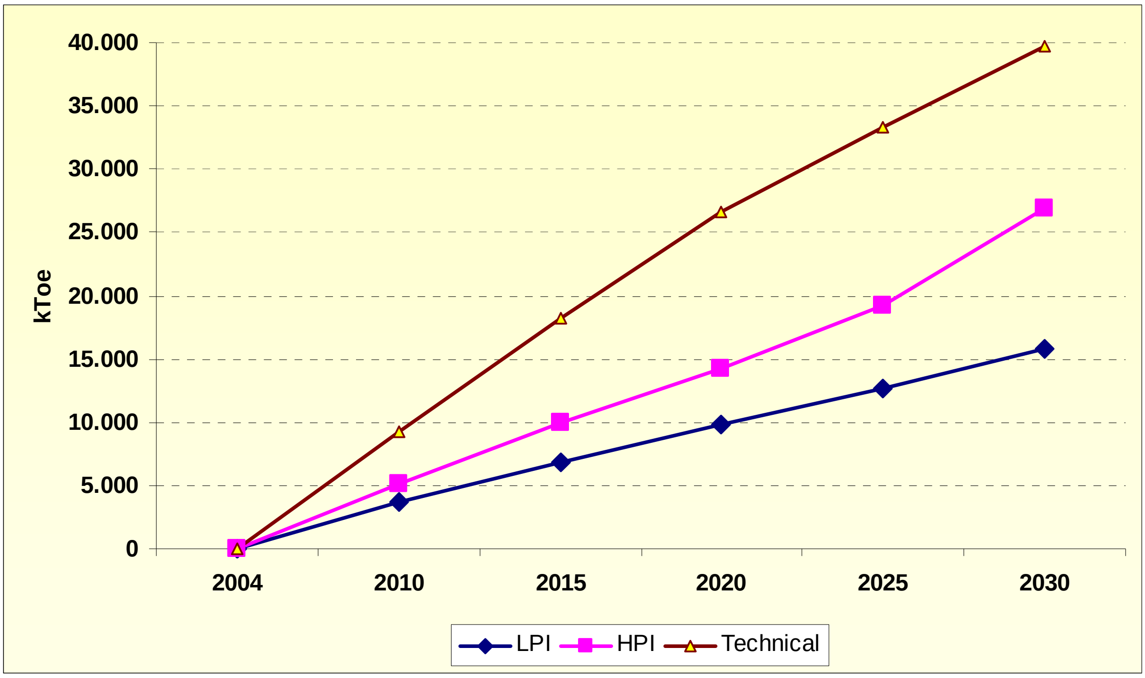


Table 10-8: Energy Efficiency potentials from the heating uses in the tertiary sector (offices and public buildings) – EU27

		2010	2015	2020	2025	2030
LPI	**ktoe**	3.658	6.769	9.811	12.630	15.821
HPI		5.119	9.945	14.296	19.243	26.961
Technical		9.218	18.262	26.627	33.271	39.667
		2010	**2015**	**2020**	**2025**	**2030**
LPI	**%**	5,1%	9,4%	13,8%	17,9%	22,8%
HPI		7,2%	13,9%	20,0%	27,3%	38,9%
Technical		12,9%	25,5%	37,3%	47,3%	57,2%

Table 10-9: Energy Efficiency potentials from the heating uses in the tertiary sector, break down by building age. EU27 ktoe

LPI	**2010**	**2015**	**2020**	**2025**	**2030**
Existing stock	3.658	6.675	9.668	12.630	15.569
New stock	0	95	143	0	252
HPI	**2010**	**2015**	**2020**	**2025**	**2030**
Existing stock	5.119	9.343	13.529	17.676	21.787
New stock	0	603	767	1.567	5.174
Technical	**2010**	**2015**	**2020**	**2025**	**2030**
Existing stock	7.367	13.439	19.461	25.427	31.336
New stock	1.851	4.824	7.166	7.844	8.331

Table 10-10: Energy Efficiency potentials from the heating uses in the tertiary sector, break down by building age. EU27 ktoe

LPI	**2010**	**2015**	**2020**	**2025**	**2030**
Existing stock	100,0%	98,6%	98,5%	100,0%	98,4%
New stock	0,0%	1,4%	1,5%	0,0%	1,6%
HPI	**2010**	**2015**	**2020**	**2025**	**2030**
Existing stock	100,0%	93,9%	94,6%	91,9%	80,8%
New stock	0,0%	6,1%	5,4%	8,1%	19,2%
Technical	**2010**	**2015**	**2020**	**2025**	**2030**
Existing stock	79,9%	73,6%	73,1%	76,4%	79,0%
New stock	20,1%	26,4%	26,9%	23,6%	21,0%

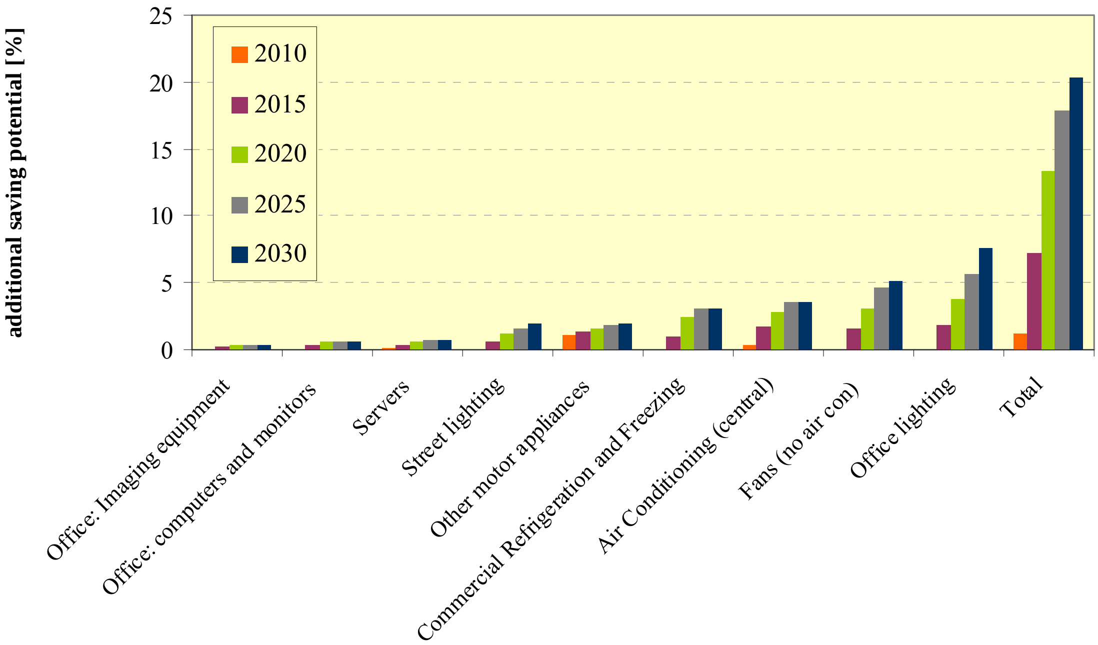
10.3.2 Results electricity uses in the tertiary sector

As the EuP studies have been used as main data source for the assessment of saving potentials in the tertiary sector's electricity consumption, the special pattern of these reports also has an influence on the results of our analysis. The results, thus, have to be interpreted slightly different than in the other sectors and with the goals of the EuP reports in mind.

Furthermore, as in the other sectors, we assessed scenarios, which show the saving potential additionally achievable in relation to an autonomous energy efficiency improvement. Thus it reflects the saving potential addressable by policies.

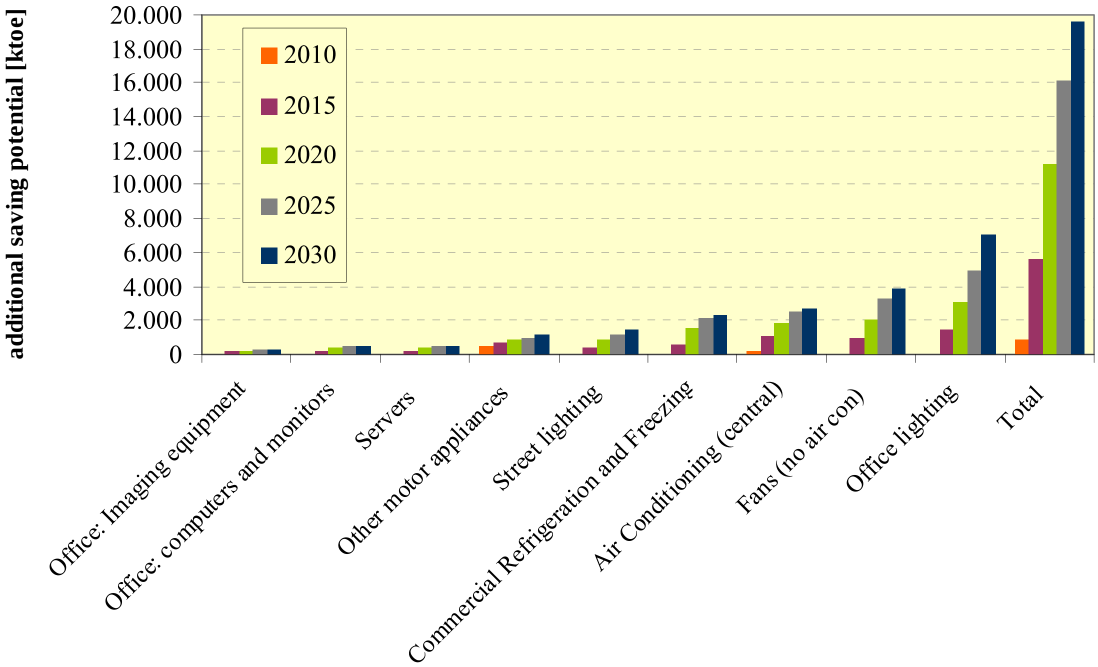
Figure 10-22 shows the development of the additional saving potentials by end-use for the EU27. The total saving potential arrives at 20% of the autonomous electricity demand development, which is very close to the EU baseline projections (see further below). This saving potential can be considered as cost effective, which means the life cycle costs of appliances are lower than they would be without implementing the saving options.

