EUROPEAN COMMISSION
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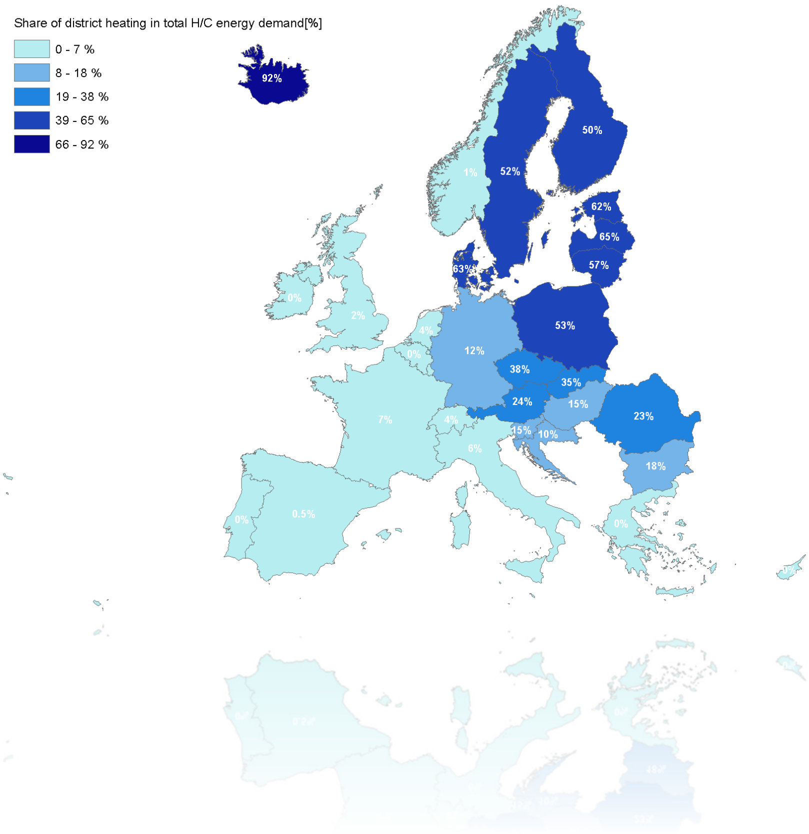
Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables)



Work package 3: Scenarios for heating & cooling demand and supply until 2020 and 2030

Work package 4: Economic Analysis

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I. Workpackage 3: Scenarios for H/C demand and supply until 2020/2030

1 Objectives and approach

1.1 Objective

The main objective of WP3 is the calculation and analysis of scenarios for the evaluation of energy demand for heating and cooling (H/C) up until 2020 and 2030. Technology-specific bottom-up models are used to simulate technology changes in the industry, tertiary, residential sectors as well as in district heating.

The key objectives of WP3 are:

- Modelling, quantification, description and graphical depiction of the final energy demand related to heating and cooling in the household (residential), industry and services/ tertiary sectors, disaggregated by energy carrier and end-use categories for the years 2020 and 2030.
- Provision of a similar quantification for useful and primary energy demand by country.
- Calculation of expected shares of renewable energy sources (RES) in the H/C sector.
- Estimation of required costs for H/C up until 2030.
- Illustration of results of a *current policy scenario* and providing datasets containing useful, final and primary energy demand.
- Performance of analyses of RES share quota schemes of the final energy demand mix and related costs

The results of WP3 build on results from WP1 and WP2 which are used to calibrate the models estimating supply and demand for heating and cooling in each country. The datasets delivered will allow a complete energy balance of heating and cooling demand and supply to be established for each of the 31 countries of the EU28 + Norway, Switzerland and Iceland in the years 2020 and 2030 for a current policy scenario and additional policy scenarios.

Scenario results in WP3 are used as input to estimate macroeconomic effects in WP4.

In line with WP1, data delivery and disaggregation particularly include the split of energy carriers, end-uses and sectors. The end-use categories of space heating, water heating, process heating, space cooling and process cooling are distinguished. For process heating and cooling, individual temperature levels are also identified. For the industrial and the tertiary sectors, energy balances by country are further broken down into sub-sectors, whereas in the residential sector they are distinguished by building type.

It has to be noted that all results depend on a large set of assumptions for climate conditions, user behaviour, energy prices, GDP, policies, technological progress and the development of the building stock. Within the project we use a set of likely developments of main drivers and focus on the development of a consistent dataset. In cases of structural breaks, different price paths or policy changes, the actual developments can deviate significantly.

1.2 Approach

In order to achieve the objectives stated above, we structure the approach into the following methodological steps:

- Modelling and quantification of heating and cooling demand in the base year

2012 and calibration to WP1 results.

- Estimation and model implementation of framework conditions and policies. First a *current policy scenario* is calculated assuming that all implemented and foreseen policy measures will be in place by the year 2030 (see chapter 3). Framework conditions are aligned to the EU 2016 reference scenario including assumptions on GDP, building stock development and fuel prices.
- The bottom-up sector models FORECAST and Invert/EE-Lab are used to simulate final and useful demand and supply of heating and cooling for end-use categories and energy carriers by country.
- Costs of heating and cooling for end-users are an output of each sector model. Costs are disaggregated into fuel costs, operation and maintenance (O&M) costs and investment costs for heating and cooling systems and efficiency measures.
- The Green-X model delivers developments of the energy carrier mix in district heating, and in the electricity sector by country, based on the demands for district heat and electricity delivered by the sector models. Furthermore Green-X is used to analyse the resulting biomass demands by country and compare them to available biomass potentials up until 2030.
- Primary energy demand for heating and cooling is derived from the electricity and district heating generation mix. Conversion efficiencies are estimated from Eurostat Energy balances for each energy carrier, to account for transformation and heat losses in district heating networks.
- Two different RES share obligation scenarios on potential RES share increases and related costs are performed.

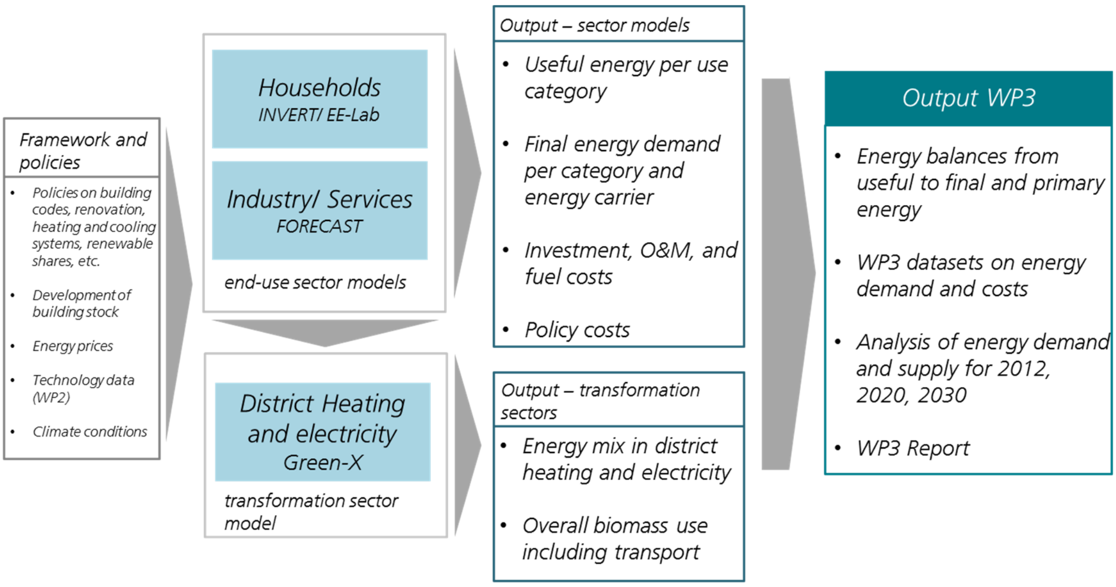
See the related datasets and illustrating figures provided in the WP3 data package for a full set of results.

2 Description of the model framework

2.1 Methodology and model links

The methodology for calculating energy balances for heating and cooling demand up to 2030 is based on two bottom-up sector models in combination with an additional bottom-up model to account for fuel inputs in the generation of district heating and electricity. For an overview of the model structure and outputs of this work package see Figure 1. The residential sector (i.e. household sector) is represented by the model INVERT/EE-Lab, while energy demand and supply in the service and industry sectors is modelled with FORECAST (see descriptions below). These two models deliver the final and useful energy demand by sector for the space heating, hot water, process cooling, space cooling, and process cooling end-use categories, for different policies and framework conditions up to 2030. Model outputs also include the supply mix for the final energy carriers defined in WP1 (fuel oil, coal, natural gas, other fossil fuels, biomass, ambient heat, geothermal heat, waste heat, waste heat from RES, solar energy, other RES, electricity, and district heating) as well as costs for heating and cooling and policy costs. To estimate primary energy use, the underlying supply mix for the final energy carriers "electricity" and "district heating", including distribution and transformation losses, have to be considered. In this project the model "Green-X" is used in combination with additional data from the EU Reference Scenario 2016 to calculate two scenarios for developments of RES shares in the district heating and electricity sectors of all 31 countries considered. Green-X also takes into account the use of RES (particularly biomass) in the transportation sector which allows for a comparison of overall modelled biomass use and biomass potentials up to 2030 (see 4.1.6).

Figure 1: Overview of sector models, model links and outputs



Results from these models are then linked to establish full energy balances for heating and cooling from useful energy to primary energy. While the focus of this project was on developing a consistent dataset for a current policy scenario up to 2030, which is described in chapter 4, additional scenarios for certain RES quotas were calculated (see framework conditions and scenario assumptions in chapter 3). Policies were implemented in each sector model and aggregated again to calculate alternative energy balances and analyse the impact of those policies on final energy demand and energy use, RES shares and costs (see results in chapter 5).

The main outputs of WP3 are energy balances for heating and cooling in all sectors, including datasets in spreadsheet format, and an analysis of demand and supply, including costs in a current policy scenario and an assessment of three policy scenarios to reach a certain RES quota. A summary of the most important findings is provided in this report. Detailed datasets with modelling results are available for further analysis.

In the remainder of this chapter the models and approaches applied for each sector in this work package will be explained.

2.2 Industry sector: FORECAST model

The scenario calculations for the industrial sector are conducted using the bottom-up energy demand model FORECAST-Industry. In the following, a brief description of the model is provided. For additional information, we refer to the model website[1] and a number of publications as mentioned below.

Compared to the other sectors, the industrial sector shows the highest degree of heterogeneity with regard to technologies and energy users (i.e. companies). This poses a huge challenge to a bottom-up model, which always needs to focus on large homogenous groups of energy uses / services. At the same time, the number of energy uses should not be too high, as gathering input data is very time and resource intensive.

Thus, the structure of the industrial sector model also reflects this heterogeneity and the data availability in the industrial sector. Selected energy-intensive processes are explicitly considered, while other technologies and energy-using equipment are considered in the form of cross-cutting technologies similarly modelled across all sub-sectors.

The model is a simulation model, which reflects the fact that investment decisions are modelled according to real-life behaviour of investors. Thus, in contrast with optimisation models often used, FORECAST does not calculate the energy system based on least system cost; even barriers to the adoption of energy efficient technologies are considered. Considering barriers and non-optimisation behaviour of investors also allows various policy instruments such as standards, taxes and subsidies to be taken into account.

Following data availability and heterogeneity, different approaches are used in the various modules to simulate technology diffusion. These range from diffusion curves to vintage stock models and discrete choice simulation. Figure 2 shows the simplified structure of FORECAST-Industry. It comprises the following main sub-modules:

- Energy-intensive processes: this module presents the core of the bottom-up quantity structure of FORECAST. 64 individual processes/products are considered via their (physical) production output and specific energy consumption (SEC). The diffusion of about 200 individual energy efficiency measures (EEMs) is modelled based on their payback period (Fleiter et al. 2012; Fleiter 2013).

Space heating: space heating accounts for about 9% of final energy demand in

[1] http://www.forecast-model.eu

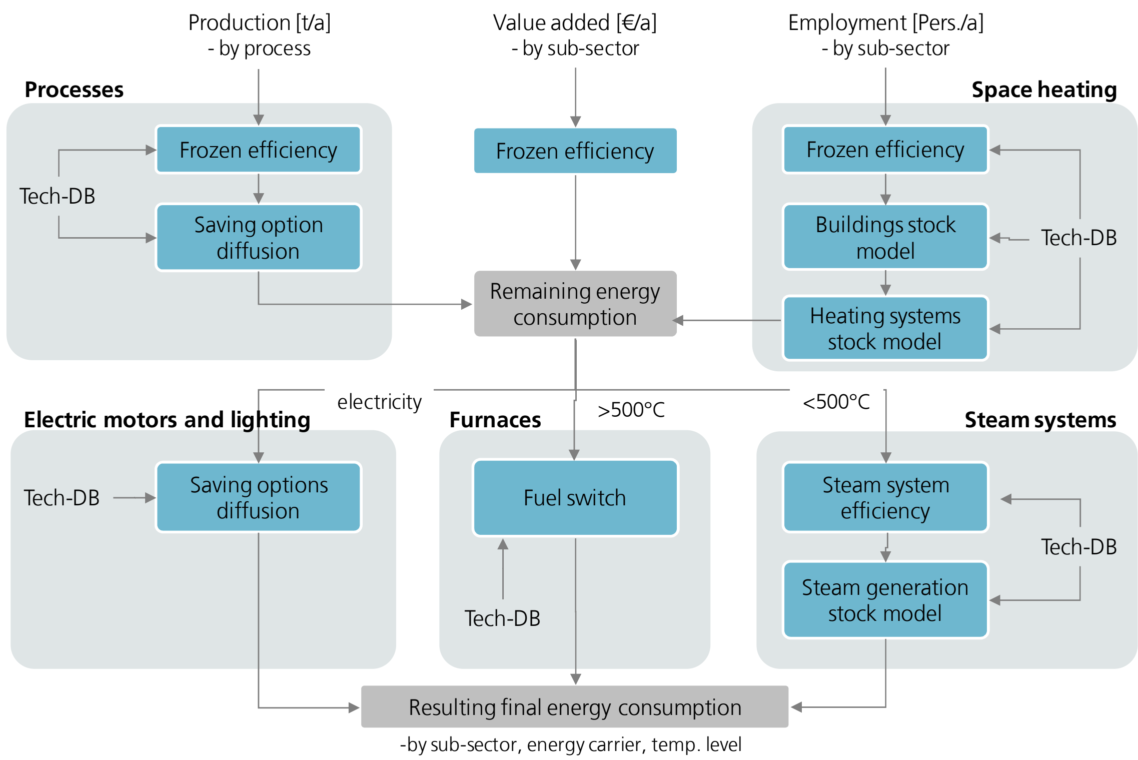
German industry. We use a vintage stock model for buildings and space heating technologies. The model distinguishes between offices and production facilities for individual sub-sectors. It considers building refurbishment, demolition and new construction, as well as demolition and new construction of space heating technologies. The investment in space heating technologies such as natural gas boilers or electric heat pumps is determined based on a discrete choice approach (Biere et al. 2014).

Electric motor systems and lighting: these cross-cutting technologies (CCTs) include pumps, ventilation systems, compressed air, machinery equipment, cold appliances, other motor appliances and lighting. The electricity demand of the individual CCTs is estimated based on typical shares by sub-sector. The modelling of the diffusion of EEMs is similar to the approach used for process specific EEMs.

Furnaces: energy demand in furnaces is a result of the bottom-up estimates from the module "processes". Furnaces are found across most industrial sub-sectors and are very specific to the production process. They typically require heat at a very high temperature level. While EEMs for individual furnaces are modelled in the module "processes", the module on furnaces simulates price-based substitution between energy carriers using a methodology similar to that described by Kesicki und Yanagisawa (2015).

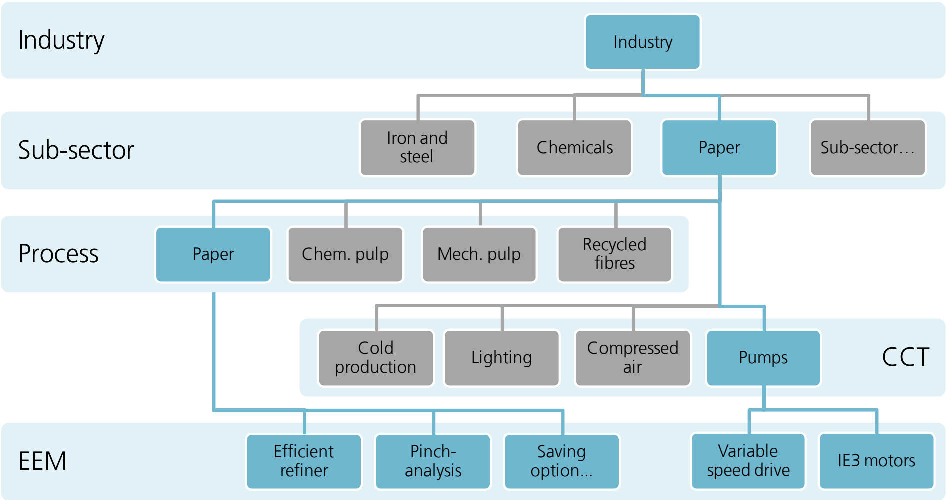
Steam systems: the remaining process heat (<500°C) is used in steam systems throughout most sub-sectors. The module comprises both the distribution of steam and hot water, as well as its generation. As very little information is available about the performance of existing steam distribution systems, based on available literature we assume exogenous efficiency improvements for each scenario. Steam generation is included in the optimisation of central heat and power generation to allow the interdependencies between the two sectors to be captured. This link allows the benefits of electricity from CHP generation and power-to-heat to be examined as a way of using electricity in times of high wind and solar generation.

Figure 2: Overview of the model FORECAST-Industry



All modules described above take into account the 14 individual sub-sectors which follow the definition of the German energy balances. The FORECAST model is based on a hierarchical structure as shown in Figure 3. 64 energy-intensive processes are considered and each is allocated to one sub-sector. CCTs are also considered by sub-sector as the share of electricity demand of the respective sub-sector. The energy demand of CCTs and processes can overlap. For example the electricity demand of the paper machine primarily comes from electric motors which provide mechanical energy. This is accounted for in the "paper" process, as well as in the individual CCTs such as pumps, machine tools and other electric motors. Both present a different perspective on the same demand. EEMs are also considered in processes. They include EEMs related to the process characteristics and those EEMs that are of a horizontal nature, such as replacing electric motors. Energy demand of processes and CCTs changes when EEMs diffuse through the technology stock.