Figure 10-22: Additional policy scenario saving potential per base year by end-use in the tertiary sector (in percentage, EU27)



Due to the chosen methodology for the tertiary sector, these saving potentials differentiated by end-use, do not consider dynamics in drivers, which means an increased diffusion of air conditioning systems or servers, as it is expected by experts, could not be considered. In other words, the shares of end-uses in total electricity consumption change only due to efficiency improvements but not due to stock changes. This methodological aspect has to be considered when interpreting the results. In general it makes the resulting long-term saving potential in air-conditioning and internet and communication technologies seem lower than it might be, given the expected increase in the usage of these technologies. However, it is uncertain to forecast growth rates for the stock of appliances and it is far from sure how technologies' growth rates will develop relative to other technologies in the future.

Figure 10-23: Additional policy scenario saving potential by end-use in the tertiary sector (in ktoe, EU27)

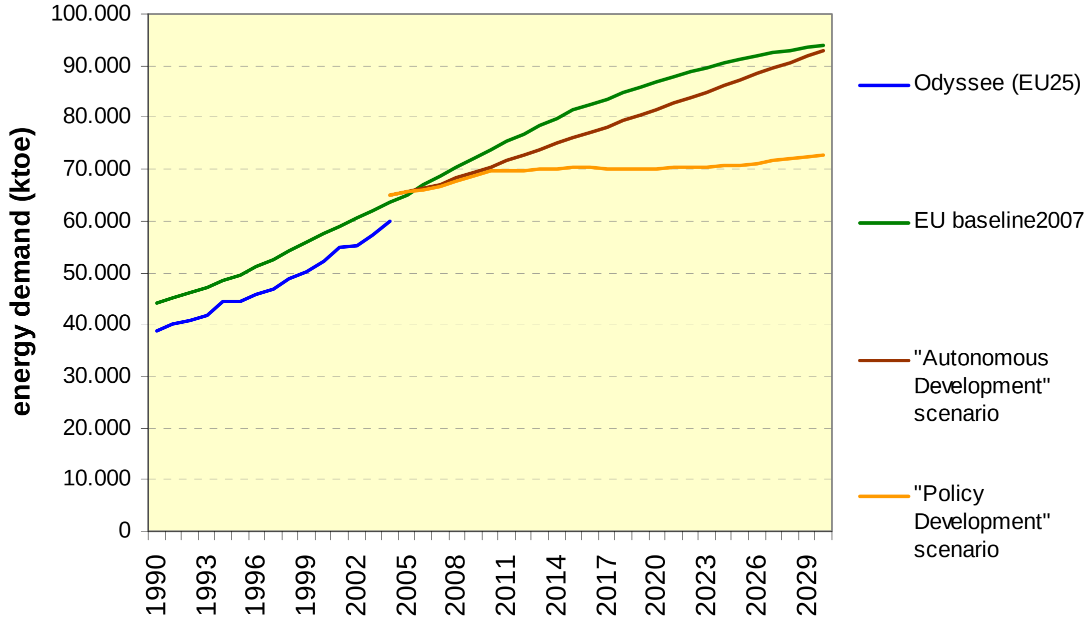


A comparison of our results with the official EU projections (baseline 2007) and empirical data is illustrated in the two following diagrams.

Figure 10-24 shows the development of electricity demand for the EU27 in the different scenarios. The long-term autonomous development follows a constantly growing trend, both, in the EU baseline as well as in the autonomous scenario. The growth of these two scenarios is also in line with the observed development from 1990 onwards (Odyssee data). In the autonomous scenario, electricity demand increased by 43% in the period from 2004 to 2030 - mainly driven by growth in GDP.

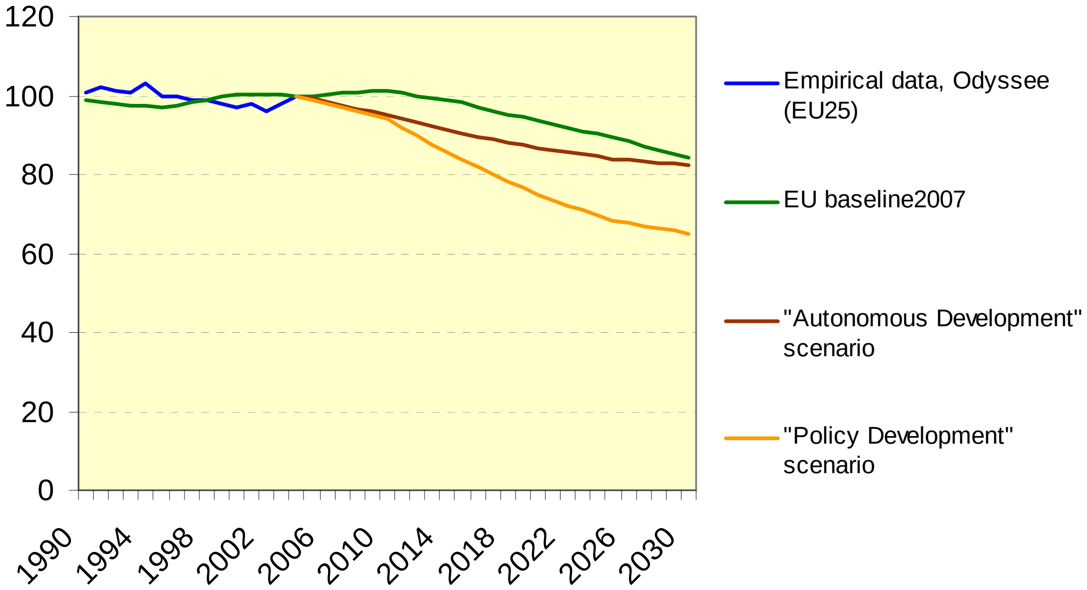
Only the policy scenario, which includes all savings mentioned above, can come close to a stabilisation of electricity demand. Although from 2004 to 2030, an increase of 12% can be noticed, the rise is far lower from 2010 onwards, when the considered saving options and measures are assumed to be in force. From 2010 to 2030 the policy scenario shows an increase in electricity demand by 5%, in contrast to 34% in the autonomous scenario.

Figure 10-24: Development of total electricity demand of EU27 in comparison to past development and the EU baseline 2007 projections



Analogously to Figure 10-24, Figure 10-25 shows how the electricity intensity of tertiary value added develops in different scenarios. Also here, our autonomous scenario calculations end at the same level in 2030 as the EU baseline. Electricity intensity in the policy scenario is about 23% lower in 2030 than in the EU baseline. However, as illustrated in Figure 10-24, this significant improvement in tertiary sector energy efficiency (measured as electricity consumption per value added) will just suffice to have a stable or slowly increasing electricity demand.

Figure 10-25: Development of electricity intensity in EU27 in comparison to empirical data and the EU baseline from 2007



For a proper interpretation of the resulting saving potentials in the tertiary sector's electricity demand, the following aspects have to be kept in mind.

- About 20% of electricity demand in the EU tertiary sector is due to space heating and hot water. The saving potentials for this end-use are not covered in this chapter on electricity, but in the chapter about building energy demand for heating in the tertiary sector.
- The structure of the EuP reports, which have been used as main data source, does not allow for a strictly "technical saving potentials" scenario, as the assessed saving potentials are assessed by political measure and in the centre of the assessment is the criteria of cost-effectiveness. The reports try to identify the option with least life cycle costs.
- Furthermore, the focus of the EuP reports is on the product, not on the system. The proposed saving options, like minimum energy performance standards (MEPS), address product specific changes. They seldomly consider options beyond the product level, which also indicates that our calculated saving potential is not the
- As for the other sectors, it is also the case in the tertiary sector, that a bottom-up analysis of distinct technologies and saving options always leaves out options and technologies, which have a lower share in electricity demand. Still, all these options and technologies together would further increase the total saving potential.

Consequently, there are still additional saving potentials in the tertiary sector available that go beyond our analysis. The total additional policy saving potential of 20% in 2030 has to be interpreted as a potential realisable by implementing recommended policies addressing electricity consumption in the most relevant end-uses. This saving potential can also be realised cost-effectively as its life cycle costs are lower than in the business as usual case.

10.3.3 Results overall tertiary sector

A summary of the results for the tertiary sector is given in the following two tables.