Figure 3: Hierarchical structure of the FORECAST-Industry model for process technologies and cross-cutting technologies (CCTs)



2.3 Tertiary sector: FORECAST model

The scenario results in WP3 are calculated using the bottom-up energy demand model FORECAST Tertiary. In addition to the description of the module in the report of WP1, and the information which can be found on the model website[2], a short overview of the scenario set-up and modelling is provided in the following paragraphs.

Starting from the base year 2012 the simulation model calculates the final energy demand for the given sub-sectors, and energy demands in yearly steps, up to 2030. The model adopts a bottom-up methodology, which consists of global drivers such as the number of employees or the fuel prices, and includes more sector specific drivers such as floor area per employee, specific energy service drivers (specific equipment or diffusion rates, e.g. share of cooled floor area, number of computers per employee) together with specific energy consumption indicators. The latter consist of technical data on the end-uses, such as installed power per unit of driver.

Since the model is a simulation model, various policy instruments such as standards, taxes and subsidies can be included, which is of importance for the scenario analysis (see chapter 2). For the scenario results it is important to understand the main model drivers, which are employees and floor area. While the number of sub-sectoral employees is constructed with the aid of different regression models, the floor area is determined from the calculated employee per subsector, and an expected specific floor area (scenario dependent). The final specific floor area will smooth the changes in floor area, because the building dynamic is much slower than economy changes. Additionally, the floor area is divided by construction period. Due to this slower change of building dynamic, the influence of specific policies on final energy demand is small at the beginning of their application period and increases with time. Additionally, the more rigid lifetime of energy demand technologies also influences the dynamic of likely changes in the energy demand structure and applied demand technologies.

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2 http://www.forecast-model.eu

2.4 Residential sector: Invert/EE-Lab model

The scenario development for the residential sector is carried out by the Invert/EE-Lab model. It is a dynamic bottom-up simulation tool that evaluates the effects of different economic and regulatory conditions in scenarios up to 2020, 2030, 2050 (or beyond) based on the total energy demand, energy carrier mix, CO_2 reductions and costs for space heating, cooling, hot water preparation and lighting in buildings. More information is available on www.invert.at or, for example, in Kranzl et al. (2013). The model has been extended through an agent specific decision approach documented, for example, in Steinbach (2013a, 2013b, 2015).

The key idea of the model is to describe the building stock, heating, cooling and hot water systems at a highly disaggregated level, calculate related energy needs and delivered energy, determine reinvestment cycles and new investment in building components and technologies, and simulate the decisions of various agents (i.e. owner types) when an investment decision is required for a specific building segment. The core of the tool is a myopical, multinominal logit approach, which optimises the objectives of "agents" under imperfect information conditions and, by that, represents the decision maker concerning building related decisions.

Invert/EE-Lab covers **residential** and **non-residential buildings**. However, in this project, the tool has only been applied to residential buildings. Industrial buildings are excluded and are covered by the Industry-Model.

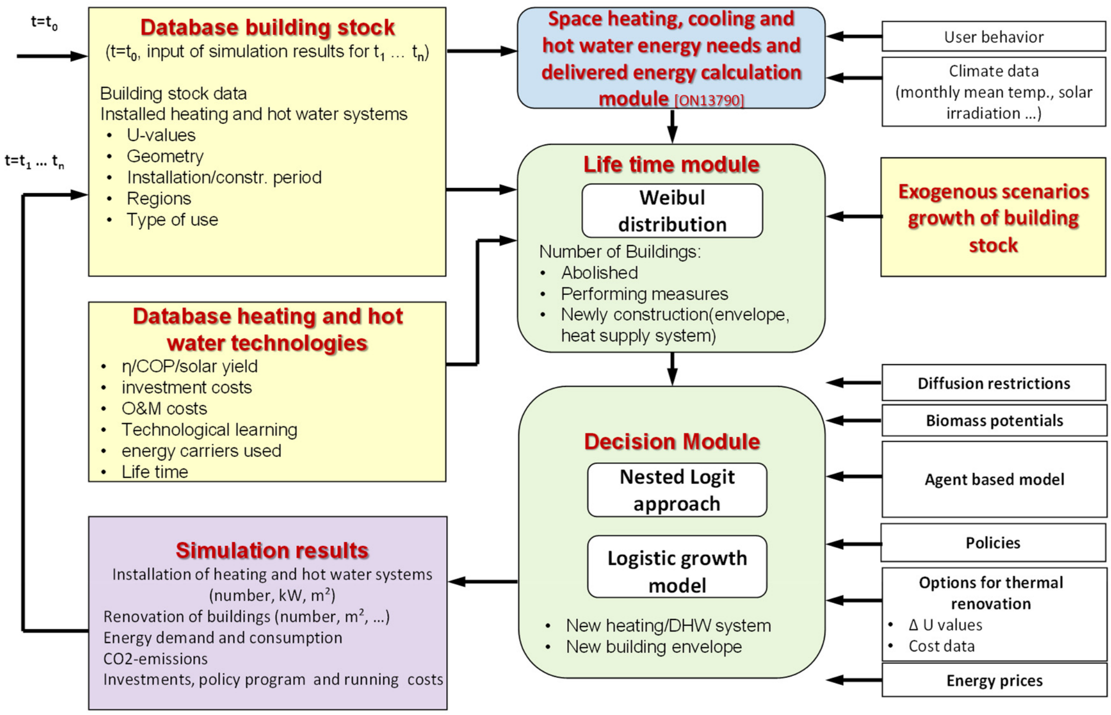
The residential building stock is distinguished according to different size of building (i.e. single family houses, apartment buildings etc.), construction period and state of thermal renovation. The levels of detail or the number of construction periods etc. depend on the data availability and structure of national statistics. Moreover, a set of about 30 heating and hot water technologies is considered in the description of the building stock, taking into account different energy carriers and technologies (e.g. local stoves or condensing boilers). In total, this leads to about 500-4500 reference building segments per country.

We use data from Eurostat, national building statistics, national statistics on various economic sectors for non-residential buildings, BPIE data hub, Odyssee, and the Entranze database (www.entranze.eu).

For **efficiency technologies,** Invert/EE-Lab models the uptake of different levels of renovation measures (country specific) and the diffusion of efficient heating, hot water, cooling and lighting technologies.

The basic structure and concept is described in Figure 4.

Figure 4: Overview structure of Simulation-Tool Invert/EE-Lab[3]



The core of the simulation model is a myopical approach which optimises objectives of agents under imperfect information conditions and in this way represents the decisions concerning building related investments. It applies a nested logit approach in order to calculate market shares of heating systems and energy efficiency measures depending on building and investor type.

The model enables a various number of different owner types to be identified as examples of predefined investor classes: owner occupier, private landlords, community of owners (joint-ownership), and housing association. Owner types are differentiated by their investment decision behaviour and the perception of the environment. The former is captured by investor-specific weights of economic and non-economic attributes of alternatives. The perception relevant variables – information awareness, energy price calculation, risk aversion – influence the attribute values (Steinbach 2013b, 2013a).

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[3] Invert simulation tool was originally developed by TU-Wien/EEG in the frame of the Altener project Invert (Investing in RES&RUE technologies: models for saving public money). The model has been extended and applied to different regions within Europe, in more than 30 projects and studies for more than 30 countries, see, or example, Eichhammer et al., Kranzl et al. (2014), Kranzl et al. (2012), Biermayr et al. (2007), Haas et al. (2009), Kranzl et al. (2006,2007), Nast et al. (2006), Schriefl (2007), Stadler et al. (2007). A major modification of the model in the year 2010 included a re-programming process and accommodation of the tool, in particular taking into account the inhomogeneous structure of decision makers in the building sector and corresponding distributions (Müller 2010, Müller 2015). The current state of the model relies on this new calculation-core (called EE-Lab) leading to the current version of the model Invert/EE-Lab. The model has been extended by an agent specific decision approach documented, for example, in Steinbach (2013b, 2013a, 2015).

Modelling approach for Space Cooling in Invert/EE-Lab

Since the modelling approach for cooling deviates from that of space heating and hot water, we will explain this approach below.

Modelling the development of energy demand for space cooling in INVERT/EE-Lab is primarily based on diffusion theory. The share of the cooled area in a defined type of building in a certain year *t* is determined by a logistic function based on the development of the proportions of cooled area in different types of buildings in a country over recent decades. In general the logistic diffusion model assumes that the diffusion of technology over time is fully reflected in its historical developments. Major changes in parameters influencing the decision of whether or not to install a technology, are reflected as far as these changes are already represented in the calibration period for determining the values of lambda. Increased renovation activities and high energy efficiency standards for new construction in the building stock may influence the diffusion of space cooling devices. In order to quantify these possible effects the logistic diffusion approach is extended.

The model Invert/EE-Lab uses a monthly time resolution to determine the useful energy demand for space cooling of the buildings. The resulting annual useful space cooling demand per area for a certain cluster of buildings, and its change over time is then used to recalculate the respective rate of diffusion.

The main input parameters for the calculation of the diffusion of cooling devices and its resulting electricity demand in the buildings are as follows:

- the maximum penetration levels,
- the current state of diffusion in the base year of simulation,
- its historical developments,
- the yearly useful cooling demand as well as the development of the efficiency of the installed devices over the simulation period.

While the useful cooling demand for each year of simulation is determined endogenously in the model, the other parameters are exogenous input. These values are estimated for different types of buildings in each country, based on an intensive literature review. The main sources analysed are the preparatory studies for the ecodesign directive, a study of the barriers and opportunities to improve energy efficiency in cooling appliances in Europe (Pout et al. 2012), and others (Adnot et al. 2003; Pardo et al. 2012). The derived parameters have also been compared to results of other studies and databases namely HARMONAC, ECOHEATCOOL, INSPIRE and ODYSSEE.

Outputs from Invert/EE-Lab

Standard outputs from the Invert/EE-Lab on an annual basis are:

- Installation of heating and hot water systems, by energy carrier and technology (number of buildings, number of dwellings supplied)
- Refurbishment measures, by level of refurbishment (number of buildings, number of dwellings)
- Total delivered energy, by energy carrier and building category (GWh)
- Total energy need, by building category (GWh)
- Policy program costs, e.g. support volume for investment subsidies (M€)
- Total investment (M€)

Moreover, Invert/EE-Lab also offers the possibility of deriving more detailed results and other types of evaluation.

2.5 District heating and electricity supply: Green-X model

A quantitative analysis was conducted to assess feasible RES developments up to 2020 through the use of a specialised energy system model (Green-X) and according to selected policy pathways (i.e. a Business-As-Usual and a High RES scenario). This indicated that RES deployment at member state and EU28 level can be expected in the near future, generating related impacts on costs and benefits. We briefly present background information and key outcomes.

About the Green-X model

TU Wien's Green-X is a specialised energy system model focussing on renewable energy technologies that offers:

- a thorough assessment of impacts stemming from various forms of energy policy interventions, offering a detailed representation of key characteristics of different energy policy instruments as input to modelling, complemented by a detailed assessment of their impacts, and
- a detailed description of renewable energy technologies, characterised by their resource potentials and related technology and feedstock cost, in Europe and in the analysed neighbouring countries.

Green-X aims to indicate consequences of RES policy choices in a real-world energy policy context. In principle, the model allows in-depth analyses of future RES deployment and corresponding costs to be conducted. Expenditures and benefits arising from the preconditioned policy choices on country, sector and technology level are determined on a yearly basis, in the time span up to 2050.

The Green-X model has been developed by the Energy Economics Group (EEG) at TU Wien under the EU research project "Green-X–Deriving optimal promotion strategies for increasing the share of RES-E in a dynamic European electricity market"[4]. Initially focussed on the electricity sector, this modelling tool, and its database on renewable energy potentials and costs, has been extended to incorporate renewable energy technologies within all energy sectors.

Green-X covers the EU28 and allows the investigation of the future deployment of RES as well as the accompanying costs (including capital expenditures, additional generation costs of RES compared to conventional options, and consumer expenditures due to applied sup-porting policies) and benefits (for instance, avoidance of fossil fuels and corresponding carbon emission savings). Results are calculated at both country- and technology-level on a yearly basis. The time-horizon allows for in-depth assessments up to 2050. The Green-X model develops nationally specific dynamic cost-resource curves for all key RES technologies, including for renewable electricity, biogas, biomass, bio-waste, on- and offshore wind, large- and small-scale hydropower, solar thermal electricity, photovoltaics, tidal stream and wave power, geothermal electricity Renewable heat and biomass, is sub-divided into log wood, wood chips, pellets, grid-connected heat, geothermal grid-connected heat, heat pumps and solar thermal heat. Besides the formal description of RES potentials and costs, Green-X provides a detailed representation of dynamic aspects such as technological learning and technology diffusion.

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[4] Contract No. ENG2-CT-2002-00607

Through its in-depth energy policy representation, the Green-X model allows an assessment of the impact of applying (combinations of) different energy policy instruments (for instance, quota obligations based on tradable green certificates / guarantees of origin, [premium] feed-in tariffs, tax incentives, investment incentives, and impacts of emission trading on reference energy prices) at both country or European level in a dynamic framework. Sensitivity investigations on key input parameters, such as non-economic barriers (influencing the technology diffusion), conventional energy prices, energy demand developments or techno-logical progress (technological learning) typically complement a policy assessment.

Within the Green-X model, the allocation of biomass feedstock to feasible technologies and sectors is fully internalised into the overall calculation procedure. For each feedstock category, technology options (and their corresponding demands) are ranked based on the feasible revenue streams as available to a possible investor under the conditioned, scenario-specific energy policy framework that may change on a yearly basis. Recently, a module for intra-European trade of biomass feedstock has been added to Green-X. This operates on the same principle as outlined above but at a European, rather than at a purely national, level. Thus, associated transport costs and GHG emissions reflect the outcomes of a detailed logistic model. Consequently, competition in biomass supply, and demand arising within and between countries from the conditioned support incentives for heat and electricity can be reflected. In other words, the supporting framework at member state level may have a significant impact on the resulting biomass allocation and use as well as on associated trade.

Key assumptions and input variables of the model

The key assumptions or restrictions and input variables of the model are based on different sources, as shown in Table 1. In order to ensure consistency with existing EU scenario and projection data on future developments of demand, and of energy/carbon prices are taken from the current EU reference scenario (European Commission 2016). With respect to the potentials and cost of RES technologies we refer to the Green-X database.

Table 1: Main input sources for scenario parameters

EU reference scenario (European Commission)	Based on the Green-X database	Defined for this study
Primary energy and CO2 prices	RES cost	RES policy framework
Conventional supply portfolio and conversion efficiencies	RES potential	Reference electricity prices
CO2 intensity of sectors	Specifications for biomass trade	
Energy demand by country and sector	Technology diffusion	
	Learning rates	
	Estimation of investment risks (based on Weighted Average Cost of Capital)	

3 Assumptions and scenario framework

3.1 Scenario definition

The objective of WP3 is to calculate and analyse scenarios for the evolution of the heating and cooling sector in Europe up to 2030. The scenarios consider both energy efficiency improvements and changes in heat supply technologies. The following scenarios were defined:

- **Current policy scenario:** The *current policy scenario* considers targets and measures concerning RES-H/C and energy efficiency which have been agreed or already implemented at the latest by the end of 2015. Within this scenario, all implemented instruments are assumed to be in place by 2030, including current financial support programs, without significant changes throughout the years.
- **RES-H/C obligation scenarios:** Two scenarios are defined that analyse the introduction of RES obligations for H/C suppliers and distributors. The scenarios are based on the current policy scenarios but assume additional obligations to be met by suppliers to increase the RES-H/C share in Europe.

The results of the current policy scenario are compared to policy scenarios introducing a **RES-H/C supply obligation,** starting from 2020, as the main support instrument for increasing the share of RES-H/C. A RES-H/C supply obligation can be added to an existing RES-H/C policy mix and act as a gap-filler in order to achieve a certain RES share. In such schemes suppliers and distributors of heating fuels (e.g. natural gas or fuel oil suppliers) are obliged to include a minimum share of renewable energies in their respective supply mix. Such obligation schemes do have a variety of design alternatives including the possibility of buying RES certificates from competing suppliers or energy service companies (ESCOs) to fulfil the required RES share.

The scenario analysis aims to analyse the effect of a RES-H/C obligation for energy suppliers and provide recommendations regarding the design of such an obligation. Conclusions are particularly drawn from the comparison of the alternative scenarios.

We assume that the RES-H/C obligation replaces other H/C subsidy schemes which have been considered in the *current policy scenario* (including subsidies for installing RES, as well as feed-in tariffs for e.g. biomass-CHP). All other policies included in the *current policy scenario* are assumed to also exist in the RES-H/C obligation scenarios.

To model the RES-H/C obligation, two alternative scenarios are defined as shown in Table 2. The first scenario (Q0.55) assumes a supplier obligation with a quota that requires an annual increase on member state level, whereas the second scenario (Q27) imposes a quota for the year 2030 on EU level. .The latter scenario allows trade of certificates among suppliers across member states.

Table 2: Overview and definition of scenarios

Name	Definition
Current policy scenario (CP)	Includes all policies and measures implemented by the end of 2015 All policies are assumed to continue until 2030 with their current design
Gradual Quota MS (Q0.55)	Annual increase in RES-H/C share of at least 0.55% Certificate trade: member state wide No other RES-H/C subsidies Other policies from current policy scenario continue until 2030
2030 Quota EU (Q27)	Total EU RES-H/C share of 27% in 2030 No particular member state restrictions Certificate trade: EU wide, no other RES-H/C subsidies Other policies from current policy scenario continue until 2030

All scenarios consider existing policies. At the European level, the relevant policy implications are set primarily by the Renewable Energy Directive[5], the Energy Efficiency Directive[6], the Directive on Energy Performance of buildings[7] and the Ecodesign Directive[8]. For the industrial sector, the EU Emissions Trading Scheme and the expected EUA price trajectory also play an important role. A full overview of policies considered, and how they are implemented in the *current policy scenario* is shown in Table 3. Note that all policies are similarly included in the three *obligation scenarios*, except the subsidy schemes listed at the end of the table, which are excluded. A more detailed description of the main EU policy initiatives and how they are included in the model system is provided in the following section.

Table 3: Overview of policies supporting efficient and renewable heating and cooling in buildings and industry in the *current policy scenario*

	EU leg.	Current policy scenario
Regulations / Information		
Energy efficiency standards for renovation	EPBD	National building code requirements, 2015 or planned tightening as far as data is available
Energy efficiency standards new buildings	EPBD	National implementation of NZEB standards after 2018 (for public buildings) and 2020 (for all buildings). Development of building codes up to 2018/2020 according to national action plans for nZEBs.[9]
Increase of renovation rate	EED	3% renovation rate achieved up to 2020 in central government buildings. Renovation obligations in the case of real estate transactions as far as they are currently implemented.