Table 10-11: Summary of energy efficiency potentials from the service sector EU27 ktoe

Economic (LPI) - Total saving potential in tertiary

	Unit	2010	2012	2015	2016	2020	2025	2030
EU27	ktoe	4476	7631	12364	14071	20900	28668	35366

Economic (LPI) - Total saving potential for heating in service buildings

	Unit	2010	2012	2015	2016	2020	2025	2030
EU27	ktoe	3658	4902	6769	7377	9811	12630	15821

Economic (LPI) - Electricity saving potential in tertiary

	Unit	2010	2012	2015	2016	2020	2025	2030
EU27	ktoe	818	2729	5595	6694	11089	16038	19545

Economic (HPI) - Total saving potential in tertiary

	Unit	2010	2012	2015	2016	2020	2025	2030
EU27	ktoe	5951	9805	15585	17564	25480	35388	46599

Economic (HPI) - Total saving potential for heating in service buildings

	Unit	2010	2012	2015	2016	2020	2025	2030
EU27	ktoe	5119	7049	9945	10815	14296	19243	26961

Economic (HPI) - Electricity saving potential in tertiary

	Unit	2010	2012	2015	2016	2020	2025	2030
EU27	ktoe	832	2755	5640	6749	11184	16145	19638

Technical - Total saving potential in tertiary

	Unit	2010	2012	2015	2016	2020	2025	2030
EU27	ktoe	10131	15709	24075	26880	38102	49789	59716

Technical - Total saving potential for heating in service buildings

	Unit	2010	2012	2015	2016	2020	2025	2030
EU27	ktoe	9218	12836	18262	19935	26627	33271	39667

Technical - Electricity saving potential in tertiary

	Unit	2010	2012	2015	2016	2020	2025	2030
EU27	ktoe	913	2873	5813	6945	11475	16518	20049

Table 10-12: Summary of energy efficiency potentials from the service sector EU27 %

Economic (LPI) - Total saving potential in tertiary

	Unit	2010	2012	2015	2016	2020	2025	2030
EU27	%	3,2	5,3	8,4	9,5	13,7	18,2	21,8

Economic (LPI) - Total saving potential for heating in service buildings

	Unit	2010	2012	2015	2016	2020	2025	2030
EU27	%	5,1	6,9	9,4	10,3	13,8	18	22,8

Economic (LPI) - Electricity saving potential in tertiary

	Unit	2010	2012	2015	2016	2020	2025	2030
EU27	%	1,2	3,6	7,2	8,4	13,2	17,7	20,3

Economic (HPI) - Total saving potential in tertiary

	Unit	2010	2012	2015	2016	2020	2025	2030
EU27	%	4,2	6,8	10,5	11,8	16,7	22,4	28,7

Economic (HPI) - Total saving potential for heating in service buildings

	Unit	2010	2012	2015	2016	2020	2025	2030
EU27	%	7,2	9,9	13,9	15,1	20	27,4	38,9

Economic (HPI) - Electricity saving potential in tertiary

	Unit	2010	2012	2015	2016	2020	2025	2030
EU27	%	1,2	3,6	7,3	8,5	13,3	17,8	20,4

Technical - Total saving potential in tertiary

	Unit	2010	2012	2015	2016	2020	2025	2030
EU27	%	7,1	10,9	16,3	18,1	24,9	31,6	36,8

Technical - Total saving potential for heating in service buildings

	Unit	2010	2012	2015	2016	2020	2025	2030
EU27	%	12,9	17,9	25,5	27,8	37,3	47,3	57,2

Technical - Electricity saving potential in tertiary

	Unit	2010	2012	2015	2016	2020	2025	2030
EU27	%	1,3	3,8	7,5	8,8	13,7	18,3	20,8

PART III

Database structure and interface to the MURE demand simulation and supply module

11 The Energy Saving Database (ESP) and the link to MURE

11.1 Database purposes (model inputs, presentation of outputs)

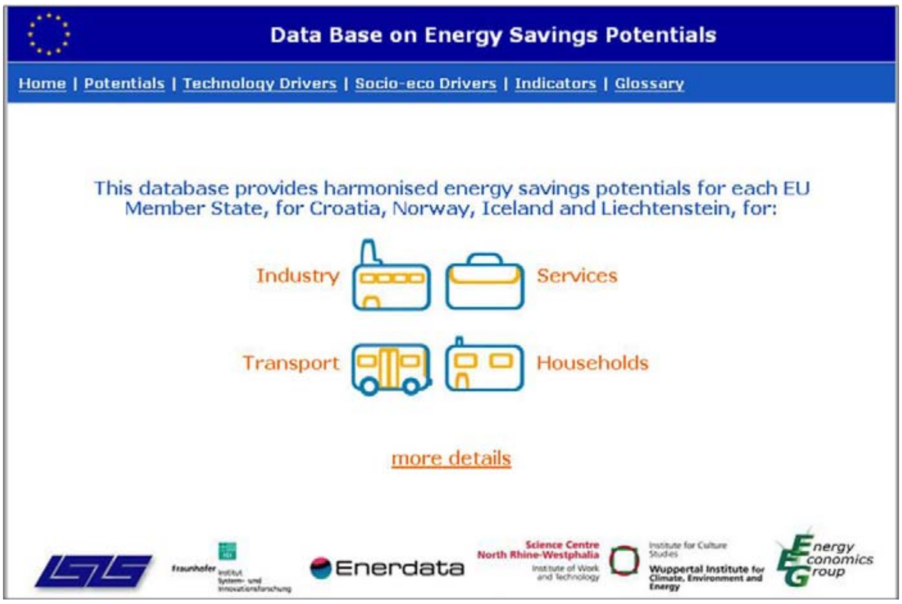
The Energy Saving Potential (ESP) database is the tool required by the DG-TREN to communicate on energy efficiency potentials, to assess easily energy efficiency potentials by country and to consult the drivers behind the calculation of these potentials. Therefore the database was restricted to the information and functionalities strictly necessary for these purposes and the emphasis was put on the user's friendliness and the relevance of the database outputs.

The database was designed as a web database so as to be easily accessible to many users, at least in the Commission, which meant a development on a dedicated Web site. DG-TREN may be able to integrate the database on the Europa Web site later on. Its address is: **www.eepotential.eu.** Its access is restricted and protected with a password.

In summary, the database will enable the Commission to access information on:

- Energy efficiency potentials by country and EU wide (in % or in Mtoe)
- Energy efficiency potentials by category
- Main drivers used in the calculation of potentials
- Energy efficiency indicators consistent with ODYSSEE indicators

During the project, the database was used by the project partners to store, organise and check the main models inputs and outputs, to guarantee the consistency between all models used and between the drivers (i.e. models inputs) and potentials



11.1.1 Contents of the database

The primary purpose of the database is to deliver information on the energy efficiency potentials by country and category altogether with the background information on the drivers of these potentials as they have been used in the calculation:

- Socio-economic and sectoral activity projections (e.g. dwellings, traffics, production)
- Market penetration of technologies or modes of transport

The database has four major components: energy efficiency potentials, socio-economic drivers, technology drivers related to energy efficiency potential calculations and energy efficiency indicators.

Energy efficiency potentials

The database enables the user to display the total potential by sector and by **sub-sector** or **end-uses**: dwelling categories (existing/new), types of appliances (refrigerators, freezers, TVs, .), industrial branches (NACE classification or energy intensive products such as cement, steel, etc…), industrial cross-cutting technologies (e.g. pumps, ventilators, compressed air, electric motors), CHP at the demand side, transport modes, transport services, etc…The potentials are given for the three types of potentials considered in the study: low policy intensity potential (LPI), high policy intensity potential (HPI) and technical potential. They can be expressed in final energy and primary energy. They are given for all energy products, and in industry for electricity and for non electric fuels (coal, oil, gas, biomass).

Table 11-1: Categories of energy efficiency potentials available in the database

Industry	Savings in whole industry : total, fuels and electricity • Savings by branch: o Steel o Non ferrous o Chemicals o Non metallic minerals: cement, glass … o Paper o Food • Savings by technology: o Heat generation : boilers and CHP with <500°C o Electrical appliances: motors, lighting …. o Industrial process: steel, aluminium, cement, paper, glass, chemicals
Transport	• Total • Passengers o Total o Technical o Modal shift • Goods o Total o Technical o Modal shift
Households	• Total • Heating : o Total o Existing stock (in dwellings built before 2000) o Existing stock from refurbishment o New dwellings (in dwellings built since 2000) o Water heating (total) • Electrical appliances : o Total o refrigerators o freezers o washing machine o dishwasher o dryers o AC o Lighting o TV o Set top Boxes o Desk Tops o Lap Top o Modem Routers o IT screens

Socio-economic drivers related to energy efficiency potential calculations

The second item in the database are socio-economic macro drivers, such as GDP, population, households, number of cars, traffic of passengers and goods, industrial production, with a single projection over the period.

Table 11-2: Socio-economic drivers available in the database

Transport	• Number of cars • Total passenger traffic • Total traffic of goods
Households	• Stock of dwellings • Construction of dwellings

Technology drivers related to energy efficiency potential calculations

Technology drivers are given for the four scenarios: autonomous scenario, low policy intensity scenario, high policy intensity scenario and technical scenario. They relate to the energy performances of new cars, the share of efficient modes of transport and the penetration rates of energy efficient equipment (e.g. shares of labels A, A+). For industry, there is no easily identifiable technology driver, due to the heterogeneity of the sector (multiplicity of process and cross-cutting technologies); therefore, no driver is shown for that sector.