5 Directive 2009/28/EG 2009b

6 Directive 2012/27/EU 2012

7 Directive 2010/31/EU 2010

8 Directive 2009/28/EG 2009a

9 Detailed in ZEB definitions are very hard to compare and to implement at a detailed level. Simplifications are necessary regarding the specific definition of indicators and national calculation methodologies.

	EU leg.	Current policy scenario
RES use obligation	RED	Current implementation in member states (only for new buildings in a few countries)
Technology standards	EDD	MEPS for all products for which regulations have been implemented before 29 February 2016
Support of CHP and DHC	EED	Realisation of lower limit of economically feasible CHP and DHC potentials
Energy labelling	ELD	Mandatory for new H/C devices
Financial policies		
Energy saving obligation	EED	Energy saving obligations of about 1-1.5% per year, but national differences in exceptions and alternative systems
Energy and CO_2 taxation	ETD	Taxes varying by fuel and sector
EU Emission allowances	ETD	CO_2 price: increase to 10 EUR/tCO_2-equ by 2030 Scope to remain as in phase 3
Subsidies for building renovation	National	Ongoing subsidy programs (MURE database)
Subsidies for efficient fossil fuel technologies	National	Ongoing subsidy programs (MURE database)
Subsidies for RES technologies	National	Ongoing subsidy programs (MURE database)
Subsidies for industrial CHP	National	Ongoing subsidy programs (MURE database)

Abbreviations: EPBD: Energy Performance of Buildings Directive, EED: Energy Efficiency Directive, RED: Renewable Energy Directive, EDD: Ecodesign Directive, ELD: Energy Labelling Directive, ETD: Emissions Trading Directive, National: National measures

3.2 Policies considered and model implementation

3.2.1 EU target framework for 2020 and 2030

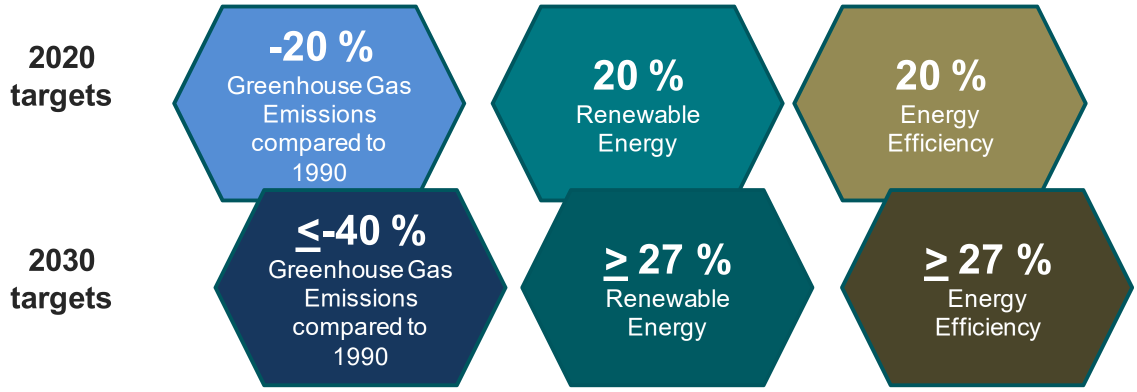
In 2007, leaders of European member states agreed on mandatory climate protection and energy saving targets for the first time. The climate and energy package sets three key targets for the European Union (EU) for the year 2020 (Council of the European Union 2008).

- 20% reduction of greenhouse gases (from 1990 levels)
- 20% share of renewable energy sources on final energy demand
- 20% improvement of energy efficiency

As a result of this agreement, member states were required to establish binding national targets. Furthermore, a set of directives was adopted setting the framework for the policy design at member states level (see below).

A continuation of the framework, with targets for the year 2030, was adopted by EU leaders in 2014. Thereby, binding targets were set for the reduction of greenhouse targets and the expansion of RES, as well as an indicative energy efficiency target (Figure 5).

Figure 5: EU target framework for 2020 and 2030



* Energy efficiency target for 2030 might be increased to 30%

Source: Fraunhofer ISI

3.2.2 Energy Efficiency Directive (EED)

The *Energy Efficiency Directive* is based on the 20% reduction target of primary energy consumption. It requires member states to set energy saving targets that, in total, take into account the fact that EU28 final energy demand is not more than 1,086 Mtoe (or the primary energy demand not more than 1,483 Mtoe) in 2020, which equates to a reduction of 20% compared to the baseline scenario.

It also addresses the uptake of energy efficiency measures in all sectors regarding generation, transport, conversion and demand for energy. Member states are required to set an overall energy efficiency target for the year 2020.

In order to reach the targets, several concrete measures are defined by the Directive. The measures have to be implemented in national law. The most important measures include:

- Mandatory energy saving target of 1.5% per year which should be reached either through the implementation of an energy saving obligation scheme for energy suppliers, or by alternative regulative, financial or fiscal support policies (DIRECTIVE 2012/27/EU 2012: § 7)
- An annual renovation rate of at least 3% should be reached for buildings owned by public governments, considering the minimum energy performance standards set by the *Building Directive* (DIRECTIVE 2012/27/EU 2012: §5)
- Member states should carry out comprehensive assessments of the application of high efficiency cogeneration and efficient district heating and cooling. The assessments should include the description of current heating and cooling demand and its forecast over a period of 10 years, as well as a national heating and cooling map indicating the municipalities and industrial zones with potential for cogeneration and district heating. (DIRECTIVE 2012/27/EU 2012: § 14)

The Energy Efficiency Directive is under review during 2016.

3.2.3 Renewable Energy Directive (RED)

Description

The *Renewable Energy Directive*[10] legislated in 2009 not only sets framework conditions for renewable energies in the electricity sector (RES-E), but also includes important requirements for the policy design of support mechanisms of renewable heating and cooling (RES-H/C). Article 13 (4) and (5) says in this respect:

(4) "By 31 December 2014, member states shall, in their building regulations and codes or by other means with equivalent effect, where appropriate, require the use of minimum levels of energy from renewable sources in new buildings and in existing buildings that are subject to major renovation [...](5) Member states shall ensure that new public buildings, and existing public buildings that are subject to major renovation, at national, regional and local level fulfil an exemplary role in the context of this Directive from 1 January 2012 onwards" (Directive 2009/28/EG 2009: § 13,(4,5))[4]

In this way, the Renewable Energy Directive requires member states to implement a use obligation for RES in new and existing buildings – the latter in the case of a major renovation. However, the paragraph leaves room for interpretation regarding alternative support measures with similar impact [5].

Model implementation

As written above, the Articles 13(4) and (5) leave room for interpretation and many Member States have not implemented this renewable obligation in a highly ambitious manner. In particular, many Member States decided to go for "means with equivalent effect" to the regulatory scheme requiring the use of renewable energy in new buildings. Thus, as far as possible, the implementation of this part of the RED has been included in the models country specific. E.g. in Germany, the act for mandatory use of renewable heat in new buildings (EEWärmeG) is implemented in the models, whereas in other countries the focus is more towards existing financial support schemes.

3.2.4 Directive on the energy performance of buildings (EPBD)

Description

The recast of the *Building Directive*[11] defines energy efficiency requirements for new and existing buildings considering "cost-optimal levels of minimum energy performance requirements for buildings and building elements" (Directive 2010/31/EU 2010: § 5(1)). These levels aim to serve member states as a calculation method with which to define building code standards. Thus, the Directive narrows the ambition level of regulative policies for energy efficiency requirements of buildings by requiring

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[10] DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

[11] DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 May 2010 on the energy performance of buildings (recast)

cost optimal levels to be applied.

In addition, the *Nearly-Zero-Energy building (NZEB)* standard is established for new buildings from 2021 onwards[12]. According to the Directive, the NZEB standard is defined by the low energy demand and the use of RES:

"The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby" (Directive 2010/31/EU 2010: § 2 (2))

A precise definition of the maximum levels of primary energy consumptions allowed should be provided by each Member State.

Model implementation

In the building stock models for residential and non-residential buildings we implement a strengthening of building codes from 2021 onwards (and from 2019 for public buildings), reflecting the nZEB standard. As far as nZEB-definitions were available from different Member States until early 2016, they have been taken into consideration. For those Member States, where no nZEB definition was yet available, assumptions regarding the average ambition level of the nZEB definition were made. We want to emphasize that the nZEB definitions between countries differ strongly in terms of the indicators used, system boundaries and calculation procedures of nZEB indicators. Within this project it was not possible to cover this huge variety of different calculation methodologies in detail. This means that there might be slight deviations of the nZEB definitions implemented in the model and their real impact on new building construction and (as far as available) for renovation.

3.2.5 Eco-design directive (EDD)

Description

The EU Ecodesign Directive (ECOD) is a key instrument in the European policy-mix for energy efficiency improvement. It provides a frame for the implementation of minimum requirements of energy-related products on the EU market. The Energy Labelling Directive provides the framework for establishing labelling for selected products. Only products with a certain market volume and a substantial potential to reduce the environmental impact are relevant for the ECOD. The standard-setting process begins with a preparatory study to assess the potentials and costs of possible standards for individual product groups (the technical ECOD term is 'lots'). It is followed by a consultation process, which involves all relevant stakeholders, and finally an impact assessment. The final outcome is mostly a regulation (termed 'implementing measure') that sets minimum energy performance standards (MEPS) for the related products of a 'lot' (alternatively self-regulation by industry is also possible). The entire process typically takes a few years per lot while several lots are treated simultaneously.

Since 2006, 44 Ecodesign preparatory studies have been launched by the European Commission, which have resulted in 24 implementing regulations (as of April 2016).

Model implementation

The Ecodesign Directive is modelled through its individual implementing measures

[12] For new public buildings, NZEB standards are already required from 2019 onwards.

(mostly regulations). Due to the technology detail of the bottom-up models, the implementing measures can be directly included in scenario assumptions. Depending on the model design, they are included as technology choice restrictions or minimum diffusion paths.

Table 4 provides an overview of lots relevant for H/C. The reference considers all lots for which regulations have been adopted up to April 2016. The date from which the regulations will be mandatory is also provided. Lots for which no date is shown in the table, do not yet have a regulation adopted and, thus, will not be considered in the reference scenario. The table further provides a rough estimate of the importance of the individual lots in terms of energy demand. It also shows the share of fuels/electricity demand of each sector included in the scope of the lot. Lots with a high share (and a potentially high impact) are modelled individually. For a more detailed description of modelling the Ecodesign Directive, with Invert/EE-lab and FORECAST, please see Fleiter et al. (2015) and Elsland et al. (2014).

As examples, the implementation of Lots 1 and 2 are described more in detail below.

- The implementation of Lot 1 boilers and combi-boilers builds on the regulation No. 813/2013 Efficiency requirements for the two steps in 2015 and 2017 included in the scenario. Moreover, in line with the regulation, the technological scope focused on space heaters and combination heaters based on natural gas, heating oil and electricity. The preparatory study for Lot 1 (Kemna et al. 2007) included solar thermal and heat pump technologies as best available technology (BAT) but stated that "*All in all, the heat pump and solar technologies are an interesting option with a large saving potential and should be promoted whenever and wherever possible. As such they should therefore have their place in the highest ranks of a labelling scheme. However, the uncertainties (and the costs) of the option should be taken into account, making the technology, as yet, not ripe for EU-wide mandatory measures.*" Thus, these technologies have not been implemented in regulation No. 813/2013, or in our assessment.
- Correspondingly, for Lot 2 water heaters, we implemented the regulation No. 814/2013 (European Commission 2013), for water heaters and hot water storage tanks based on natural gas, heating oil and electricity in the model.

Table 4: Overview of Ecodesign Directive implementing measures with relevance for H/C (as of April 2016)

Product Groups	Preparatory study completed	Requirement/ Regulation mandatory from	Sector addressed		
			Industry	Tertiary	Household
Lot 1 Boilers and Combi-boilers	Yes	26 September 2015	x	x	x
Lot 2 Water Heaters/Boilers	Yes	26 September 2015		x	x
Lot 10 Room air conditioning	Yes	01 January 2013			
Lot 12 Commercial Refrigerator- and Freezers	Yes				
Lot 15 Solid fuel boilers	Yes	10 August 2015		x	x
Lot 20 Local space heating products	Yes	10 August 2015	x	x	x
Lot 21 Central Heating Products	Yes				
Lot 22 Household and Commercial Ovens	Yes	20 February 2014			x
ENTR Lot 1 Refrigerators and Freezers	Yes	01 July 2015	x		
ENTR Lot 4 Combustion Plants and Ovens	Yes				
ENTR Lot 6 Air-conditioners and Ventilation Systems > 12kW	Yes	01 January 2016	x	x	
ENTR Lot 7 Steam boilers	Yes				

Legend	
Relevance (as share of electricity/fuel consumption)	
High (>10%)	
Medium (5-10%)	
Low (1-5%)	
Not relevant (<1%)	
Per Definition not in question	
No Data	

Lots marked with an "x" are explicitly modelled in the reference scenario

3.2.6 European Emission Trading System (ETS)

Description

The first trading period of the EU ETS began in 2005. It obliged companies from various energy intensive sectors to buy emission certificates and surrender these allowances (the so called EUAs) based on their annual emission balance. The largest sector is power generation, but sectors from industry, such as refineries, iron and steel or the cement industry, also have high proportions of the total number of verified allowances per year. The total number of allowances surrendered equals the overall emissions cap. The cap is reduced from year-to-year and participants in this cap-and-trade scheme can buy and sell allowances from each other.

Currently, the EU ETS covers about 45% of the EU's greenhouse gas emissions, and more than 11,000 individual installations from power generation and industry fall under the scope of the scheme. EUA prices, however, have been falling as a result of over allocation induced by the economic crisis. At the beginning of 2016, the EUA price was about 5 Euros per ton of CO_2-equ.

Model implementation

The EU ETS is relevant for the industry and central heating supply sectors. The implementation is described in the following paragraphs, first for industry and then for central heating units.

The EU ETS can be explicitly modelled via the price of EU Allowances (EUAs). An EUA price path is exogenously assumed, based on the most recent EU scenario from 2016, and illustrated in Table 5. We assume a recovering of EUA prices, in the coming years, to reach 32 Euros by 2030.

Table 5: Assumed development of EUA prices for all scenarios [Euro]

2005	2010	2015	2020	2025	2030
22	14	8	15	22	32

Source: EU Reference Scenario 2016

The EUA price is considered in the industry model in two ways: by defining processes included in the scope of the EU ETS and by defining individual CHP units and boilers as cross-cutting technologies. Possible double counting is avoided.

- **Processes**: The model considers 64 individual energy intensive processes and products. Each process is defined as being included in, or excluded from, the scope of the EU ETS, distinguishing between phase 3 (from 2013 onwards) and before. Examples of products include: clinker, flat glass, container glass, primary and secondary aluminium, oxygen steel, electric steel, coke, sinter, paper, ceramics, ammonia, adipic acid, and chlorine. The price of EUAs then affects the cost-effectiveness of energy-efficiency measures and, consequently, the investment decision of companies.
- **CHP and boiler units**: Regardless of the sub-sector, or the process to which they are applied, large CHP and boiler units with a combustion capacity above 20 MW_{th} are included in the EU ETS. This is achieved by adding the EUA prices to the running costs of the plants. As a consequence, plants with high specific CO_2 emissions (e.g. coal boilers) experience lower cost-effectiveness and have a lower likelihood of being chosen by companies.

3.2.7 Energy Taxation Directive (ETD)

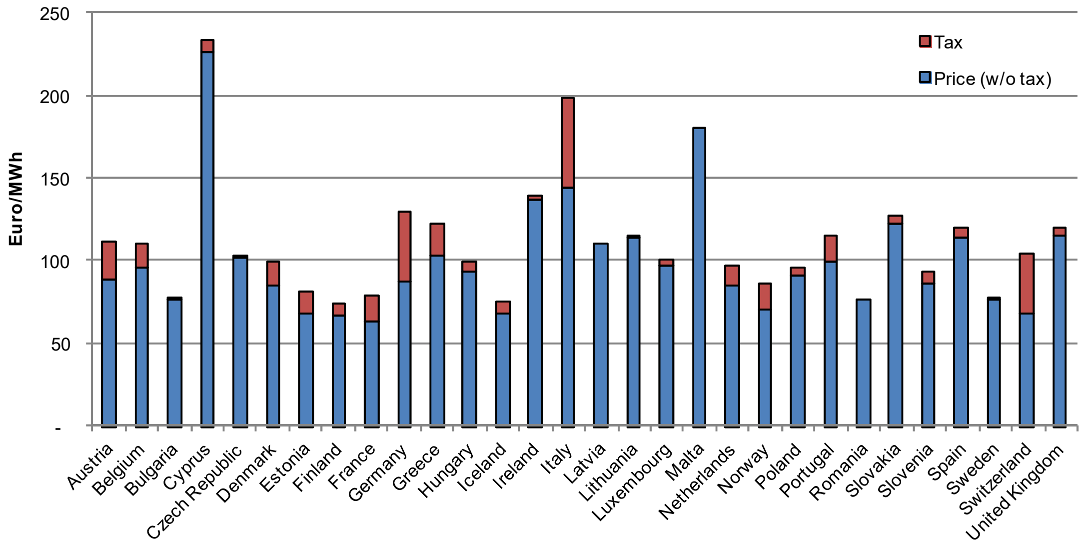
Description

The Energy Taxation Directive (ETD) came into force in 2004 and provides a common framework for the taxation of energy products in the EU. It covers motor and heating fuels. Member states are required to introduce minimum energy taxes as laid out in the ETD. The taxation is currently based on volume of energy products (e.g. natural gas or fuel oil) and the CO_2 content is not specifically taken into account. A revision of the directive was proposed by the European Commission in 2011 including CO_2 emissions and energy content of the products in scope. However, the proposal was not successful and was withdrawn in 2015.

Model implementation

As all bottom-up models explicitly consider end-use energy carrier prices in the simulation of investment decisions, energy taxes can be included in a straight-forward manner into the scenario analysis as a mark-up on energy prices. Statistical data on energy prices and energy taxes was retrieved from Eurostat for electricity and natural gas by consumer groups and from the International Energy Agency for other energy carriers such as fuel oil or coal. Taxes for the year 2012 were assumed to remain constant until 2030 if above the minimum tax required in the ETD. Otherwise the minimum taxes are applied. Figure 6 shows exemplary assumptions on prices and taxes for industrial electricity consumers as used in the scenario analysis.

Figure 6: Electricity prices and taxes for industrial consumers in 2012 by country (Source: Eurostat)



Source: Eurostat

3.2.8 Supplier obligations for renewable heating and cooling

Description

A RES-H/C supplier obligation can be added to an existing RES-H/C policy mix in order to achieve a certain RES share. In such schemes, suppliers and distributors of heating fuels, are obliged to included a minimum share of renewable energies in their respective supply mix. The main design principles of a quota based support scheme for RES-H/C include the definition of

- energy sources subject to the obligation (e.g. fossil fuel suppliers)
- obliged suppliers and
- quota fulfilment options (see Steinbach et al. 2013).

Eligible quota fulfilment options could include physical integration of RES in the fuel mix or technological based mitigation options such as highly efficient RES installations in buildings and for industrial processes which requires a methodology to calculate the amount of heat or cold generated from the RES installations. Another important design option is whether and to what extend trading of RES certificates are allowed among obliged suppliers in order to fulfil the required RES share.

Model implementation

The use of four detailed bottom-up models for this study is both an advantage and a challenge for the modelling of supply obligations.

It is an advantage, because the models simulate the investment decision based on technology and fuel costs. The RES certificate price can either be directly included in the investment decision, or it can be transformed into a subsidy for RES technologies. In both options, the improved cost-effectiveness of RES technologies will result in higher market shares.

The disadvantage is because the four sectors are modelled separately, and interaction is principally not foreseen. However, in the case of supply obligations, it is assumed that the search processes of market actors, such as suppliers and ESCOs, will result in the implementation of least cost investments independent of the economic sector..In theory, RES obligations in combination with tradable certificates can result in least cost RES deployment. In order to map cross-sectoral optimisation in the model and thus ensuring a least cost RES deployment, the following steps are are conducted.

1. Inclusion of RES-H/C certificate price in the investment decision for new heating systems (e.g. in the form of one-time subsidy or remuneration for the generated RES energy).
2. Calculation of various certificate price scenarios to generate a marginal RES deployment cost curve for each sector and country. The cost curves show the additional RES share or RES use on the x-axis and the specific costs of a certain amount of RES energy use on the y-axis. The individual steps of the curve are sorted from low to high cost. The cost curve represents not only additional H/C system cost, but also takes consumer and company preferences and barriers to RES investment into account. Therefore, it indicates the support level needed to convince investors to install RES-H/C options.
3. Merging of individual cost curves of different sectors to country specific and one overall EU marginal cost curve that allows cross-sectoral optimisation.
4. Selection of certificate price scenarios based on the required RES deployment as defined by the design of the obligation – for example, 27% in 2030. The certificate price is determined from the marginal cost curve as being the intersection point between the required RES deployment and the curve.

The results represent a least cost allocation of the additional RES-H/C quantities needed to reach the RES-H/C quota.

As the modelling takes place at member state level, i.e. individual suppliers are not explicitly mapped in the models, we implicitly assume perfect markets in certificate trading within each member state.

3.3 External framework conditions of the scenario analysis

Framework conditions are assumed to be alike in all scenarios calculated. They comprise assumptions on the future development of the climate, macroeconomic or sectoral drivers such as industrial production or floor area in buildings. The main framework parameters are described in the following paragraphs. Whenever possible, framework conditions are aligned to the EU reference scenario 2016 (European Commission 2016) to allow a maximum comparability across studies.

3.3.1 Climate conditions

The effect of expected change in climate conditions is included in the models by interpolating current trends of average temperatures for the scenario period using the Eurostat dataset on heating degree days (HDD). The dataset covers the development in heating degree days from 1980 to 2009. Additional data were gathered to complete the dataset up to 2014. The projection of HDDs is based on a linear trend regression for each country. (see Table 6). The population weighted EU average temperature rise corresponds to an increase of around 0.4°C from 2012 to 2030.The development of HDDs is used to calibrate the climate conditions for the base year 2012 and implement climate trends in the Invert/EE-Lab and FORECAST models.

Table 6: Estimated average of heating degree days in 2012 and 2030 and estimated differences in mean annual temperatures between 2030 and 2012

Country	Average HHD 2012	Average HDD 2030
Austria	3554	3209
Belgium	2772	2397
Bulgaria	2611	2375
Croatia	2649	2248
Cyprus	826	575
Czech Republic	3399	3126
Denmark	3423	2950
Estonia	4579	3957
Finland	5857	5024
France	2441	2137
Germany	3126	2818
Greece	1655	1404
Hungary	2771	2540
Iceland	5066	4536
Ireland	2858	2476
Italy	1968	1609
Latvia	4320	3819
Lithuania	4082	3619
Luxembourg	2917	2576
Malta	662	321
Netherlands	2814	2420
Norway	5561	5132
Poland	3552	3202
Portugal	1348	1126
Romania	3090	2747
Slovakia	3299	3005
Slovenia	2832	2598
Spain	1871	1625
Sweden	5504	4785
Switzerland	3575	3274
United Kingdom	3183	2753

3.3.2 Macroeconomic context

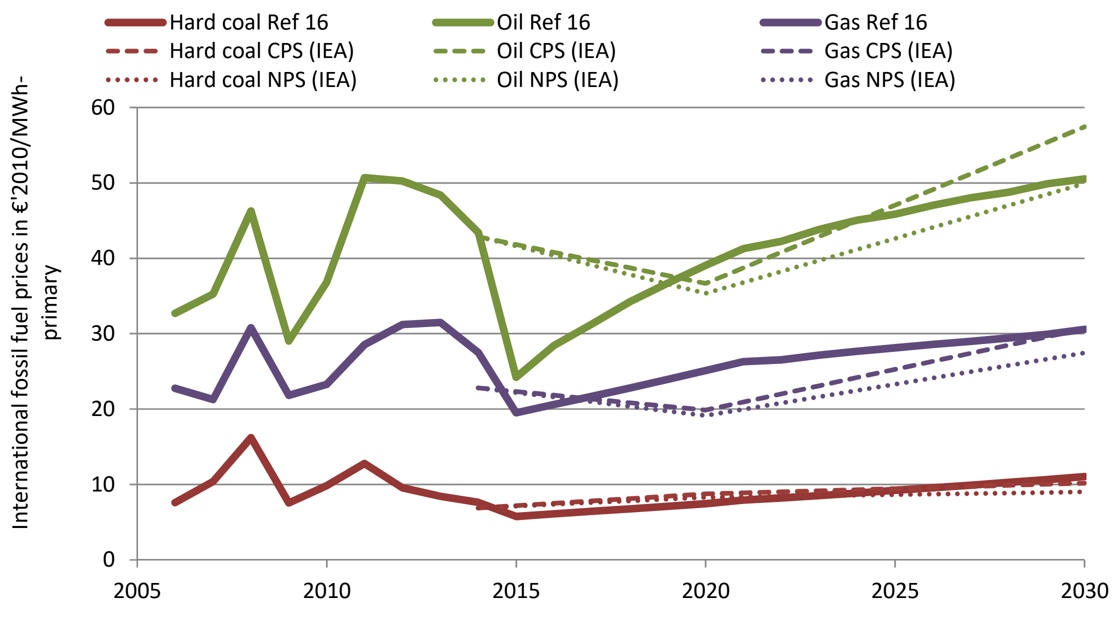
The macro-economic development substantially affects future heating and cooling demand in all sectors. However, macro-economic drivers such as GDP or population do not directly affect the sectoral demand for heating and cooling. Instead, they are broken down to more specific demand drivers for the individual sectors – e.g. industrial value added by sub-sector, floor area in service sector buildings or the number of households in the residential sector.

The underlying macro-economic development is aligned with the most recent EU reference scenario (European Commission 2016). Accordingly, a GDP increase from 2010 to 2030 of about 1.3% per year and an annual population increase of about 0.16% is assumed. While these values are averages for the EU28 member states, the development by country can deviate substantially, taking into account country specific trends. At 1.05% per year, the increase in industrial value-added is slower than that of the service sector value-added, at about 1.44% per year, resulting in a substantial structural change towards a more service based economy. A structural change from energy intensive industries towards machinery, chemicals and other sectors within industry is also considered.

3.3.3 Energy and CO2 prices

A comparison of the specific energy costs of fossil fuels is presented in Figure 7. The "Ref 16" prices are used as a basis for the modelling in this report. Compared to the two price scenarios from the World Energy Outlook 2015 of the International Energy Agency (Current Policy Scenario -CPS- and New Policy Scenario -NPS-) (IEA, 2015), the EU price scenario show a lower critical wholesale price for the year 2015. After the year 2015 the specific energy prices rise steadily in the "Ref 2016" case, while the IEA projections show decreasing coal and oil prices up to the year 2020.

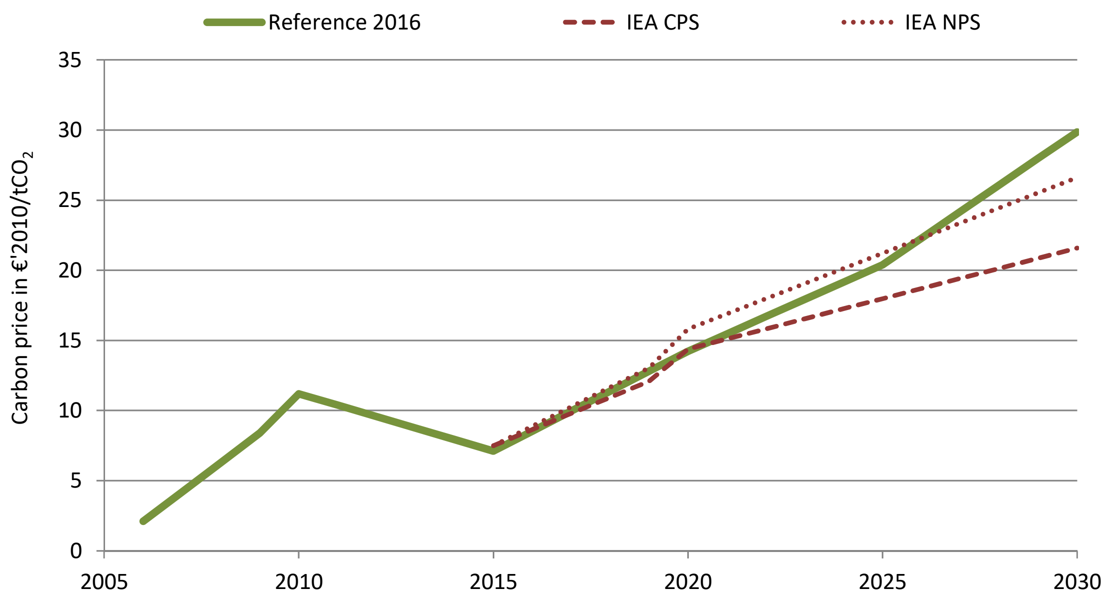
Figure 7: A comparison of specific wholesale price projections for primary energy carriers in € 2010/MWh



Source: IEA (2015), European Commission (2016)

In contrast to the energy price scenarios, the price trends for greenhouse gas (GHG) emission certificates show greater consistency up to the year 2020 in the EU reference scenario 2016 and the IEA World Energy Outlook. After the year 2025 the Reference 2016 projects faster growing certificate prices (see Figure 8).

Figure 8: Price trends for GHG emission certificates in the Reference 2016 scenario



Source: IEA (2015),European Commission (2016)

3.3.4 Development of building stock

The development of the building stock is also aligned to the EU reference scenario 2016. For residential buildings, relevant indicators are the projection of population, number of households as well as the average size of households (persons / household). However, floor area is also essential for calculating energy demand in buildings, which is not given in the EU reference scenario. It is derived from the development of households as well as income elasticities based on the GDP projections of the EU reference scenario. This approach leads to the assumed development of residential floor area for the scenario period. It takes into account the development of the number of buildings, the structural change of the size of households (e.g. more single person households) and the overall tendency to an increasing floor area for each household size, with growing GDP.

Overall, this leads to a growth of floor area in residential buildings by 9% from 2012 up to 2030.

3.3.5 Production of energy-intensive products

Besides value-added by sub-sector, physical production of main industrial bulk products is a central demand driver and assumed to be exogenous by country and product. In total, 64 such energy-intensive products are distinguished. While the future evolution of production output is certainly related to the value-added of the respective sub-sectors, it does not necessarily need to be linearly correlated.

Table 7: Production of selected energy-intensive products/processes in the EU28 for 2012, 2020 and 2030 [Million tonnes/a]

Sub-sector / process	2012	2020	2030
Chemical industry			
Ammonia	17.56	17.86	18.27
Carbon black	1.56	1.54	1.53
Ethylene	13.37	13.83	14.67
Methanol	1.28	1.31	1.35
Soda ash	8.02	8.02	8.02
Titanium dioxide	0.45	0.48	0.53
Food, drink and tobacco			
Bread & bakery	24.26	24.50	24.63
Brewing	37.81	38.28	38.53
Dairy	68.91	70.10	70.92
Meat processing	54.17	54.92	55.30
Sugar	15.53	15.83	16.05
Iron and steel			
Blast furnace	98.53	99.65	84.99
Coke oven	42.25	44.36	39.62
Electric arc furnace	70.06	78.60	80.46
Rolled steel	155.12	164.03	152.74
Sinter	109.51	114.57	100.08
Non-ferrous metals			
Aluminum, primary	2.00	2.06	1.77
Aluminum, secondary	3.00	3.45	3.43
Non-metallic minerals			
Bricks	79.86	81.24	82.18
Clinker calcination-dry	119.60	138.17	150.88
Clinker calcination-semidry	9.43	8.62	6.75
Clinker calcination-wet	4.09	3.86	3.14
Container glass	22.03	23.33	23.49
Flat glass	12.23	13.52	14.61
Gypsum	110.95	112.89	114.28
Lime burning	35.12	40.62	45.04
Other glass	1.59	1.79	1.99
Paper and printing			
Chemical pulp	26.24	26.64	27.71
Mechanical pulp	8.37	8.25	8.58
Paper	92.19	95.33	100.08
Recovered fibres	47.93	50.38	53.32

Source: FORECAST

For instance, trends towards a more service based value-added or structural changes within the sub-sectors, might result in a value-added which increases quickly and a slower production output (or vice versa).

Assumptions for major energy-intensive products are shown in Table 7, for the EU28 as an aggregate. In the simulation they are included as country specific values. The projection considers saturation (e.g. cement production per capita) as well as process shifts towards secondary production (e.g. steel, aluminium, paper) taking into account limitations such as, for example, the availability of steel scrap.

For most products, a stagnating production or slow increase is assumed, which is in line with a slowly growing value-added in the energy intensive industries.

4 Results of current policy scenario

This chapter discusses the results of the *current policy scenario*. Firstly, overall results of all three sectors are shown, followed by a detailed analysis for the industry, tertiary and the residential sectors, and for district heating. The development of electricity generation up to 2030 is also briefly discussed in order to evaluate the results with regard to primary energy consumption for heating and cooling.

This report mainly comprises overall results for the EU28 presenting the development of energy carriers for the different end-use categories and sectors. Detailed results of the scenario analysis at country level, including Norway, Switzerland and Iceland, can be found in the datasheets provided as separate attachment to the report. In line with the scope of this project, the scenario analysis covers the heating and cooling sector together with all relevant end-uses[13].

The scenario results are based on policy assumptions and framework conditions outlined in the preceding chapter, as well as technology assumptions as described in WP2. The *current policy scenario* reflects the impact of policies implemented up to the end of 2015. All important EU initiatives are included, as well as major programmes in individual member states. The scenario analysis is performed for the period 2012 to 2030[14].

The fact that FED for H/C in 2012 is deviating from the results in WP1 is explained by the climate assumptions for 2012. The numbers in WP1 are based on (real) average temperatures of the year 2012, while in the scenario analysis of this work package the 2012 temperature equates to the long term trend. This climate correction of 2012 values had to be conducted to make the results of the *current policy scenario* for 2020 and 2030 comparable to 2012.

4.1 Total results across all sectors

This section gives an overview of the overall results for final, primary and useful energy demand, together with the development of RES-H/C shares, CO_2 emissions, import shares, and the deployment of biomass potentials. The last subsection presents the resulting heating and cooling generation costs considering, besides fuel and operation and maintenance costs, the overall investment in H/C installations and energy efficiency measures up until 2030.

4.1.1 Final energy demand

Table 8 and Figure 9 show the development of final energy demand (FED) and final energy mix for H/C in the EU28. FED for H/C decreases by around 7% from 6,350 TWh in 2012 to 5,930 TWh in 2030 in the *current policy scenario*. The decrease is mainly driven by thermal efficiency measures in buildings and by higher average outdoor temperatures.

The use of renewable energy sources increases by 38% by 2030 compared to 2012, reaching a total of 1,093 TWh, whereas the direct use of fossil fuels reduces by 15%.

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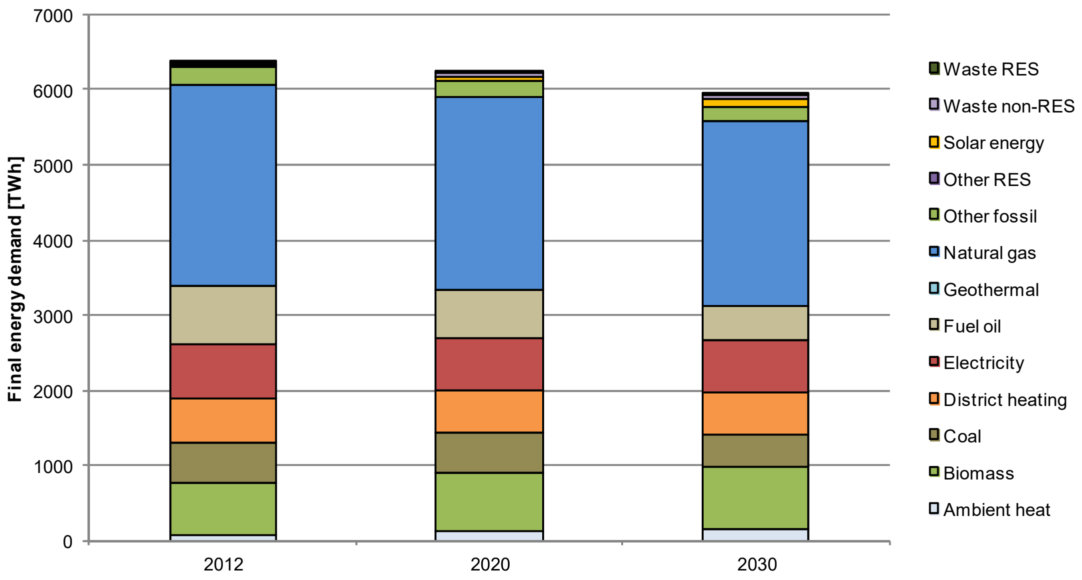
[13] End-uses other than for H/C such as mechanical energy are not included in the scenario analysis.

[14] Note that the difference in FED for H/C in 2012, compared to the assessment in WP1, results from a temperature correction. The WP1 data show the actual consumption of 2012 while a temperature correction has been applied for the scenario analysis, taking into account the long term trend in outdoor temperatures, in order to make results for 2020 and 2030 comparable to 2012.