Table 11-3: Technology drivers available in the database

Transport	• Specific consumption of new cars (l/100 km)
	• Share of public transport (rail+bus) in total passenger traffic (%)
	    o Urban
	    o Interurban
	• Share of public transport (rail+water) in total traffic of goods (%)

Households	• Heating :
	    o insulation of existing stock
	        ▪ % of refurbished dwellings (cumulated since 2004)
	        ▪ saving rate after refurbishment (average for all refurbished dwellings)
	        ▪ energy savings index of new dwellings (2004 standards=100)
	        ▪ share of efficient heating systems : heat pumps, wood pellet heaters
	    o Water heating : share of solar water heaters
	• Electrical appliances (share of efficient classes)[64]
	    o refrigerators[65]
	    o freezers[66]
	    o washing machine[67]
	    o dishwasher[68]
	    o dryers[69]
	    o AC[70]
	    o Lighting[71] : share of labels A

---

[64] The different efficient class to be displayed are indicated in the footnotes for each appliance

[65] share of labels A+, A++, Newcat

[66] share of labels A+, A++, Newcat

[67] share of label A, Newcat, BAT

[68] share of labels A, BAT

[69] share of label Newcat, A

[70] share of label A+

Energy efficiency indicators

The energy efficiency indicators relate to unit energy consumption by mode of transport, by end-use and appliance for households and by type of product in industry. They are provided for the four scenarios: autonomous scenario, low policy intensity scenario, high policy intensity scenario and technical scenario.

Table 11-4: Energy indicators available in the database

Industry	• Total energy intensity of industry to value added: total, fuels and electricity • Energy intensity to value added by sub-sector (in index, 2004=100) o Chemicals o Food o Engineering • Unit consumption per ton o Steel o Aluminium o Cement o Glass o Paper • Diffusion indicators for cross-cutting technologies (%): o Share of CHP in heat production o Share of efficient motors in motor stock (label EFF1 and above)
Transport	• Specific consumption of car stock (litre/100 km) • Average yearly consumption per car (toe/car) • Average consumption of road transport of goods per tonne-km (goe/tkm) • Average consumption of transport of goods per tonne-km (goe/tkm) • Average consumption of passenger transport per passenger-km (goe/pkm)
Households	• Total unit consumption per dwelling • Heating : unit consumption o Total : per dwelling and per m2 o Existing stock (per m^2) (dwellings built before 2000) o New dwellings (per m^2) (for all dwellings built after 2000) • Water heating (unit consumption per dwelling) • Electrical appliances (unit consumption in kWh/year) o Total: per dwelling o Refrigerators per appliance (stock average) o Freezers per appliance (stock average) o washing machine per appliance (stock average) o dishwasher per appliance (stock average) o dryers per appliance (stock average) o AC per appliance (stock average) o Lighting per appliance (stock average) o TV per appliance (stock average) o Other ICT's per dwelling (set top boxes, desk tops, Lap Top, modem routers, IT screens)

[71] share of label A

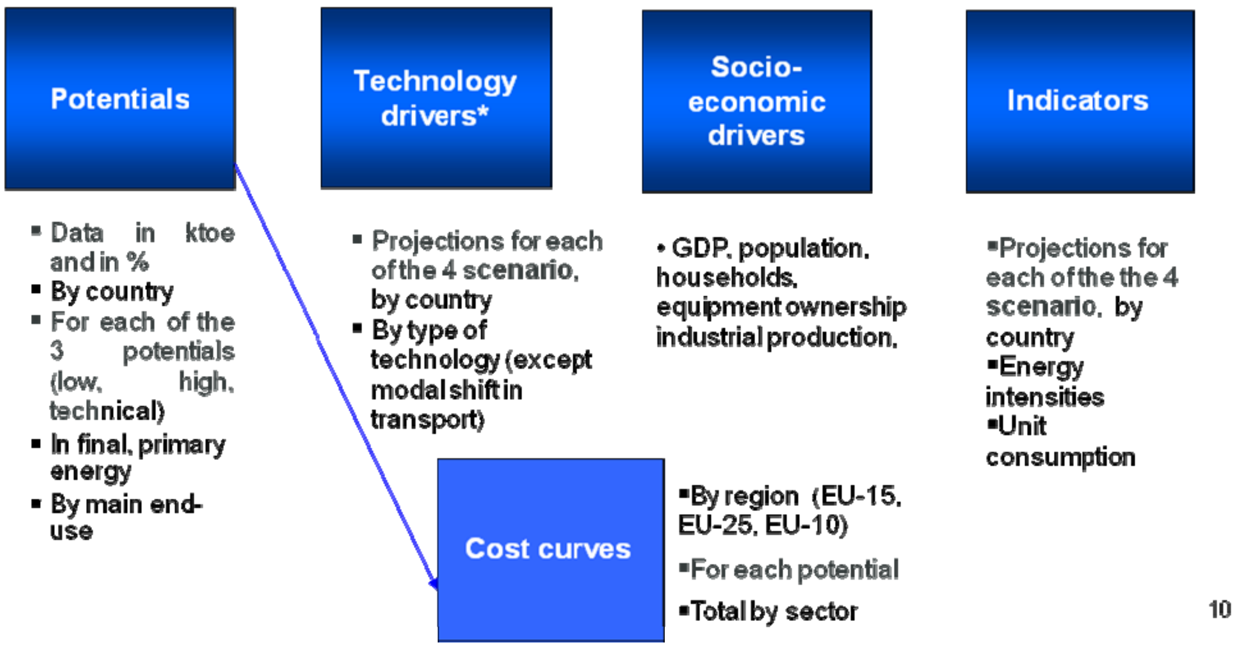
11.1.2 Disagregation level

The energy efficiency potentials are displayed by country for the following **countries** and for four countries aggregates: EU27, EU15, EU-12 and EEA countries (which include EU27, Iceland, Liechtenstein and Norway. For simplicity reasons, Croatia, which most likely will enter the EU in short time, was also integrated into this aggregate). The list of countries covered is given in the Table below:

Table 11-5: Countries in the ESP

Austria	France	Malta
Belgium	Greece	The Netherlands
Bulgaria	Hungary	Norway
Croatia	Ireland	Poland
Cyprus	Iceland	Portugal
Czech Republic	Italy	Romania
Germany	Liechtenstein	Spain
Denmark	Lithuania	Sweden
Estonia	Luxembourg	Slovenia
Finland	Latvia	Slovak Republic
		United Kingdom

The **target year**s considered for the potentials are: 2010, 2015, 2020, 2025, 2030, plus two intermediate years, 2012 and 2016, as key years for the ESD. For the drivers and indicators, the values for 2004, the base year, are also given.



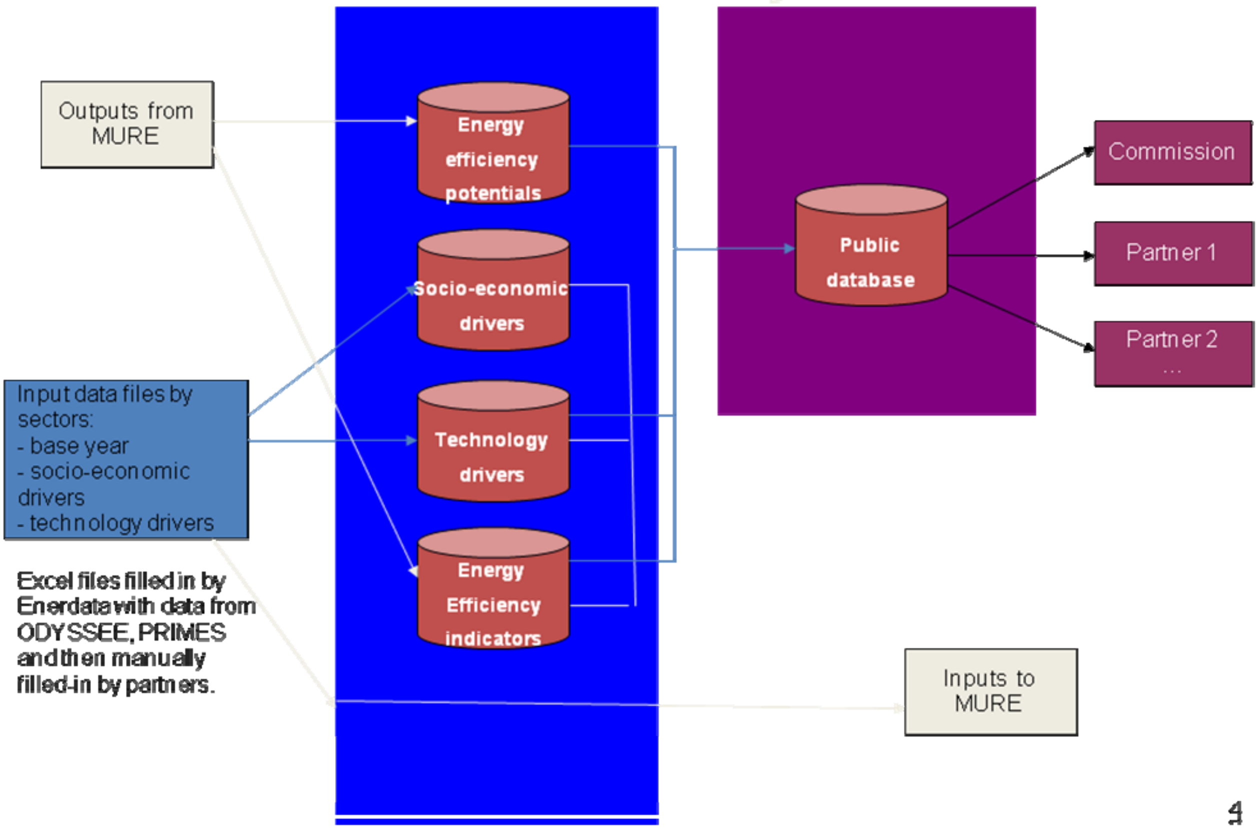
11.2 Database main structure

The data used in the project were organised in two types of data set in Excel format:

- input data files by sector, in which data have been input manually; these files are called “data inputs” (e.g. file “**data input** household" for households) as they include mostly inputs to the MURE model; the various scenario drivers displayed in the database are also included in these input data files; these files were shared by all partners
- “output data” files by sector that store the results of the MURE model and are only used to feed the database for the potentials and indicators

Figure 11-1 shows the link between all these databases.