Electricity and district heating exhibit a slight decrease of -7% and -3%, respectively.

Figure 9: Final energy demand for H/C in the EU28 in all sectors by energy carrier, *current policy scenario* [TWh]



Although the use of natural gas decreases by 7%, it still remains by far the most important final energy carrier, accounting for 40% of supply in 2030. The share of coal in the final energy demand for H/C stays relatively constant, despite a decrease of coal fired heating systems in the residential and tertiary sector, since coal is still one of the main energy carriers in the industry sector for high temperature process heating. The sharpest decrease in results is found in oil fired heating systems; under the price assumptions in the current policy scenario, final energy consumption of heating oil decreases by around 43% accounting for only 8% of FED in 2030. The share of biomass use increases from 11% to 14% of FED and remains by far the most important renewable energy source. Solar thermal energy and ambient heat exhibit the highest increase within the scenario period. However, the share of total final energy demand, at 5%, is still low in 2030.

The share of electricity in final energy demand for cooling H/C does not significantly change in the scenario period, despite an increase of electricity driven appliances, in particular heat pumps This is because a switch from direct electric heating to heat pumps reduces electricity demand for heating purposes due to higher efficiencies.

The supply of heat through district heating stays at around 9% of total heat supply even if a significant increases can be observed in some countries.

Table 8: Final energy demand for H/C in the EU28 in all sectors by energy carrier, current policy scenario [TWh]

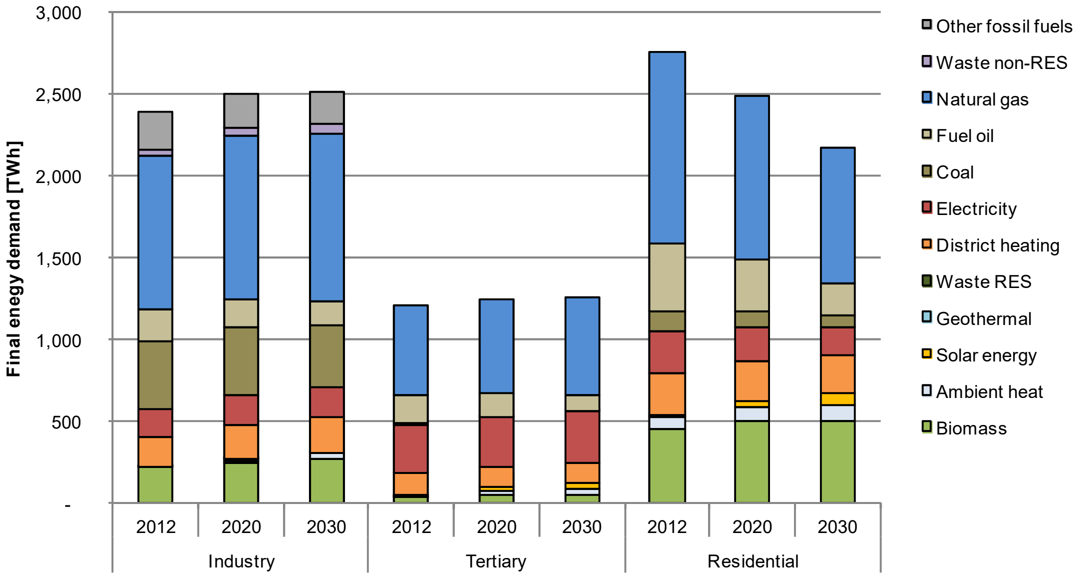
Energy Carrier	2012 Total	2012 Share	2020 Total	2020 Share	2030 Total	2030 Share	Change 2030/2012
Ambient heat	80	1%	126	2%	168	3%	111%
Biomass	692	11%	786	13%	813	14%	18%

Energy Carrier	2012 Total	2012 Share	2020 Total	2020 Share	2030 Total	2030 Share	Change 2030/2012
Coal	538	8%	524	8%	448	8%	-17%
District heating	578	9%	578	9%	559	9%	-3%
Electricity	727	11%	689	11%	675	11%	-7%
Fuel oil	782	12%	621	10%	448	8%	-43%
Geothermal	0	0%	0	0%	0	0%	-81%
Natural gas	2657	42%	2567	41%	2460	41%	-7%
Other fossil	237	4%	211	3%	185	3%	-22%
Other RES	0	0%	0	0%	0	0%	0%
Solar energy	19	0%	60	1%	108	2%	455%
Waste non-RES	37	1%	50	1%	61	1%	65%
Waste RES	3	0%	3	0%	3	0%	37%
Total	6349	100%	6217	100%	5931	100%	-7%
Total RES[15]	794	13%	975	16%	1093	18%	38%
Total non-RES	4251	67%	3974	64%	3603	61%	-15%
Total secondary energy	1305	21%	1267	20%	1234	21%	-5%

The development of final energy demand by economic sector is shown in Figure 10. While all sectors exhibit a substantial increase in the use of RES, most of the increase in industry is due to biomass, while the residential sector also experiences a substantial increase in solar energy. Total final energy demand decreases rapidly in the residential sector as a result of thermal building insulation, while it increases slightly in industry, where remaining energy efficiency potentials are lower. Natural gas remains the most important individual energy carrier in all sectors. Fuel oil decreases in every sector, particularly in the residential sector.

[15] Excluding RES in district heating and electricity

Figure 10: Current policy scenario final energy demand for H/C by sector and energy carrier in 2012, 2020 and 2030 for the EU28 [TWh]



In Figure 11 and Figure 12 the energy carrier mix for each country is shown for the years 2012 and 2030. Ambient heat and solar thermal contributions increase in all countries, whereas the development of district heating varies between the different member states. There is a significant increase in district heating results for Austria, Belgium, Norway, Slovenia and Switzerland, while district heating decreases for instance in Bulgaria, Estonia, Poland, Romania, and Slovakia by 2030. The share of natural gas increases in more than half of the countries. In Germany the proportion rises from 43% in 2012 to 46% in 2030. Even if natural gas is often seen as a sustainable substitute for coal and oil fired systems, it is questionable whether rising gas shares which are often supported by subsidies for efficient condensing boilers are compatible with long term emission targets of the EU. Modelling results also suggest that under current policies the share of coal in final energy supply rises up to 2030 which might also be problematic regarding the overall emission targets for the energy sector.

Figure 11: *Current policy scenario* energy carrier mix by country as share of total FED for H/C in 2012 and 2030 - part I Austria to Latvia

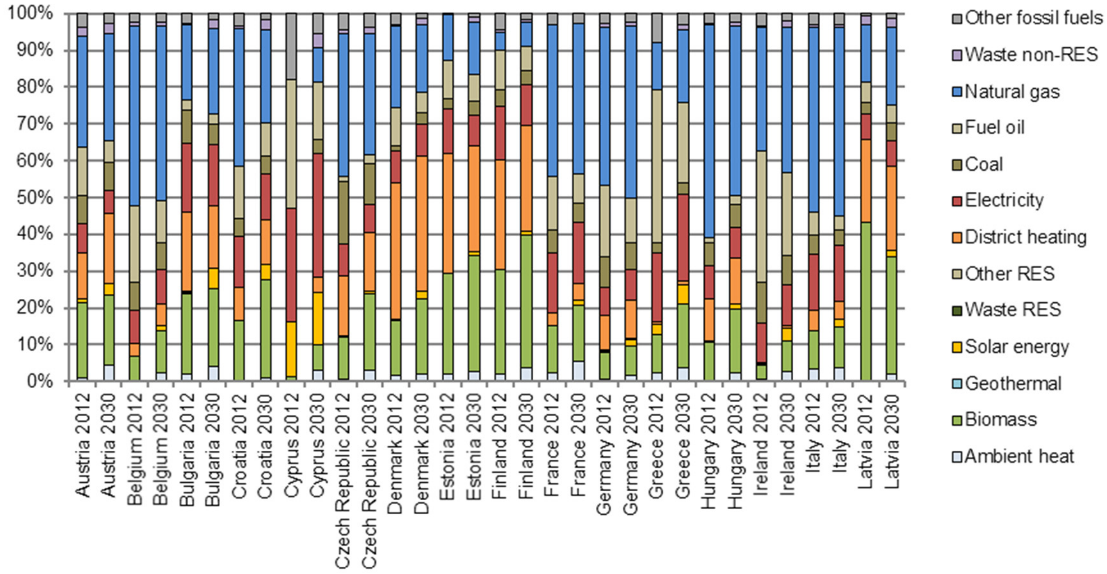
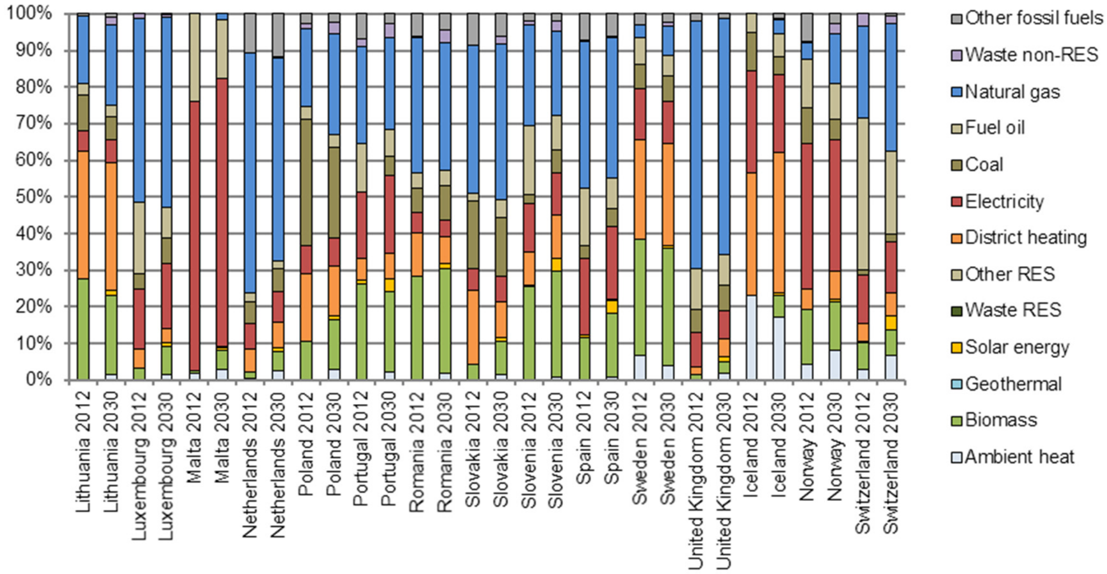


Figure 12: *Current policy scenario* energy carrier mix by country as share of total FED for H/C in 2012 and 2030 – part II Lithuania to Switzerland



The following maps provide information on the change in the total final energy demand for H/C by country and the proportion of individual RES (solar energy, biomass, ambient heat from heat pumps) in total FED for H/C in 2030. It can be observed that typical RES distribution patterns of today are also valid for 2030 in the current policy scenario. For instance, solar energy is mostly used in southern European countries, biomass in northern and eastern countries and ambient heat is most dynamic in countries where heat pumps already today exhibit high market shares (e.g. Sweden, Switzerland and France).

Figure 13: Current policy scenario – change of final energy demand for H/C from 2012 to 2030 [%]

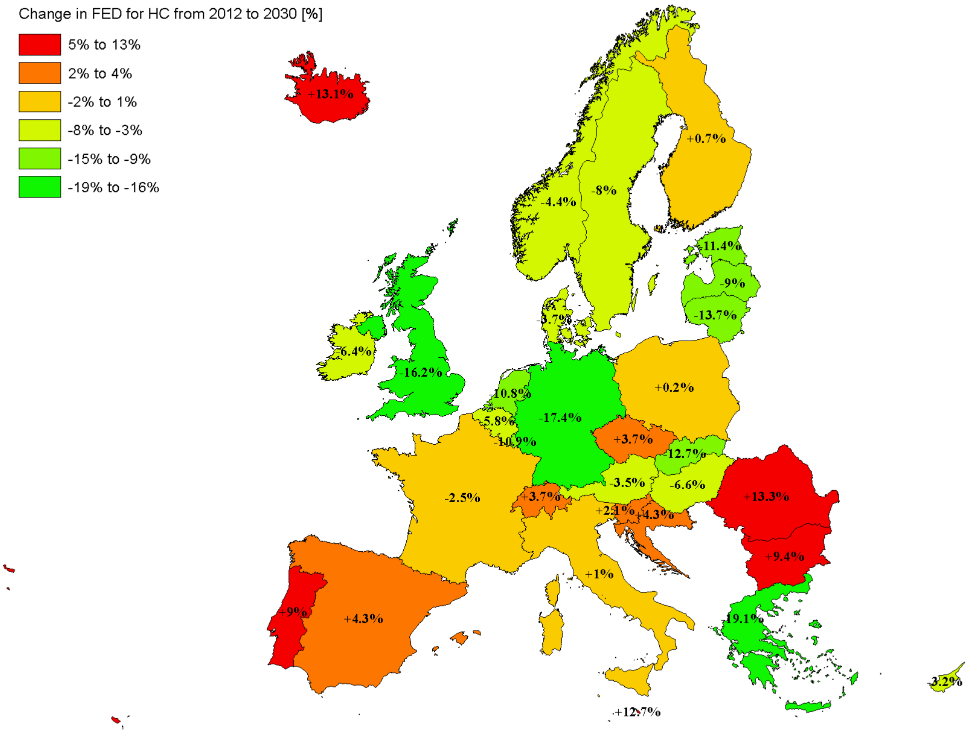


Figure 14: Current policy scenario – share of solar energy in total final energy demand for H/C in 2030 [%]

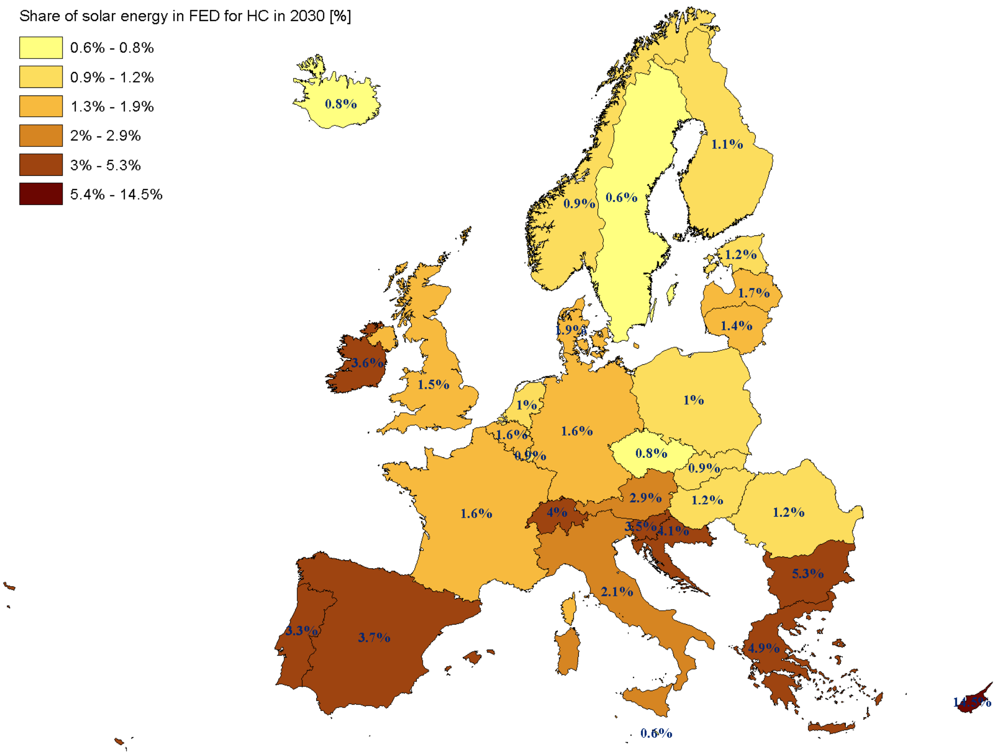


Figure 15: Current policy scenario – share of bio energy in total final energy demand for H/C in 2030 [%]

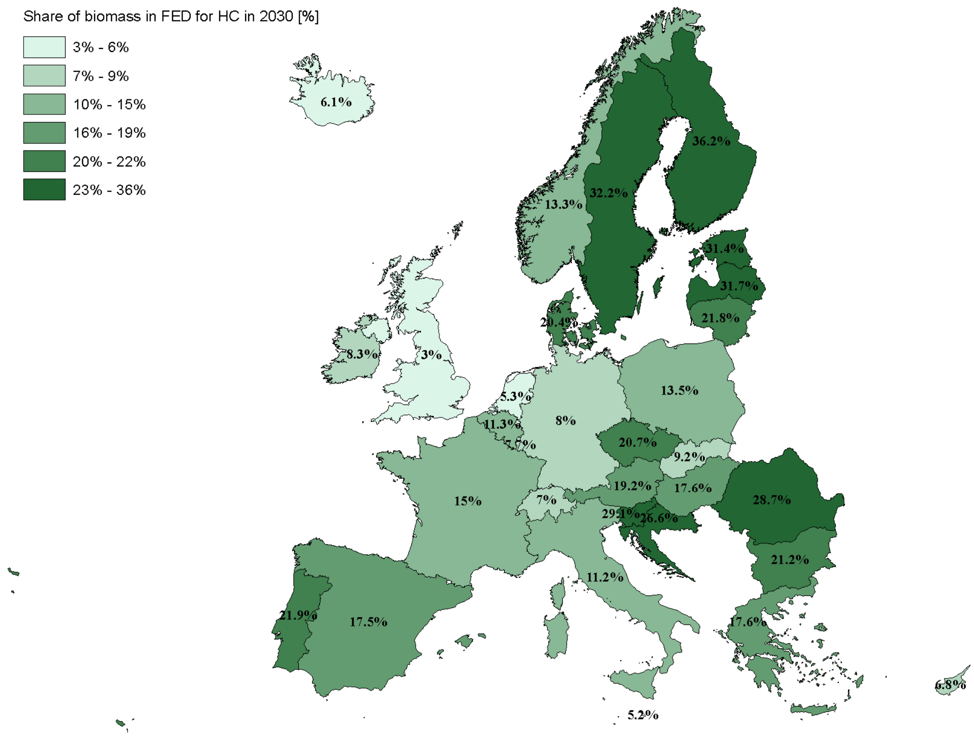


Figure 16: Current policy scenario – share of ambient heat in total final energy demand for H/C in 2030 [%]

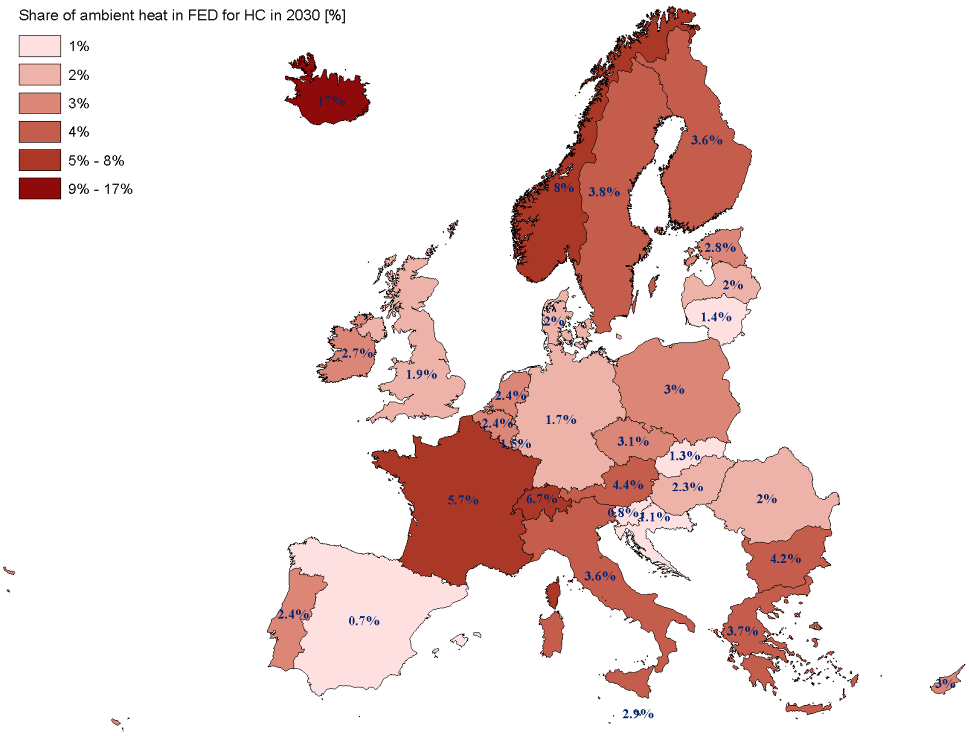


Table 9 and Figure 17 illustrate the final energy demand per end-use category, including the respective share of total final energy demand for H/C, and changes in 2020 and 2030 compared to 2012. The share of space heating decreases significantly from 54.2% in 2012 to 46.8% in 2030 mainly due to building renovation measures. On the other hand final energy demand for space cooling increases by 41.7%. However, space cooling still accounts for only 3.2% of total H/C final energy demand in 2030. Demand for water and process heating rise by 5.8% and 8.3%, respectively. Process cooling demand nearly equally distributes to the sectors industry and tertiary. The reduction until 2030, however, is mainly realised in the tertiary sector where extensive efficiency potentials are still available, e.g. in supermarkets. Process heating on the other side is mainly resulting from industry sector and most processes exhibit low efficiency potentials in the short and medium term. For details on developments in each sector see section 4.2.1 to 4.2.3.

Figure 17: *Current policy scenario* FED for H/C in the EU28 by end-use [TWh]

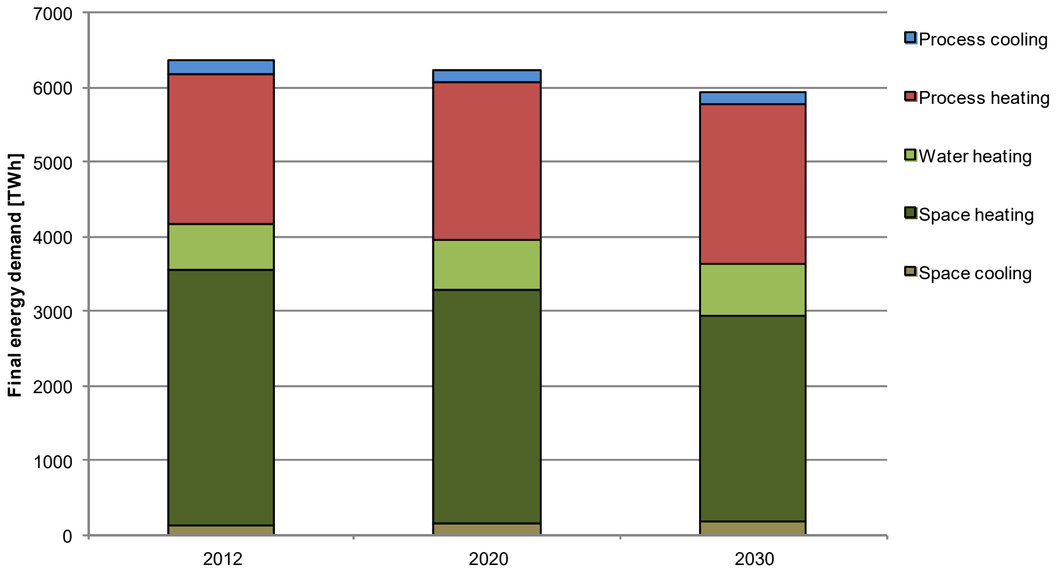
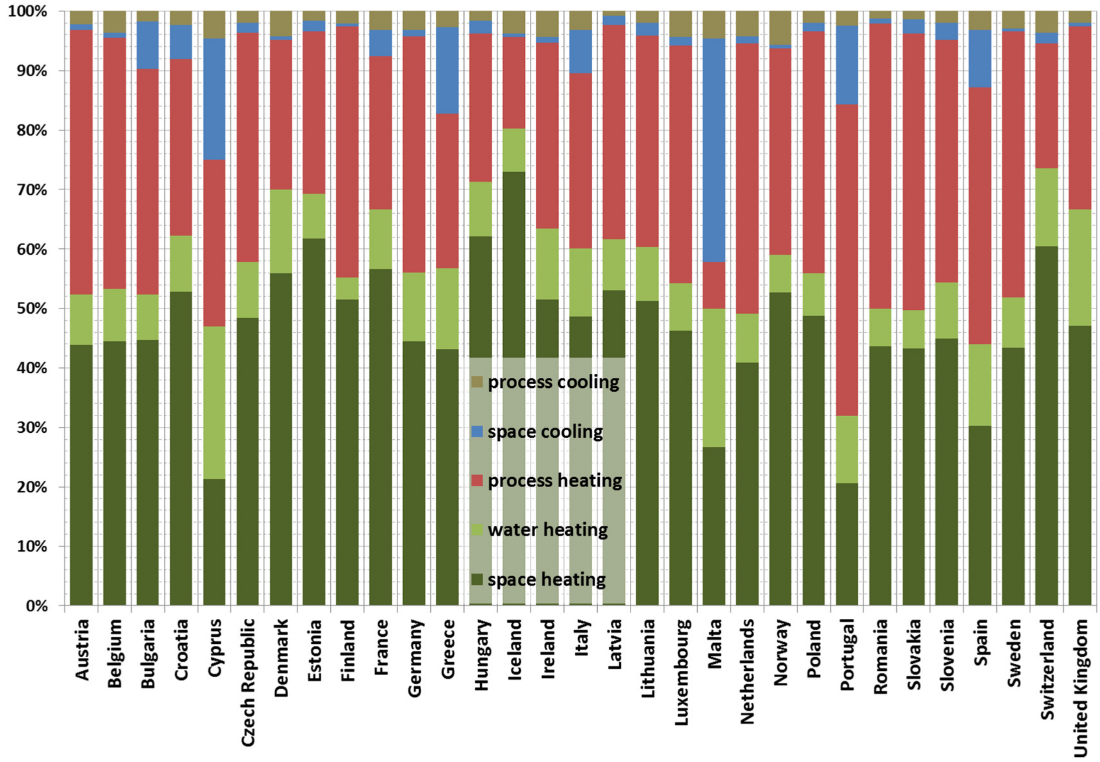


Table 9: *Current policy scenario* FED for H/C in the EU28+3 by end-use [TWh]

Year	Space heating	Water heating	Process heating	Space cooling	Process cooling	Total
	Final energy demand for H/C [TWh/a]					
2012	3547	631	2031	136	199	6544
2020	3225	656	2161	167	175	6385
2030	2850	668	2200	193	175	6086
	Share of total FED for H/C [%]					
2012	54.2%	9.6%	31.0%	2.1%	3.0%	100%
2020	50.5%	10.3%	33.8%	2.6%	2.7%	100%
2030	46.8%	11.0%	36.1%	3.2%	2.9%	100%
	Change compared to 2012 [%]					
2020	-9.1%	4.0%	6.4%	22.7%	-11.8%	-2.4%
2030	-19.6%	5.8%	8.3%	41.7%	-11.9%	-7.0%

Figure 18 shows the split of final energy demand end-use category by country. The share of process heating depends on the industry structure of each country while proportions of space cooling and space heating are driven by in particular by the renovation of the building stock in each country. Heating needs account for more than 80% of final energy demand for heating and cooling in all countries except for Malta and Cyprus.

Figure 18: Current policy scenario share of end-uses of total FED by country in 2030



Finally, Table 10 illustrated the distribution of final energy demand across the three demand sectors. The numbers show that overall reduction by 2030 is mainly realised in the residential sector with a reduction of 20.6%, while the final energy demand of the industry sector increases by 5.7%. The latter is a result of increasing economic activities assumed for the scenario (see 3.3.2) as well as limited energy efficiency potentials, especially in energy intensive industries. The residential sector on the other hand offers large potentials for efficiency gains through thermal refurbishments and minimum energy efficiency requirements for new buildings. The final energy demand of the tertiary sectors decreases only slightly by 1%. By 2030 the industry sector accounts for 42.5% of total final energy demand for heating and cooling, overtaking households, for which the share drops from 43.5% in 2012 to 37.1% in 2030.

Table 10: Sector split of final energy demand in the EU28+3, *current policy scenario*

Year	Industry	Residential	Tertiary	Total
	Final energy demand [TWh/a]			
2012	2445	2846	1251	6544
2020	2555	2574	1255	6385
2030	2584	2261	1240	6086
	Share of total demand [%]			
2012	37.4%	43.5%	19.1%	100%
2020	40.0%	40.3%	19.7%	100%
2030	42.5%	37.1%	20.4%	100%
	Change compared to 2012 [%]			
2020	4.5%	-9.6%	0.3%	-2.4%
2030	5.7%	-20.6%	-0.9%	-7.0%

4.1.2 Primary energy demand

The calculation of primary energy demand is based on the modelling results of final energy demand. For heating systems, using direct fuel input such as natural gas, heating oil or biomass, primary energy demand equals final energy demand assuming a primary energy factor of 1. The secondary energy carriers electricity and district heat are converted using results of the Green-X model. For the energy carrier mix calculated with the Green-X model (see 2.5), additional data from the EU reference scenario 2016 as well as assumptions on transformation and grid losses, are used to calculate the primary energy factors of district heating and electricity by country.

Figure 19 illustrate the resulting primary energy demand for EU28 in the years 2012, 2020 and 2030[16]. The figure depicts all primary energy carrier used for heating and cooling including those used in the transformation sector[17]. Total primary energy demand for H/C in the EU28 decreases by 9% from 7,495 TWh/a in 2012 to 6,823 TWh/a in 2030 in the *current policy scenario*. The reduction of primary energy is caused, on the one hand, by implemented efficiency measures and the assumed increase in average outdoor temperatures, and on the other hand, by an increase of RES in the transformation sectors[18]. Furthermore, average efficiency of conventional power and district heating plants increases within the scenario period due to replacements by newer more efficient plants.

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16 A detailed illustration of the results is shown in the annex.

17 For instance, electricity used for heating and cooling is broken down into respective primary energy carriers used for generating electricity (e.g. nuclear, coal, wind power, hydro etc.)

18 In the primary energy calculation, efficiencies of RES-E (Wind, PV, Hydro) installations are 100% in accordance with the EUROSTAT energy balance.

Figure 19: Primary energy carrier mix, EU28, current policy scenario

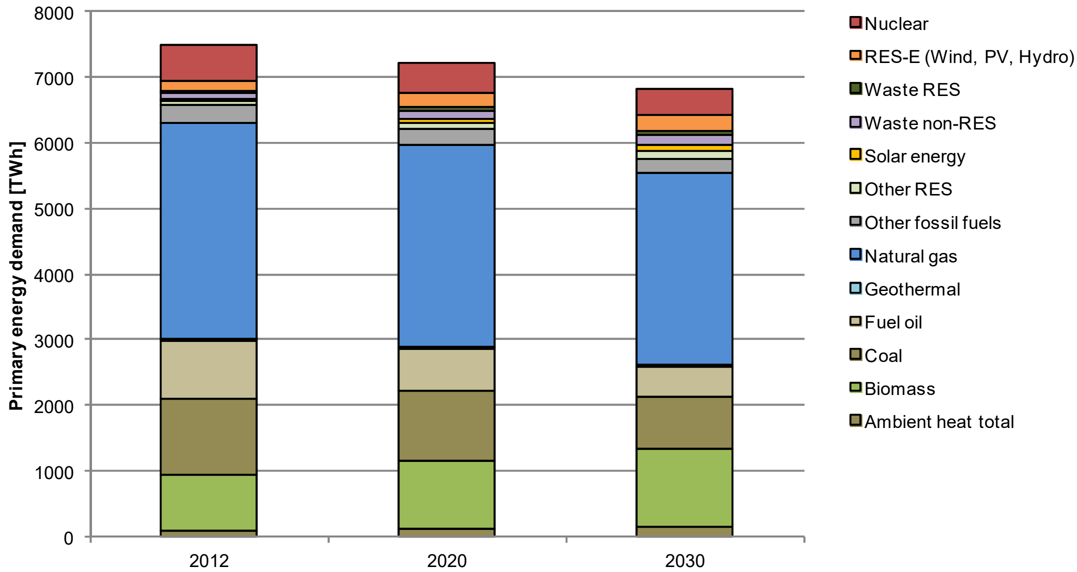


Figure 20 shows the relative and absolute changes for each energy carrier. Fuel oil exhibits the highest decline with 50% in the period 2012 to 2030 However, the results are based on the energy price assumptions of the EU reference scenario 2016 which assumes rising oil price within the scenario period. Natural gas as primary energy carrier for heating and cooling decreases by around 11%, or 360 TWh/a up to 2030. The share of natural gas in total primary energy supply for heating and cooling stays at around 43% by 2030 (43.9% in 2012). The largest relative increase exhibit solar thermal energy and ambient heat through the use of heat pumps. The largest absolute increase results for biomass with an additional 283 TWh of primary energy being used for heating and cooling.

Figure 20: Changes of energy carriers in primary energy demand mix 2030 compared to 2012, EU28, current policy scenario

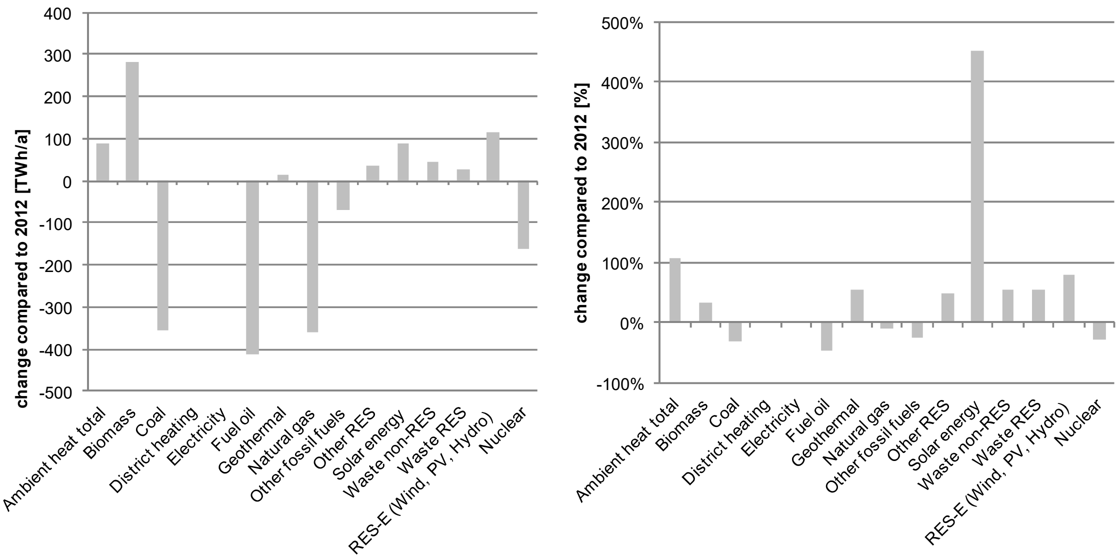


Figure 21 illustrate the shares of end-use categories in primary energy demand. While the share of space heating declines from 51% to 48% in 2030, the primary energy demand for space cooling increases from 4% (291 TWh/a) to 5% (347 TWh/a) in 2030. Water heating stays relatively constant, in absolute terms, with a share of 11% in 2030. Process heating increases from 29% in 2012 to 35% in 2030.

Figure 21: Primary energy demand by end-use category, EU 28, current policy scenario

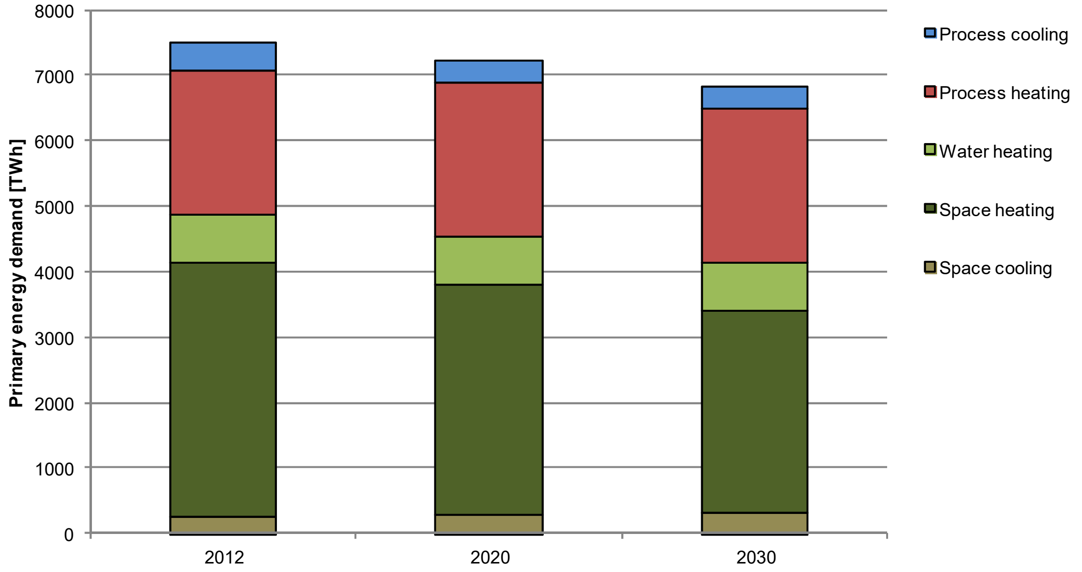


Figure 22 shows the share of end-use categories in primary energy demand for each country in the year 2030. In most member states cooling energy demand accounts for less than 25% of total demand for heating and cooling. Only two countries have higher shares in 2030: 30% in Cyprus, and 50% in Malta. Apart from the influence of climate conditions, these figures are a result of fossil fuel based electricity production in the countries.