Figure 11-1: Organisation of the database inputs and outputs



11.2.1 Detailed operational structure of the database

11.2.2 Input data files

The input data files are organised on Excel in 3 sheets: base year data, socio-economic c drivers and technology drivers, the later being differentiated according to the type of potentials

- The **base year data (BY)** (only one year 2004) are of two origins depending on whether they are available in another database or need to be input manually
  - data already available in an external database (e.g. ODYSSEE); they have been imported automatically from the database
  - data that are not already organised in a database, that were missing from ODYSSEE or that needed some external assessment by the project partners, (e.g. estimate of the specific consumption of new cars according to urban/non urban from the average):

- The **socio-economic drivers (SD)** were in general available in an electronic format and were extracted from the results or input data from Primes and Tremove).
- The **technology drivers (TD)** contain the main assumptions on the different type of scenarios; their projections were defined for each of the 4 scenarios; they are of two types:
  - drivers used for models simulation and not included in the database for consultation, as two detailed and complex;
  - drivers available for consultation in the database.

Figure 11-2: Organisation of input data

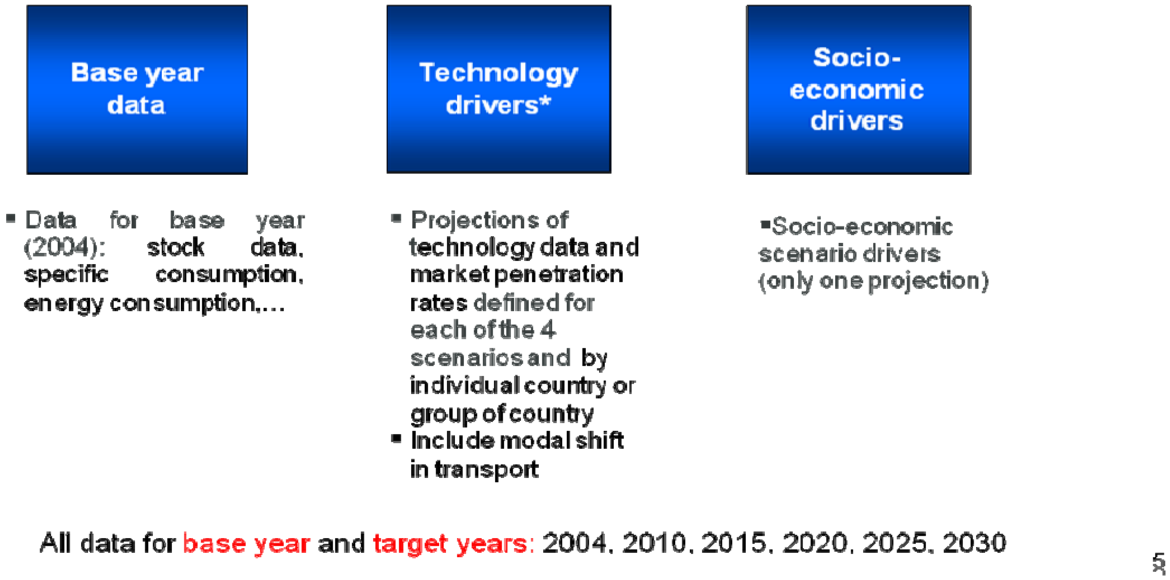
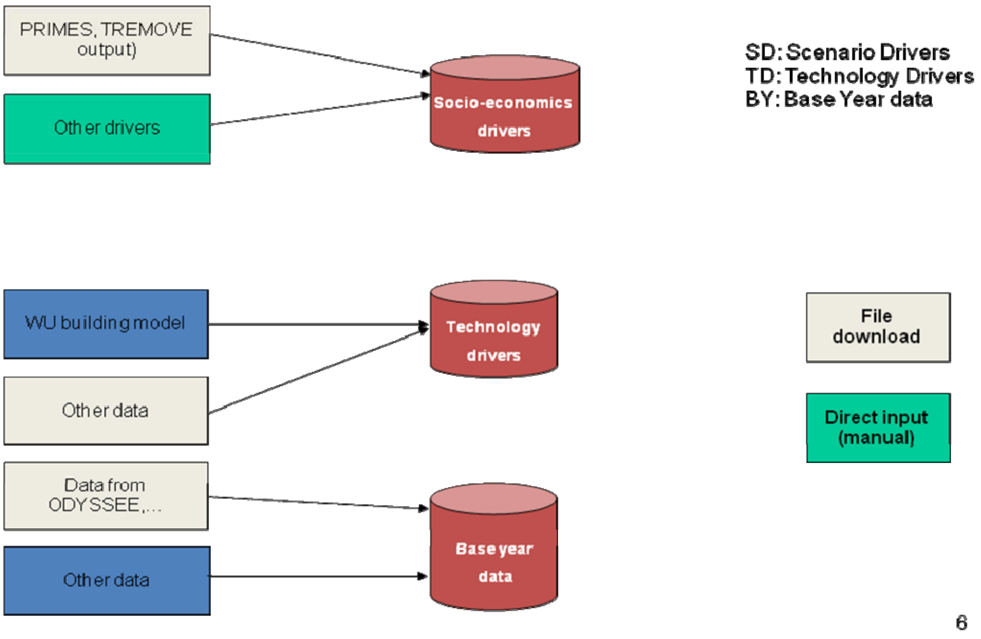


Figure 11-3: Sources of data



11.2.3 Output data from the models

The outputs from MURE needed for the database were exported in one data file by sector. The next section discusses further the linkage with MURE.

11.2.4 Public database

This database is the final output and deliverable of the project. It was conceived so as to be very user friendly so as to enable:

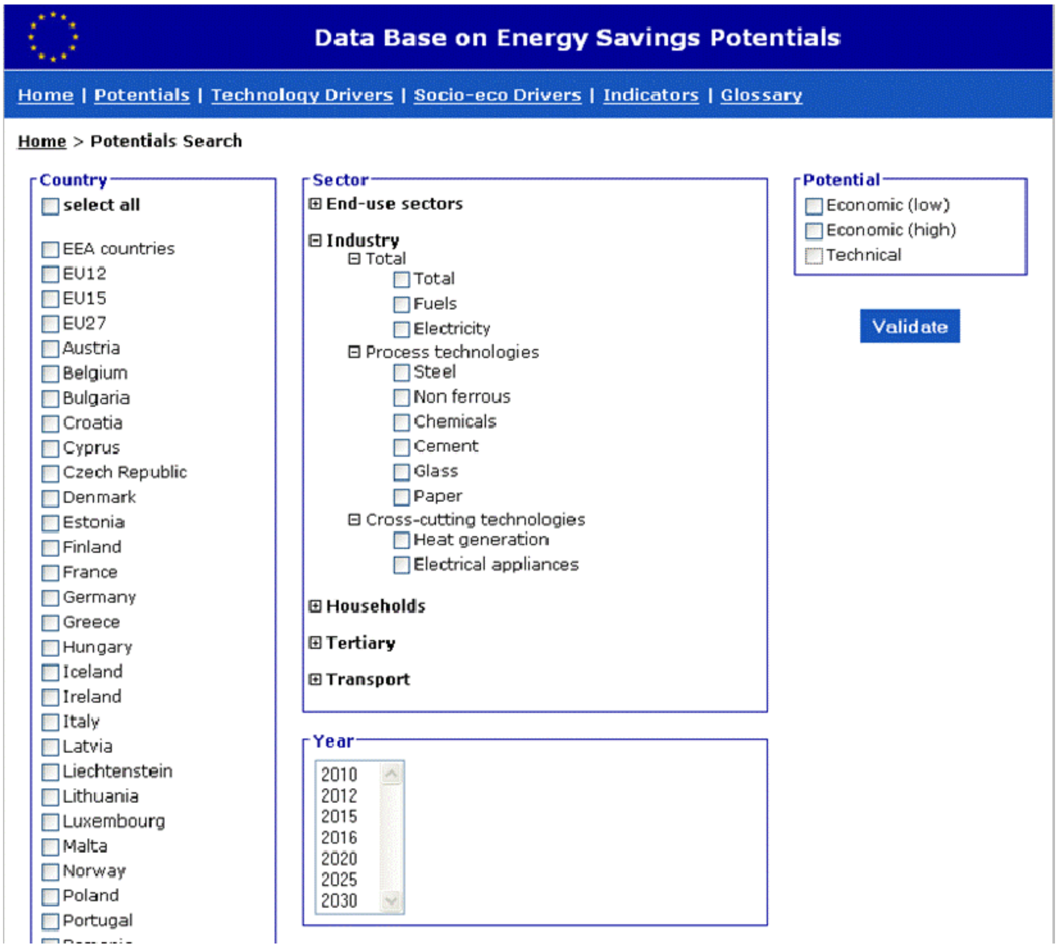
- Easily retrieving and nicely displaying of the information stored in the database.
- Provision of more elaborated and readily available information products through data tables.

Three querying logics were implemented:

- Querying country data on energy efficiency potentials (years x country x sector/category x potentials); data can be retrieved by type of potential (comparison for one country of the values for the different potentials selected) or by country (cross-country comparison of the values by type of potential ; at any time links are proposed to the main economic and technical drivers used in the calculation, and to related indicators;

- Querying country data on technology drivers (years x country x technology x scenario); data can be retrieved by scenario (comparison for one country of the values for the different scenario selected) or by country (cross-country comparison of the values by type of driver for each of the scenario selected);
- Querying country data on energy efficiency indicators (years x country x indicator x scenario); data can be retrieved by scenario in the same way as the drivers;
- Querying country data on socio-economic drivers (years x country x driver); data are retrieved by country.

Figure 11-4: Database content

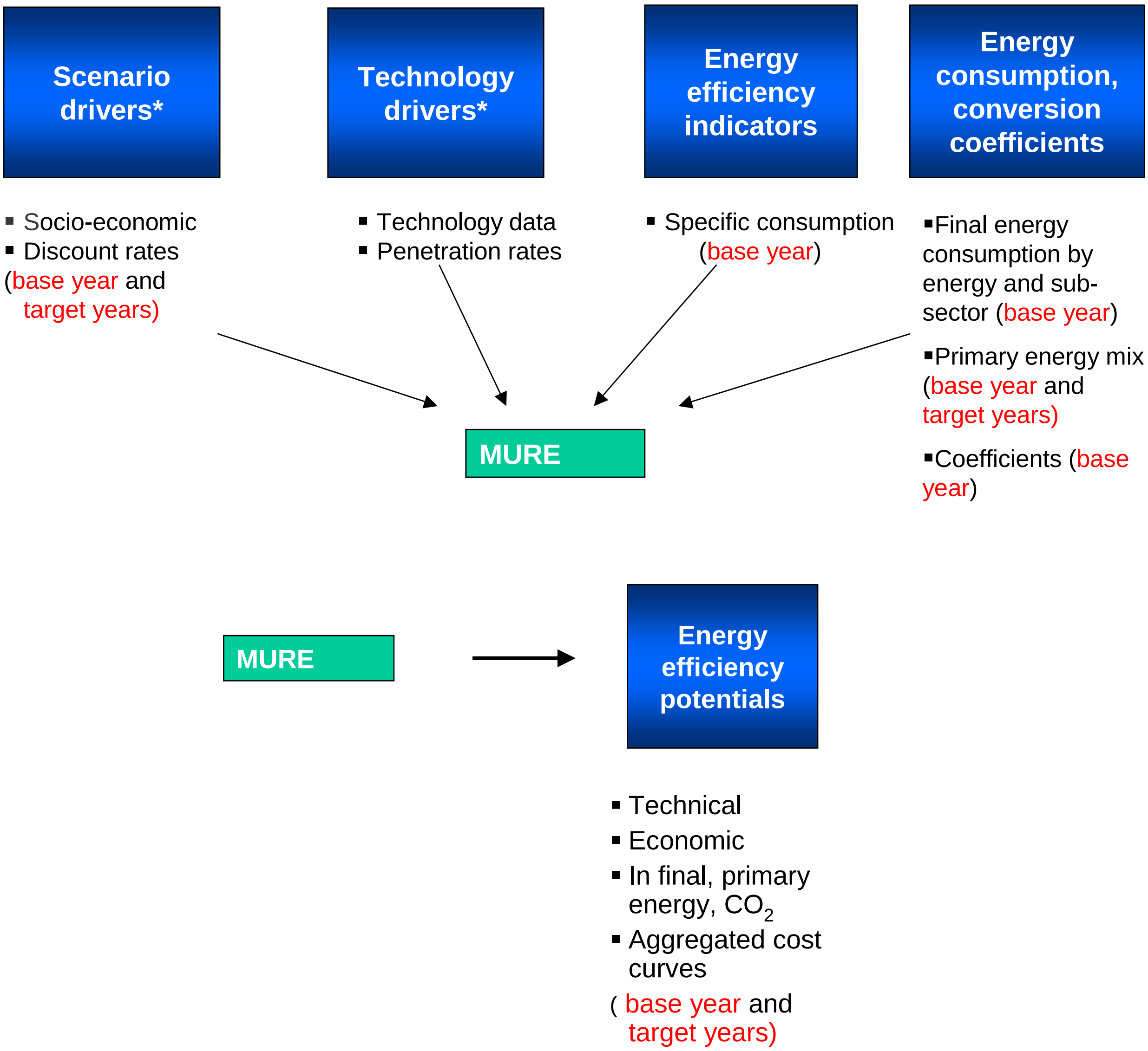


11.3 Interface with the MURE model

The interface between the database and the MURE model is displayed on the following graph. It has the following two main functions:

- Supply of data to MURE, on the one hand
- Output form MURE to the database (e.g. potentials), on the other hand

Figure 11-5: Inputs data to MURE and outputs from MURE



12 References

ADEME (2005): Energy Efficiency Monitoring in the EU15, Paris: ADEME.

Adnot, J.; Riviere, P.; Marchio, D.; Holstrom, M.; Naeslund, J.; Saba, J.; Waide, P. (2003): Energy Efficiency and Certification of Central Air Conditioners, Paris: ARMINES.

Almeida, A.T.; Ferreira, F.; Fong, J.; Fonseca, P. (2007): EUP Lot 11 Motors, Coimbra.

Almeida, A.T.; Ferreira, F.; Fong, J.; Fonseca, P. (2007): Preparatory studies for ecodesign requirements for EuPs - EUP Lot 11 Motors, Coimbra.

Almeida, A.T.; Fonseca, P.; Ferreira, F.; Guisse, F.; Blaise, J.; Clair, E.; Diop, A.; Previ, A.; Dominioni, A.C.; Di Pillo, M.; Russo, S.; Falkner, H.; Reichert, J.; Tönsing, E.; Malmose, K. (2001): Improving the penetration of energy-efficient motors and drives - In Cooperation with University of Coimbra / Department of Electri-cal Engineering; Electricite de France; ENEL (Italy); ETSU (UK); NESA (Denmark), Fraunhofer ISI (Germany), Coimbra(Portugal): University of Coimbra.

Almeida, A.T.D.; Ferreira, F.; Fonseca, P.; Chretien, B.; Souet, P.; Falkner, H.; Reichert, J.; Peterson, C.T.; Both, D. (2000): VSDs for electric motor systems, ISR-University of Coimbra (Portugal); Agence de l'Environnement et de la Maîtrise de l'Energie (France); ETSU; Fraunhofer-Institut für Systemtechnik und Innovationsforschung (Karlsruhe) (eds.), Coimbra, Portugal: ISR-University of Coim-bra.

BBR (Bundesamt für Bauwesen und Raumordnung) (2005): Bauwirtschaftliche Kooperationschancen bei der energetischen Sanierung des Wohnungsbestandes in MOE-Partnerstaaten am Beispiel der Ukraine. Project on behalf of the Federal Ministry of Transport, Building and Urban Affaires. Bonn.

BBR (Bundesamt für Bauwesen und Raumordnung) (2006): Siedlungsentwicklung und Infrastrukturfolgekosten. Bilanzierung und Strategieentwicklung. Project on behalf of the Federal Ministry of Transport, Building and Urban Affaires. Bonn. http://www.bbr.bund.de/cln_007/nn_23582/DE/Veroeffentlichungen/BBR-Online/2002-2006/DL__ON032006,templateId=raw,property=publicationFile.pdf/DL_ON032006.pdf

Bertoldi, P. and Atanasiu, B. (2006): Residential Lighting Consumption and Saving Potential in the Enlarged EU. European Commission – DG Joint Research Centre, Institute for Environment and Sustainability, Ispra. Proceedings of EDAL'06 Conference, London, UK, 21-23.06.2006.

Bosseboeuf, D., Lapillonne, B., Eichhammer, W. and Faberi, S.: *Energy Efficiency Monitoring in the EU.* Ademe Editions, Paris, 2005.

Bosseboeuf, D., Lapillonne, B., Eichhammer, W. and Landwehr, M.: *Energy Efficiency Indicators: The European Experience*. Ademe Editions, Paris, 1999.

Boverket, MMR (2005): Housing Statistics in the European Union 2004. National Board of Housing, Building and Planning, Sweden (Boverket) and Ministry for Regional Development of the Czech Republic (MMR). Karlskrona.

Carbon Trust (2006): Energy saving fact sheet - lighting, London: Carbon Trust. Online: http://www.thecarbontrust.co.uk/publications (Accessed: 27.10.2006).

Danko, J.L.P. (2005): Combined heat and power (CHP) electricity generation in the EU25 in 2002 totalled 299.2 TWh, 9.9% of total gross electricity generation, Eurostat (ed.), Environment and Energy, Luxembourg: European Communities.

Dechent, Jens (2006): Zur Entwicklung eines Baukostenindexes. Statistisches Bundesamt , Wirtschaft und Statistik 2.2006. Wiesbaden.

Duke, R.; Kammen, D.M. (1999): The economics of energy market transformation pro-grams. In: The Energy Journal, 20 (4), pp. 15-64.

ECCP working group on energy efficiency in end-use equipment and industrial processes (2001): European Climate Change program final report, Brussels.

Ellis, M.; Jollands, N.; Harrington, L. and Meier, A.(2007): Do energy efficient appliances cost more? Paper presented at the eceee 2007 conference ECEEE 2007 Summer Study "Saving Energy – Just Do It!", La Colle sur Loup, France, 2007.
http://www.eceee.org

Energy Information Administration (2006): *Annual Energy Outlook 2006 with projections to 2030*, http://www.eia.doe.gov/oiaf/aeo/index.html

ETSU; CETIM; D.T.Reeves; NESA; Technical University Darmstadt (2001): Study on improving the energy efficiency of pumps, Brüssel: European Commission.

EU, DG TREN (2007): PRIMES. Brussels.