Figure 22: Primary energy demand by end-use category, by country, current policy scenario

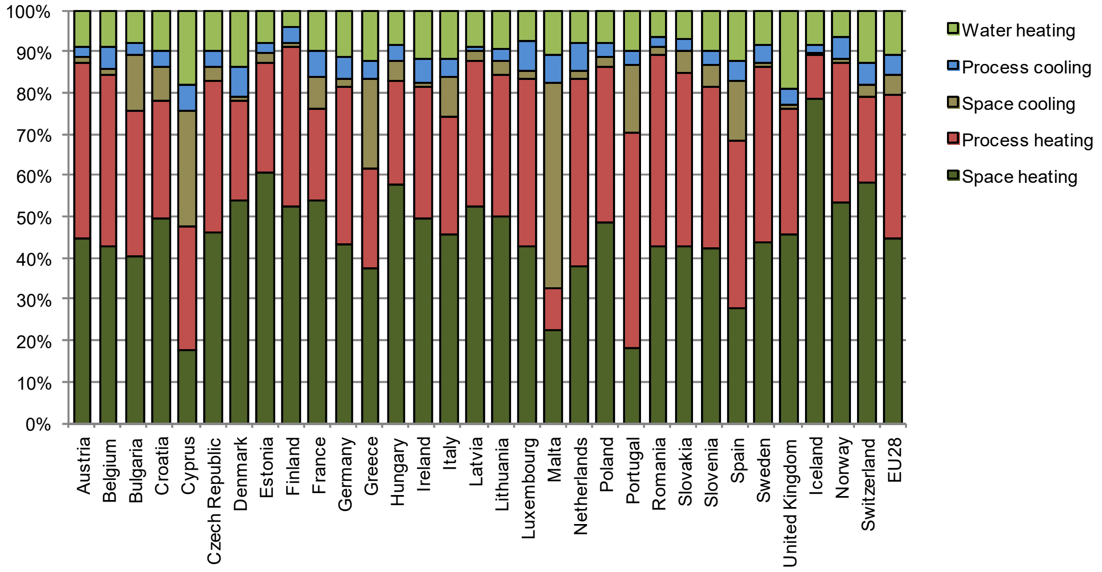


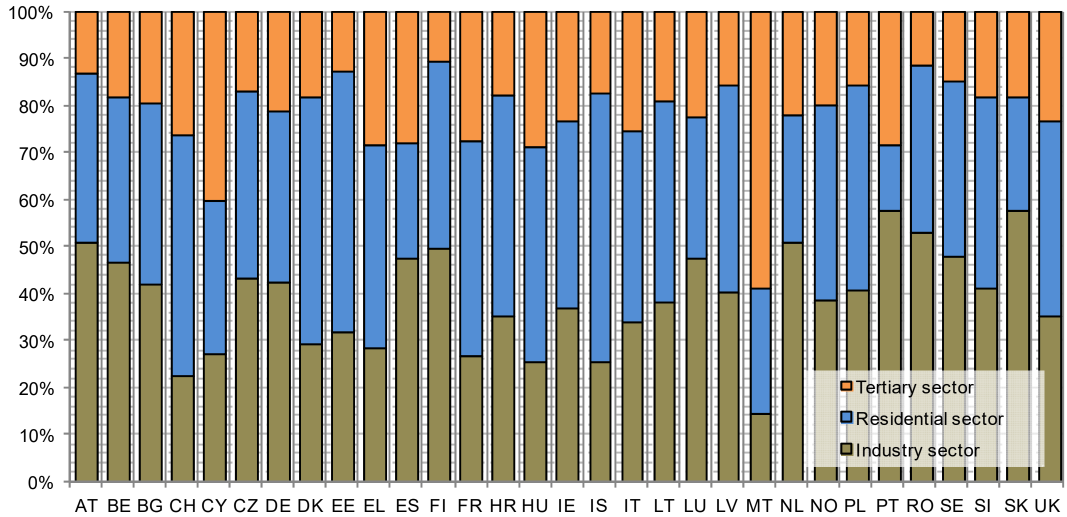
Table 11 summarises the primary energy demand development in the current policy scenario for each sector, and the relative change compared to the base year 2012. Primary energy demand in the residential sector decreases by 23.4% up to 2030, while it increases by 4.7% in the industry sector. The relative share of the tertiary sector in total primary energy increases slightly to 23.2% within the scenario period while the share of the residential sector decreases from 42.7% in 2012 to 35.9% in 2030.

Table 11: Sector split of primary energy demand for heating and cooling, EU28 current policy scenario

	Industry	Tertiary	Residential	Total
Primary energy demand [TWh/a]				
2012	2,663	1,633	3,198	7,495
2020	2,796	1,599	2,838	7,233
2030	2,788	1,585	2,450	6,823
Share of total demand [%]				
2012	35.5%	21.8%	42.7%	100.0%
2020	38.7%	22.1%	39.2%	100.0%
2030	40.9%	23.2%	35.9%	100.0%
Change compared to 2012 [%]				
2020	5.0%	-2.1%	-11.3%	-3.5%
2030	4.7%	-2.9%	-23.4%	-9.0%

Figure 23 illustrates the distribution of primary energy demand on the different sectors for each country in the year 2030. Differences in the shares of sectors between the countries mainly result from the differences in economic activities and climate conditions. The share of primary energy demand from the tertiary sector is typically higher in warmer countries as a result of higher cooling needs in this sector (e.g. office buildings, shopping centres).

Figure 23: Sector split of primary energy demand for heating and cooling by country, 2030, *current policy scenario*



4.1.3 Useful energy demand

The useful energy demand is calculated according to the methodology defined in Work package 1 of this study[19]. Figure 24 as well as Table 12 show the development of the useful energy demand by end-use for all countries within the scope of the study. The overall demand is expected to decrease slightly by 5% from 5,172 TWh to 4,920 TWh in 2030, whereas the demand for space cooling, water heating and process heating increases. Space heating demand decreases by about 20%, whereas space cooling demand is expected to increase by 46%. Water heating and process heating rise by 14%. The proportion of space heating of the overall total useful energy demand drops from 52% to 44%.

19 Please refer to Fleiter, T.; Steinbach, J.; Ragwitz, M. et al. (2016): Mapping and analyses for the current and future (2020 - 2030) heating/cooling fuel development (fossil/renewables) –Work Package 1: Final energy consumption for the year 2012. Brussels: European Commission, DG Energy.

Figure 24: Total useful energy demand for all sectors by end-use in EU28

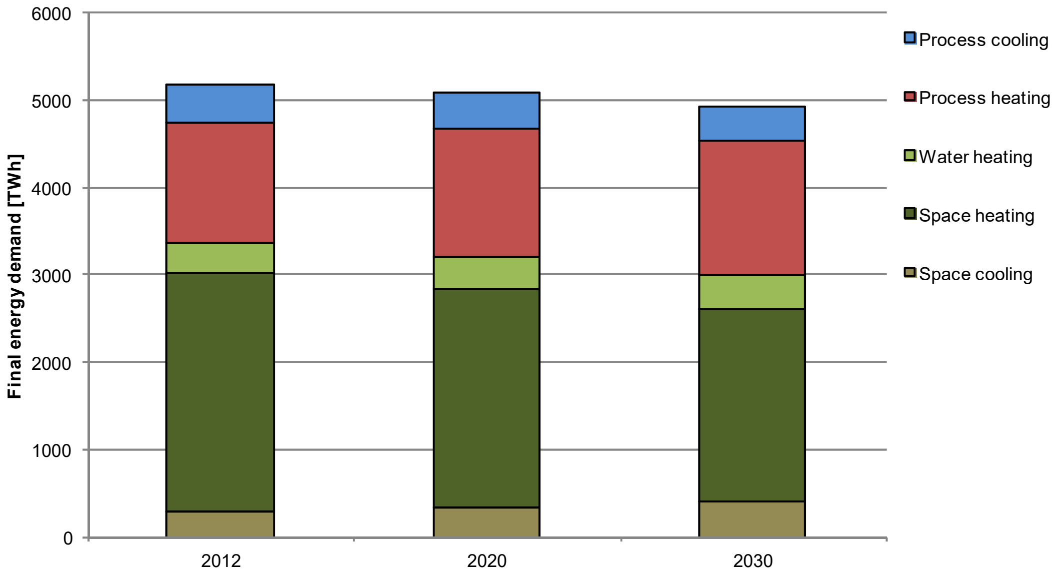


Table 12: Total useful energy demand for all sectors by end-use in EU28 [TWh]

	2012	2020	2030	Change 2030/2012
Space cooling	290	357	419	44%
Space heating	2730	2473	2183	-20%
Water heating	338	363	384	14%
Process heating	1373	1479	1533	12%
Process cooling	441	398	402	-9%
Total	5172	5070	4920	-5%

Please refer to the annex for an illustration of useful energy demand for all sectors by country end-use

4.1.4 CO_2 emissions

CO_2 emissions are calculated by applying the specific emission factors (see Table 13) to the primary energy consumption. Therewith, only direct emissions of the energy conversion are included. Life cycle emissions – e.g. emissions occurring in the manufacturing process of heating appliances or insulation materials – are not considered. For the energy carrier category "other fossil fuels", the emission factor of fuel oil is applied. For waste incineration of non-renewable waste the average emission factor for all countries is used. Emissions from coal include lignite as well as hard coal. Proportions of lignite and hard coal are estimated based on the IEA energy balances for countries with significant shares of lignite (Bulgaria, Czech Republic, Germany, Greece, Hungary, Poland, Slovenia and Slovakia).

Table 13: Emission factors used to calculate CO_2 emissions

	Emission factor [kgCO_2/kWh primary]
Lignite	0.396
Coal	0.342
Fuel oil	0.288
Natural gas	0.198
Other fossil fuels	0.288
Waste non-RES	0.36

Table 14 shows the resulting CO_2 emissions from heating and cooling in the *current policy scenario* for the EU28. Total emissions drop by 22.5% from 1,427 million tonnes per year in 2012 to 1,106 million tonnes in 2030. Several effects lead to this reduction:

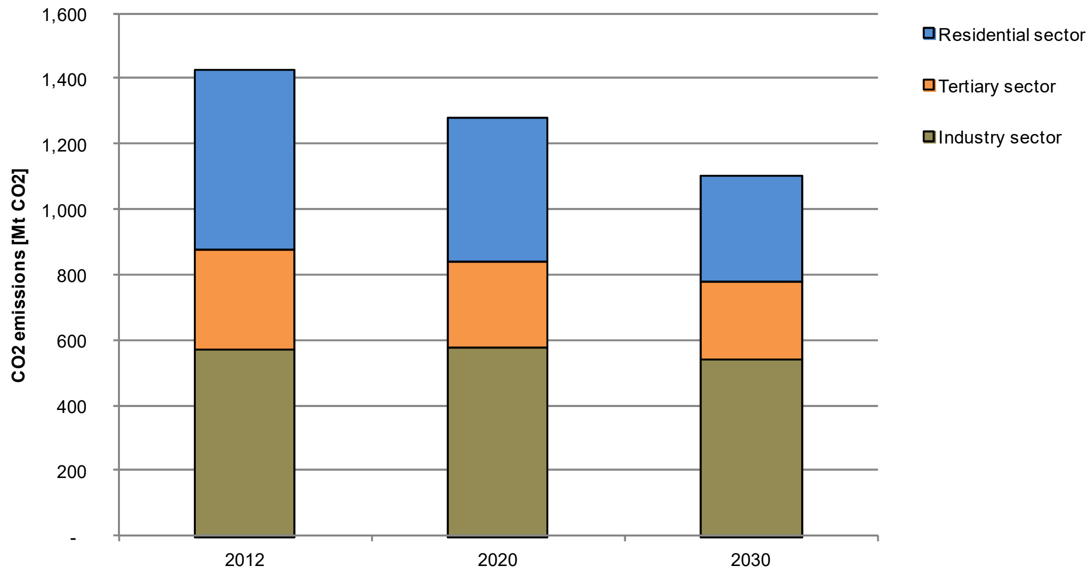
- Reduction of useful energy needs due to thermal efficiency measures.
- Reduction of final energy demand due to efficiency gains in conversion technologies.
- Increased share of RES in the final energy carrier mix for H/C
- Increased transformation efficiencies and increased shares of RES in the electricity and district heating sector.

Table 14: Sector split and development of CO_2 emissions, EU28, current policy scenario

	CO2 Emissions [Mt CO2]			Shares of total emissions			Change
	2012	2020	2030	2012	2020	2030	2030 vs. 2012
Industry	577	580	546	40.4%	45.3%	49.4%	-5.3%
Residential	548	436	324	38.4%	34.0%	29.3%	-40.9%
Tertiary	302	264	236	21.2%	20.6%	21.4%	-21.9%
Total	1427	1280	1106	100%	100%	100%	-22.5%

Table 14 and Figure 25 also illustrate the contribution of each sector to total emissions. The industry sector is responsible for most emissions and its contribution increases from 40.4% in 2012 to 49.4% in 2030 (-5.3% vs. -40.9% and -21.9% in the residential and tertiary sectors respectively). There are two main reasons for this difference. On the one hand, a greater potential to reduce energy needs through efficiency measures in the building sector compared to the industry sector, in which efficiency potentials have already been exploited to a larger extent, particularly in energy intensive sectors. On the other hand, there are limited options to integrate RES in industry especially for high temperature process heat.

Figure 25: Sector split and development of CO_2 emissions from H/C, EU28, *current policy scenario*



The sources of emissions in terms of energy carriers are shown in Figure 26 and Figure 27. Although coal as a direct fuel input only accounts for 8% of final energy demand for heating and cooling, the share in total CO_2 emissions is significantly higher due to its use in electricity generation and district heating. Despite a drop of emissions from coal by 31% by 2030 in the *current policy scenario*, the total emissions from coal combustion still account for more than 25% of total emissions in 2030. The largest portion of emissions in the H/C sector is generated by the use of natural gas. While total emissions from natural gas decreases by 11% up to 2030 in the *current policy scenario*, its share in total emissions increases from 46% to 52% by 2030. CO_2 emissions from heating oil combustion and other fossil fuels decrease by 47% due to substitution by natural gas and RES.

Figure 26: Source of CO_2 emissions for H/C [Mt CO_2] by energy carrier, EU28, *current policy scenario*

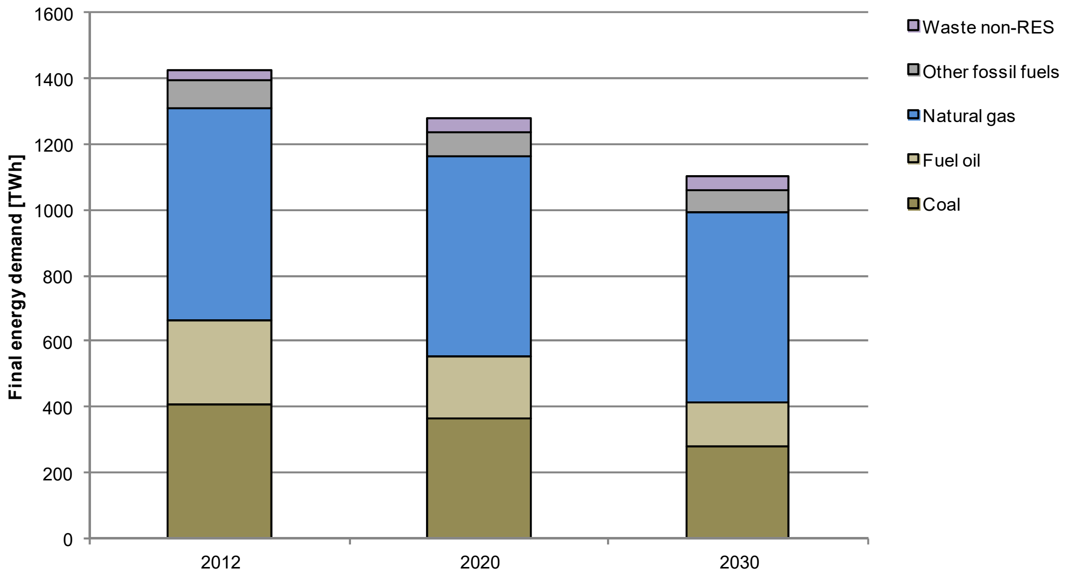


Figure 27: Source of CO2 emissions for H/C [Mt CO2] by energy carrier and by sector, EU28, current policy scenario

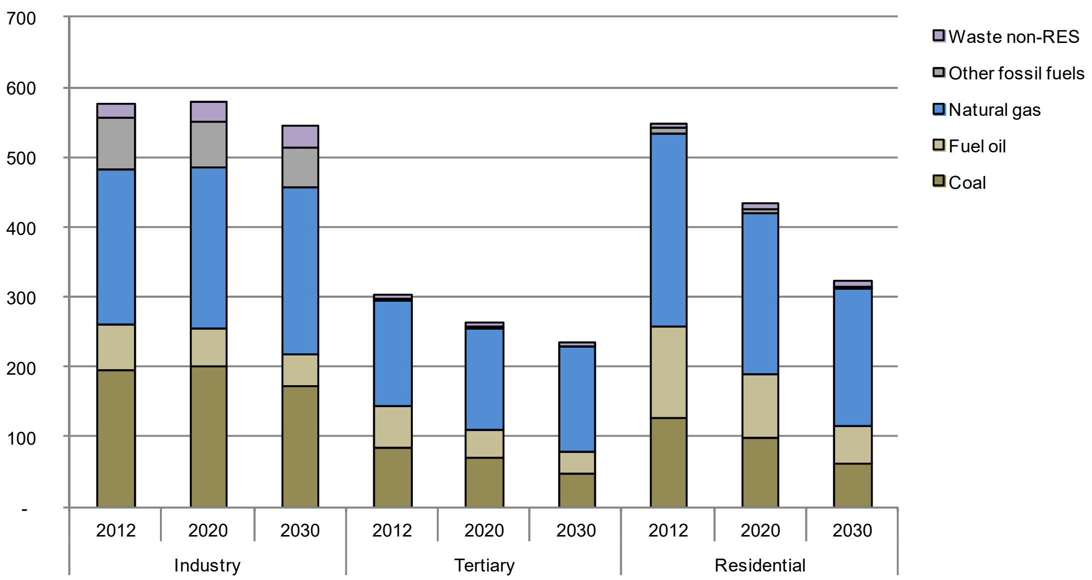
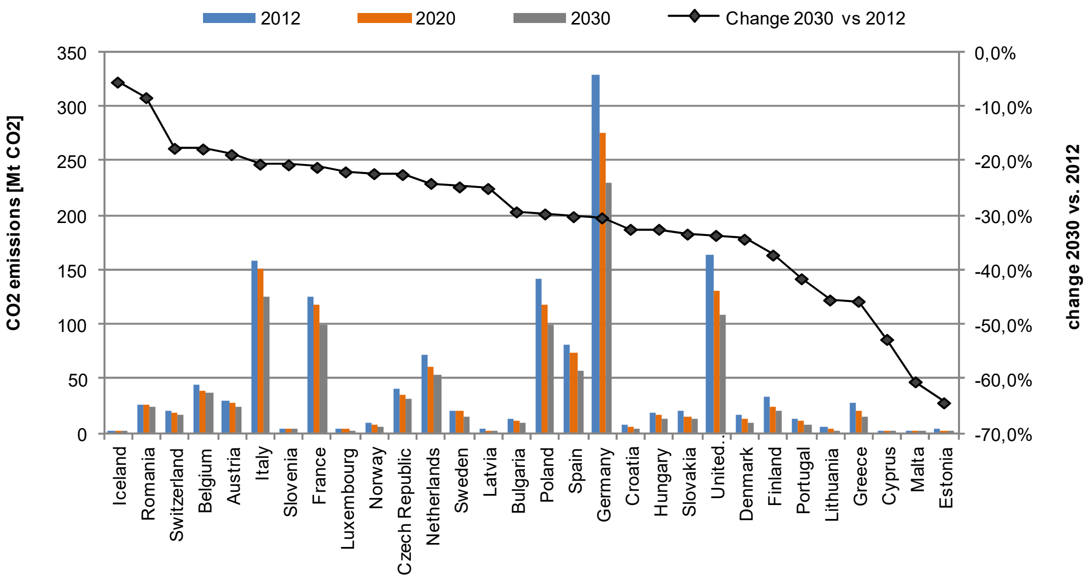


Figure 28 illustrates the total emissions caused by H/C for all 31 countries, and relative changes in emissions from 2012 to 2030. Five countries (Germany, United Kingdom, Italy, Poland, and France) account for almost two thirds of total emissions. All countries expect Romania and Iceland show reductions of more than 15% by 2030. Countries with high emissions in absolute terms exhibit emission reductions between 18% and 33%.