EuP Preparatory Studies "Personal Computers (desktop and laptops) and Computer Monitors" (Lot 3). IVF Industrial Research and Development Corporation for the European Commission DG TREN. Final Report. 27 August 2007. www.ecocomputer.org

EuP Preparatory Studies "Televisions" (Lot 5). Contractor: Fraunhofer IZM, Berlin for the European Commission DG TREN. Final Report. Berlin, 2nd August 2007. www.ecotelevision.org

EURIMA, ECOFYS (2005a): Cost-effective Climate Protection in the Building Stock of the New EU Member States. Beyond the EU Energy Performance of Buildings Directive. European Insulation Manufacturers Association (EURIMA). Brussels, Cologne.

EURIMA, ECOFYS (2005b): Cost-Effective Climate Protection in the EU Building Stock. European Insulation Manufacturers Association (EURIMA). Brussels, Cologne.

Euroconstruct (ed.) (1999): EUROPARC – Der Bestand an Gebäuden in (West-) Europa (Deutschland, Frankreich, Großbritannien, Italien und Spanien). Bearbeitung der deutschen Fassung und des Länderberichts Deutschland: Ifo Institut für Wirtschaftsforschung. München.

Europe Economics; Fraunhofer ISI; BSR Sustainability; Ffe (2007): Impact assessmen study on a possible extension, tightening or simplification of the framework directive 92/75 EEC on energy labelling of household appliances. Appendix 2 Product studies, London: Europe Economics.

European Communities (2006): European Energy and Transport – Trends to 2030, Update 2005. European Commission, Brussels

European Communities (2008): European Energy and Transport – Trends to 2030, Update 2007. European Commission, Brussels

Eurostat (2001): Combined heat and power production (CHP) in the EU, Luxembourg: European Communities.

Eurostat (2006): Statistische Aspekte der Energiewirtschaft 2004. Zunehmende Energieabhängigkeit der EU25. Eurostat Abteilung Umwelt und Energie. Heft 5.2006. Luxemburg.

Eurostat (2006): Statistische Aspekte der Energiewirtschaft 2004. Zunehmende Energieabhängigkeit der EU25. Eurostat Abteilung Umwelt und Energie. Heft 5.2006. Luxemburg. http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-NQ-06-005/DE/KS-NQ-06-005-DE.PDF

Eurostat (2007): Annual price indices for new residential buildings. http://epp.eurostat.ec.europa.eu/portal/page?_pageid=0,1136195,0_45572097&_dad=portal&_schema=PORTAL (accessed 05.07.07).

Eurostat (2007): Labour cost surveys. http://epp.eurostat.ec.europa.eu/portal/page?_pageid=0,1136184,0_45572595&_dad=portal&_schema=PORTAL (accessed 27.06.07).

EWI/prognos (2005): Energiereport IV. Die Entwicklung der Energiemärkte bis zum Jahr 2030. Energiewirtschaftliche Referenzprognose. Schlussbericht für das Bundesministerium für Wirtschaft und Arbeit. Köln, Basel, April 2005.

Falkner, H. (2007): EuP Lot 11: Water pumps (in commercial buildings, drinking water pumping, food industry, agriculture).

Fichter, K. (2007): Zukunftsmarkt Energieeffiziente Rechenzentren, Dessau: Umweltbundesamt.

Fleiter, T. (2008): Wirtschaftlichkeitsvergleich der langfristigen Stromeinsparpotenziale bei Elektromotorsystemen und Beleuchtungsanlagen in der Industrie, 10. Symposium Energieinnovationen der Universität Graz 13-15.02.2008, Graz.

Fraunhofer Institute for Reliability and Microintegration (IZM) (2008): Preparatory studies for ecodesign requirements for EuPs - Lot 4: Imaging equipment, Berlin: Fraunhofer IZM.

Fraunhofer ISI (2003): Druckluft Effizient: Druckluftanwendung, Fraunhofer-Institut für System- und Innovationsforschung (Karlsruhe) (ed.), Karlsruhe. Online: http://www.druckluft-effizient.de/fakten/fakten-00-09.pdf (Accessed: 16.01.2007).

Fraunhofer ISI et al. (2005): Technical and legal application possibilities in the compulsory labelling of the standby consumption of electrical household and office appliances. On behalf of the Federal Ministry of Economics and Labour. Karlsruhe, Munich, Dresden. www.isi.fraunhofer.de

Fraunhofer ISI, CEPE (Cremer C. et al.) (2003): Der Einfluss moderner Gerätegenerationen der Informations- und Kommunikationstechnik auf den Energieverbrauch in Deutschland bis zum Jahr 2010 – Möglichkeiten zur Erhöhung der Energieeffizienz und zur Energieeinsparung in diesen Bereichen. Im Auftrag des Bundesministeriums für Wirtschaft und Arbeit. Karlsruhe/Zürich, 2003.

Fraunhofer ISI, FfE, TU Dresden: (Schlomann, B.; Gruber, E. et al) (2004): Technische und rechtliche Anwendungsmöglichkeiten einer verpflichtenden Kennzeichnung des Leerlaufverbrauchs strombetriebener Haushalts- und Bürogeräte. Im Auftrag des Bundesministeriums für Wirtschaft und Arbeit. Karlsruhe, München, Dresden, April 2005.

Fraunhofer ISI/FfE (Schmid et al.) (2003): Möglichkeiten, Potenziale, Hemmnisse und Instrumente zur Senkung des Energieverbrauchs branchenübergreifender Techniken in den Bereichen Industrie und Kleinverbrauch. Karlsruhe/München, Juli 2003.

Fraunhofer ISI/Forschungszentrum Jülich-STE (Cremer, C. et al.) (2001): Systematisierung der Potenziale und Optionen. Endbericht an die Enquete-Kommission "Nachhaltige Energieversorgung unter den Bedingungen der Globalisierung und der Liberalisierung" des Deutschen Bundestages. Karlsruhe/Jülich, Dezember 2001.

GfK (2007): Sales Units IT appliances. GfK Panelmarket Western and Eastern Europe. 2004 and 2006.

Greenberg, S.; Mills, E.; Tschudi, B.; Rumsey, P.M.B. (2006): Best Practices for Data Centers: Lessons Learned from Benchmarking 22 Data Centers. Proceesings of ACEEE summer study August 2006, Asilomar, California.

Gudbjerg, E.; Andersen, H. (2007): Using coatings to reduce energy consumption in pumps and ventilators, ECEEE Summer Study, La Colle sur Loup.

Hjorth, Hans (2008): Another way of checking building compliancy. Swedish experience with compliance and the use of metered data. Speech at IEA"International Workshop on Meeting Energy Efficiency Goals. Enhanced Compliance, Monitoring and Evaluation. Stream 1: Buildings. 28-29.02.2008. Paris.

Hofer, R. (1994): Analyse der Potenziale industrieller Kraft-Wärme Kopplung, 28, IFE Schriftenreihe.

Hoffmann, C.; Pfitzner, G. (1994): Ventilatoren, Instrumente für Klimagas-Reduktionsstrategien Teilprojekt 8., Querschnittstechniken, Jülich: Forschungs-zentrum, Zentralbibliothek.

Horn, M., Ziesing H.-J., Matthes, F.C., Harthan R., Menzler, G. (2007) Ermittlung der Potenziale für die Anwendung der Kraft-Wärme- Kopplung und der erzielbaren Minderung der CO2-Emissionen einschließlich Bewertung der Kosten (Verstärkte Nutzung der Kraft-Wärme-Kopplung). Dessau: Umweltbundesamt

http://epp.eurostat.ec.europa.eu/portal/page?_pageid=0,1136184,0_45572595&_dad=portal&_schema=PORTAL (accessed 27.06.07).

http://www.bbr.bund.de/cln_006/nn_21948/DE/Forschungsprogramme/AllgemeineRessortfoschung/BereichBauwesen/BauwirtschaftlicheKoopChancen/DL__StroheLangfassung,templateId=raw,property=publicationFile.pdf/DL_StroheLangfassung.pdf

http://www.defra.gov.uk/Environment/energy/eec/pdf/eec-evaluation.pdf

IEA (2000): Experience Curves for Energy Technology Policy, International Energy Agency (IEA) (ed.), Paris: OECD / IEA.

IEA (2004): 30 Years of Energy Use in IEA Countries, Paris: International Energy Agency (IEA).

IEA (2006): Light's labour's lost - policies for energy efficient lighting, International Energy Agency (ed.), Energy efficiency policy profiles, Paris: IEA.

IEA (2007): Tracking Industrial Energy Efficiency and CO2 Emissions, Paris: Interna-tional Energy Agency (IEA).

Itard, Laure; Frans Meijer; Evert Vrins, Harry Hoiting (2007): Building Renovation and Modernisation in Europe. State of the Art Review. OTB Research Institute for Housing and Mobility Studies. Delft University of Technology. Delft.

IWU (Institut für Wohnen und Umwelt) (1994): Passivhaus-Bericht Nr. 7. Fenster und Rahmendämmung im Passivhaus. Darmstadt.

IWU (Institut Wohnen und Umwelt) (2006): Gebäudetypologie Bayern. Entwicklung von 11 Hausdatenblättern zu typischen Gebäuden aus dem Wohnungsgebäudebestand Bayerns. Report on behalf of Bund Naturschutz Bayern e.V. Darmstadt.

IZT Institute for Futures Studies and Technology Assessment gGmbH; COGEN Europe – European Association for the Promotion of Cogeneration; RISØ National Laboratory; ECN Netherlands Energy Research Foundation; unit[e] unit energy europe agJenbacher AG (2002): Decentralised Generation Technologies - Poten-tials, Success Factors and Impacts in the Liberalised EU Energy Markets, Berlin: IZT.

Jakob M. and Madlener R. (2004): Riding Down the Experience Curve for Energy-Efficient Building Envelopes: The Swiss Case for 1970-2020, International Journal of Energy Technolo-gy and Policy (Special Issue on "Experience Curves"), 2(1-2): 153-178. http://www.cepe.ch/download/staff/reinhard/IJETP_vol2_no1_2_jakob_madlener.pdf

Jakob M. and Madlener R. (2004): Riding Down the Experience Curve for Energy-Efficient Building Envelopes: The Swiss Case for 1970-2020, International Journal of Energy Technology and Policy (Special Issue on "Experience Curves"), 2(1-2): 153-178. http://www.cepe.ch/download/staff/reinhard/IJETP_vol2_no1_2_jakob_madlener.pdf

Jakob M., Jochem E. and Christen K. (2002). Grenzkosten bei forcierten Energieeffizienzmassnahmen bei Wohngebäuden, CEPE und HBT, ETH Zürich, Studie im Auftrag des Forschungsprogramms EWG des Bundesamts für Energie (BFE), September 2002.
http://www.cepe.ch/research/projects/grenzkosten/Grenzkosten_Schlussbericht_Teil1.pdf
http://www.cepe.ch/research/projects/grenzkosten/Grenzkosten_Schlussbericht_Teil2.pdf
http://www.cepe.ch/research/projects/grenzkosten/Grenzkosten_Schlussbericht_Teil3.pdf

Jakob M., Jochem E. and Christen K. (2002). Grenzkosten bei forcierten Energieeffizienzmaßnahmen bei Wohngebäuden, CEPE und HBT, ETH Zürich, Studie im Auftrag des Forschungsprogramms EWG des Bundesamts für Energie (BFE), September 2002.
http://www.cepe.ch/research/projects/grenzkosten/Grenzkosten_Schlussbericht_Teil1.pdf
http://www.cepe.ch/research/projects/grenzkosten/Grenzkosten_Schlussbericht_Teil2.pdf
http://www.cepe.ch/research/projects/grenzkosten/Grenzkosten_Schlussbericht_Teil3.pdf

Jakob, M. (2004). Marginal Costs, Cost Dynamics and Co-Benefits of Energy Efficiency Investments in the Residential Buildings Sector. Energy Policy, Invited contribution to Special Issue on the eceee 2003 Summer Study "Time to turn down energy demand"
http://www.cepe.ch/download/staff/martin/EnergyPolicy_JEP1609_ArticleInPress.pdf

Jakob, M.; Madlener, R. (2004): Riding down the experience curve for energy efficient building envelopes: the Swiss case for 1970 to 2020. In: International Journal Energy Technology and Policy, 2 (1), pp. 153-178.

Kemna, René, Martijn van Elburg; William Li; Rob van Holsteijn (2007): Eco-design of Boilers. Task 3 Report. Consumer Behaviour and Local Infrastructure. Van Holsteijn en Kemna reported for EC. Delft.

Koomey, J.G. (2007): Estimating total power consumption by servers in the US and in the world.

Lechtenböhmer, S., Barthel, C., Hanke, Th. and Wissner, M.: Least investment cost strategies for market transformation to high efficiency residential appliances and lighting – results of a country by country scenario analysis for 30 European countries, Paper presented at the 4th International Conference on Energy Efficiency in Domestic Appliances and Lighting – EEDAL'06, London, June 2006.

Lees, E. Energy (2006): Evaluation of the Energy Efficiency Commitment 2002-05. Report to DEFRA.

Mandil, C. (2005): Long-term Energy Security in the Context of High Energy Prices, Presentation at the BDI/BIAC Roundtable on Energy: World Energy Outlook 2005, Berlin, 23 November 2005.

Meyer, J.; Kruska, M.; Kuhn, H.-G.; Sieberger, B.-U.; Bonczek, P. (2000): Rationelle Energienutzung in der Ernährungsindustrie - Leidfaden für die betriebliche Pra-xis, Braunschweig: Vieweg.

MIIR (Ministry of Infrastructure of the Italian Republic), FIHF (Federcasa Italian Housing Federation) (2007): Housing Statistics in the European Union 2005/2006. Rome.

Monier, V.; Mudgal, S.; Iyama, S.; Tinetti, B. (2007): Preparatory studies for ecodesign requirements for EuPs - Lot 12: Commercial refrigerators and freezers: Bio Intelligence Service.

Neelis, M.; Ramirez-Ramirez, A.; Patel, M.; Farla, J.; Boonekamp, P.; Blok, K. (2007): Energy efficiency developments in the Dutch energy-intensive manufacturing industry, 1980-2003. In: Energy Policy, 35 (12), pp. 6112-6131.

Neij, L.; Andersen, P.D.; Durstewitz, M.; Helby, P.; Hoppe-Kilpper, M.; Morthorst, P.E. (2003): Experience Curves: A Tool for Energy Policy Assessment, Lund: Lund University, Department of Technology and Society.

Radgen, P. (2002): Market study for improving energy efficiency for fans, Stuttgart: Fraunhofer IRB Verl.

Radgen, P.; Blaustein, E. (2001): Compressed air systems in the European Union, Stutt-gart: LOG_X.

Radgen, P.; Oberschmidt, J.; Corry, W.T.W. (2007): Preparatory studies for ecodesign requirements for EuPs - Lot 11: Fans for ventilation in non residential buildings, Karlsruhe.

Roth, K. et al. (2007): Miscellaneous Residential Electric Loads: Energy Consumption Characterization and Savings Potential. Final Report by TIAX LLC. Cambrigde, MA

Schäppi, B.; Bellosa, F.; Przywara, B.; Bogner, T.; Weeren, S.; Anglade, A. (2007): Energy efficient servers in Europe - energy consumption, saving potentials, market barriers and measures: The Efficient Server Consortium.

Schenk, N.J.; Moll, H.C. (2007): The use of physical indicators for industrial energy demand scenarios. In: Ecological Economics, 63 (2-3), pp. 521-535.

Stern Review (2007): The Economics of Climate Change, http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm

Sulzer Management, A.G.; (Winterthur) (1997): Sulzer-Kreiselpumpen-Handbuch, 4. Aufl, Essen: Vulkan-Verl.

TCO Development; Swedish Environmental Institute (2007): Preparatory studies for ecodesign requirements for EuPs - Lot 3: Personal computers (desktops and laptops) and computer monitors, Mölndal: IVF Industrial Research and Development Corporation.

Tichelen Van, P.; Geerken, T.; Jansen, B.; Vandem Bosch, M.; Van Hoof, V.; Vanhooydonck, L.; Vercalsteren, A. (2007a): Preparatory studies for eco-design requirements for EuPs - Lot 9: Public street lighting: VITO.

Tichelen Van, P.; Jansen, B.; Geerken, T.; Vandem Bosch, M.; Van Hoof, V.; Vanhooydonck, L.; Vercalsteren, A. (2007b): Preparatory studies for ecodesign requirements for EuPs - Lot 8: Office lighting: VITO.

Van Tichelen, P.; Geerken, T.; Jansen, B.; Vandem Bosch, M.; Van Hoof, V.; Vanhooydonck, L.; Vercalsteren, A. (2007): Preparatory studies for eco-design requirements for EuPs - Lot 9: Public street lighting: VITO.

Walraven, H.; As, E. (2006): Intelligent Road and Street Lighting in Europe - Work package 2: Market assessment and review of energy savings, E-Street Initiative.

Warren (2008): Compliance with Building Regulations. Speech at IEA"International Workshop on Meeting Energy Efficiency Goals. Enhanced Compliance, Monitoring and Evaluation. Stream 1: Buildings. 28-29.02.2008. Paris.

WETO-H2 (2005): World Energy Technology Outlook - 2050 (WETO-H2) - Reference projection.

Worrel, E.; Neelis, M.; Price, L.; Galitsky, C.; Nan, Z. (2007): Best practice in energy intensity values for selected industrial sectors, Berkeley: Ernest Orlando Law-rence Berkeley National Laboratory.

Wuppertal Institut (1996): Regionales CO_2 Minderungskonzept für das Bergische Städtedreieck Solingen, Wuppertal und Remscheid. Band I Grundlagen, Energieversorgung, Energieverwendung im Gebäudesektor. Wuppertal.

Wuppertal Institut (1999): Die Sanierung des Wohngebäudebestandes – Eine Chance für Klimaschutz und Arbeitsmarkt?. Endbericht im Auftrag von IG BAU und Greenpeace e.V. Wuppertal.

Wuppertal Institut (2000): Klimaschutz- und Innovationsstrategie für die Landkreise Lahn-Dill und Gießen. Wuppertal.

Wuppertal Institut (2005): Target 2020: Policies and Measures to reduce Greenhouse gas emissions in the EU. A report on behalf of WWF European Policy Office. Wuppertal.

Wuppertal Institut, Öko-Institut (2001): Bewertung eines Ausstiegs aus der Kernenergie aus klimapolitischer und volkswirtschaftlicher Sicht mit überarbeiteter Zusammenfassung vom Januar 201. Wuppertal, Freiburg.

Wuppertal Institut/ebök (2001): Klimaschutz durch Effizienzsteigerung von Geräten und Anlagen im Bereich Haushalte und Kleinverbrauch; Sachstand / Projektionen / CO2-Minderungspotenziale. Bericht zu Händen des Umweltbundesamtes. FB 298 97 345. Wuppertal/Tübingen.