Malta and Cyprus show very large reductions in emissions, of over 50%, due to increasing shares of solar thermal energy, significant reductions in heating demand and increasing shares of RES-E deployment. The large emission reduction in Estonia is a result of significant increases in the use of biomass in the residential and tertiary as well as in the district heating sector. Low emission reduction potentials in Iceland arise because shares of RES (geothermal and ambient heat) are already very high in 2012. Reductions in emissions in Romania are low because the increase in economic activities assumed in the scenario, resulting in higher emissions from the industry sector, leads to low overall emission reductions.

Figure 28: Development of CO_2 emissions by country in the *current policy scenario*



4.1.5 RES-H/C shares

The RES-H/C share is a key performance indicator for RES-H/C policy in the EU. Eurostat monitors RES shares including RES-H/C in the framework of the SHARES project. The SHARES project developed a methodology to calculate RES shares based on the final energy demand balances reported by Eurostat[20]. An extraction of RES-H/C shares from 2004 to 2014 is shown in the annex of this report. It can be observed that the average EU28 RES-H/C share, but also that of most individual countries, increased substantially from 2004 to 2014.

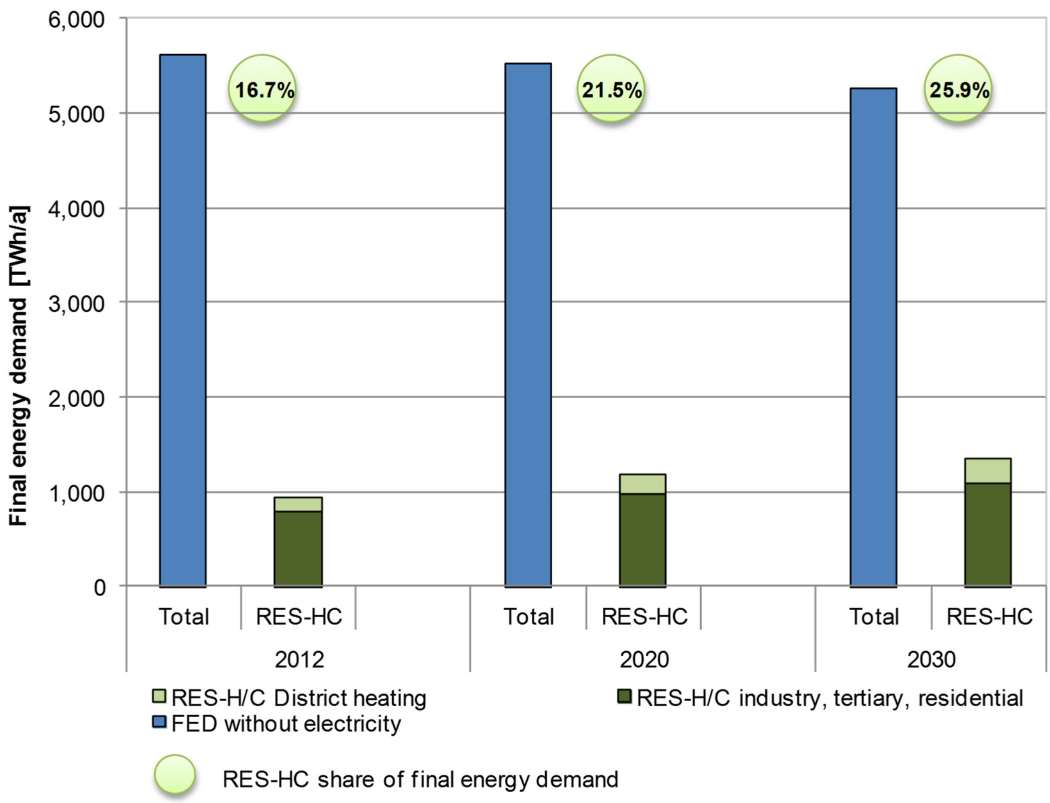
Our approach to the calculation of RES-H/C shares follows the main lines of the SHARES methodology.We calculate the RES-H/C share as the total demand for renewable energy sources (RES) in industry, residential, tertiary and district heating sectors divided by the total final energy demand (FED) minus electricity, as shown in the following formula:

[20] See also SHARES website for a detailed description of the methodology and recent results: http://ec.europa.eu/eurostat/de/web/energy/data/shares

$$\frac{RES_{Ind,Ter,Res,DH}}{FED_{Ind,Ter,Res} - Electricity_{Ind,Ter,Res}}$$

Figure 29 shows the development of total FED and RES-H/C in the *current policy scenario*. The FED excluding electricity of the EU28 member states decreases by 90 TWh from 2012 to 2020 and by 276 TWh to 5,256 TWh in the period 2020 to 2030. The overall RES-H/C share increases from 16.7% in 2012 to 25.9% in 2030.

Figure 29: Development of FED and RES-H/C in the current policy scenario in the EU28 from 2012 to 2030



Difference in RES-H/C shares reported by EUROSTAT

A main difference to the SHARES methodology is that the agriculture sector is not included in the FED of this study. Furthermore, ambient heat used for heating with heat pumps is considered as RES in our study but is not included in the final energy balance of Eurostat.

The resulting country specific RES-H/C shares, and their development until 2030, are shown in Figure 30. A detailed picture of the resulting RES-HC shares and related FED and RES energy demands by country is provided in Table 15.

It becomes obvious that from 2012 to 2030 the RES share increases in most countries. This does not necessarily mean that the absolute RES demand increases. For instance, total RES-H/C demand decreases slightly in Germany and Austria from 2020 to 2030. However, as the total FED also falls, the resulting RES shares increase. A few countries with high RES shares show decreasing trends from 2020 to 2030.

Figure 30: RES-HC share by country in the *current policy scenario* for 2012, 2020 and 2030

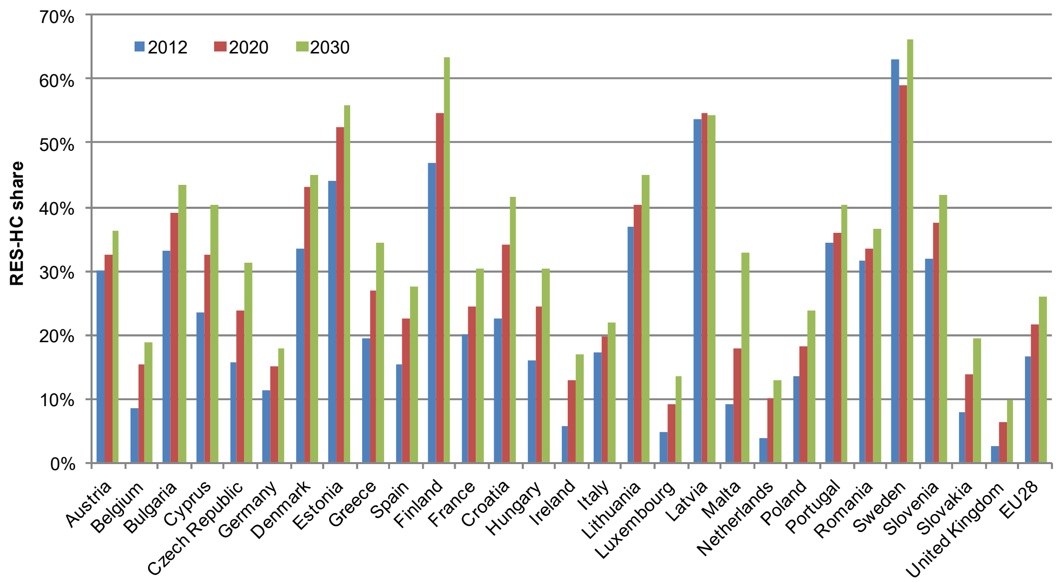
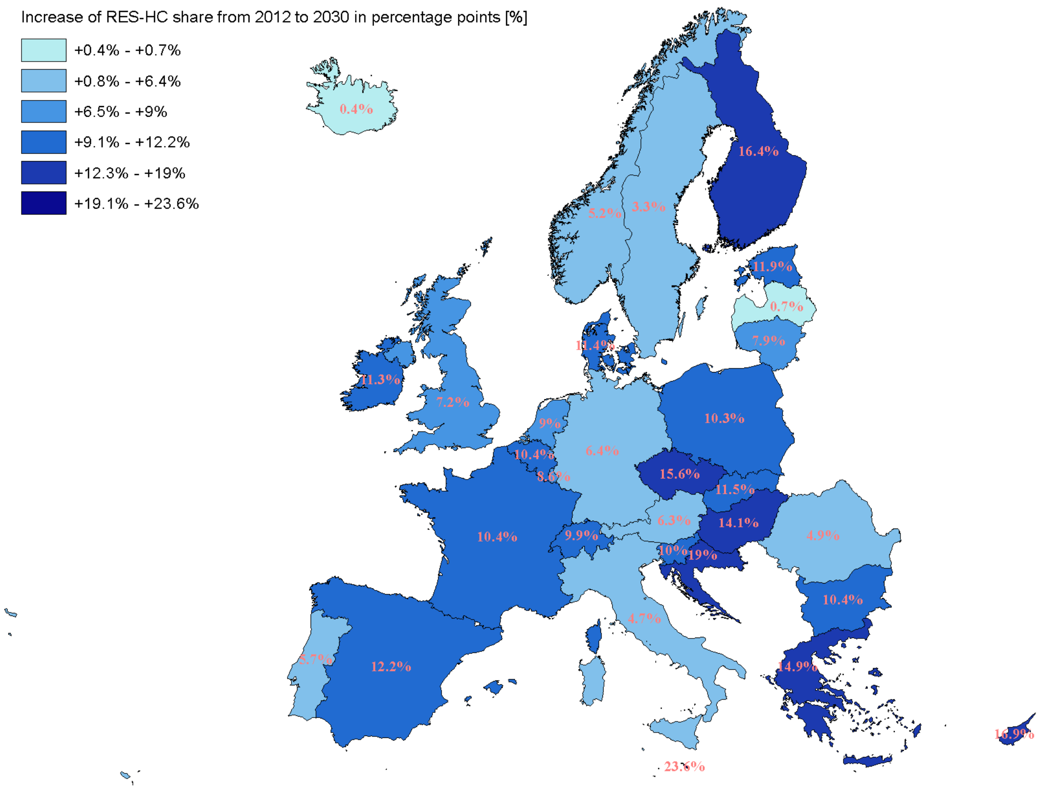


Table 15: Current policy scenario RES-H/C shares in 2012, 2020 and 2030 by country

Country	FED (excl. Elec.) [TWh]			RES-H/C [TWh]			RES-H/C Share		
	2012	2020	2030	2012	2020	2030	2012*	2020	2030
Austria	156	162	153	47	53	56	30.0%	32.7%	36.3%
Belgium	187	188	176	16	29	33	8.4%	15.3%	18.9%
Bulgaria	43	47	48	14	18	21	33.0%	39.2%	43.4%
Cyprus	4	4	3	1	1	1	23.5%	32.5%	40.3%
Czech Republic	143	149	150	22	35	47	15.6%	23.6%	31.2%
Germany	1248	1147	1023	142	173	182	11.4%	15.1%	17.8%
Denmark	71	71	69	24	31	31	33.6%	43.1%	45.0%
Estonia	16	16	15	7	8	8	44.1%	52.4%	56.0%
Greece	73	63	56	14	17	19	19.3%	26.8%	34.5%
Spain	301	310	318	46	69	88	15.4%	22.4%	27.5%
Finland	152	156	160	71	86	101	47.0%	54.7%	63.4%
France	633	651	617	126	159	187	19.9%	24.5%	30.3%
Croatia	26	27	28	6	9	12	22.5%	34.0%	41.5%
Hungary	88	90	83	14	22	25	16.1%	24.3%	30.2%
Ireland	49	48	45	3	6	8	5.7%	12.9%	17.0%
Italy	638	655	647	111	130	142	17.3%	19.8%	22.0%
Lithuania	26	25	22	10	10	10	37.0%	40.3%	44.9%
Luxembourg	12	12	11	1	1	1	4.8%	9.0%	13.4%
Latvia	25	25	23	14	14	13	53.7%	54.8%	54.4%
Malta	0	0	0	0	0	0	9.2%	17.7%	32.8%
Netherlands	283	261	248	11	26	32	3.7%	10.1%	12.8%
Poland	369	374	370	49	68	87	13.4%	18.3%	23.7%
Portugal	56	58	58	19	21	23	34.5%	36.1%	40.2%
Romania	132	147	150	42	49	55	31.6%	33.3%	36.5%
Sweden	165	162	156	104	96	104	63.0%	59.2%	66.3%
Slovenia	21	21	21	7	8	9	32.0%	37.4%	42.0%
Slovakia	82	73	71	6	10	14	7.8%	13.8%	19.3%
United Kingdom	624	586	533	15	37	51	2.4%	6.3%	9.6%
EU28	5622	5528	5255	941	1187	1360	16.7%	21.5%	25.9%

* The 2012 RES-HC shares deviate slightly from the Eurostat figures published in the SHARES project (e.g. our figures show 16.7% for the EU28, where Eurostat reports 16.3%). While our approach generally follows the SHARES methodology, a few items are different due to different data availability.

Figure 31: Current policy scenario – increase in RES H/C share from 2012 to 2030 in percentage points



4.1.6 Biomass demand and potentials

In this section total biomass demand in the H/C sector is compared to the available biomass potential. In a first step this is done at EU level, and in a second step at national level. The data used for the actual and future biomass potential originate from a yet to be published final report of an EU project[21].

In 2012 bio-energy represents 100 Mtoe (1163 TWh) of primary energy deployment in the electricity and heating and cooling sectors. Heat is still the largest sector of final bio-energy consumption with its main end-use in the residential sector. Solid biomass, mainly from forest resources, represents the largest share (84.6 Mtoe primary energy consumption), followed by biogas (8.4 Mtoe) and organic waste (7.4 Mtoe).

Potential domestic supply in the EU28, in 2030, ranges between 338 Mtoe (3930 TWh) in the restricted scenario to 391 Mtoe (4547 TWh) in the resource scenario. The future share of solid biomass and liquid biofuels supply from extra-EU sources ranges between 4% in the restricted scenario to 14% in the resource scenario compared to 4% in 2013.

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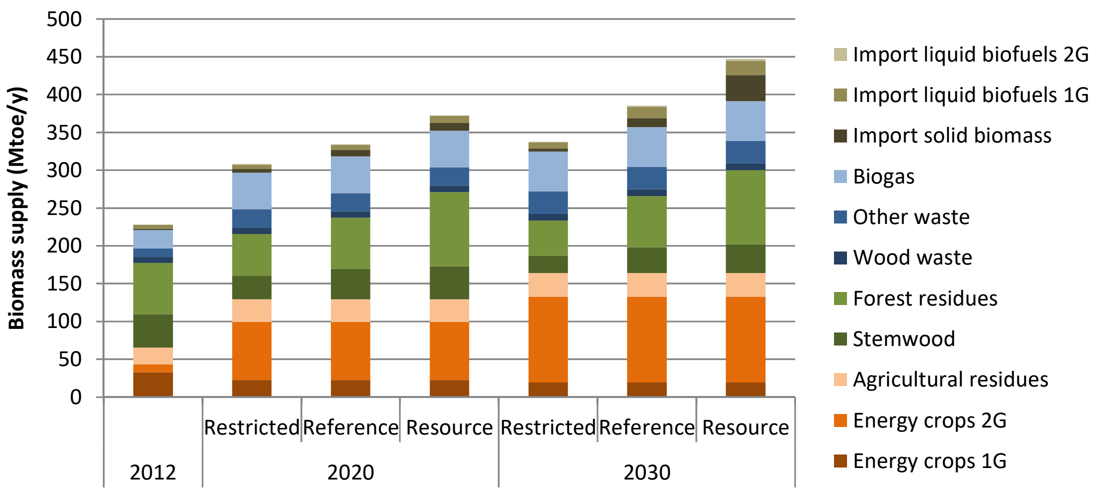
[21] PricewaterhouseCoopers EU Services EESV's consortium for the European Commission, Directorate General for Energy, "Sustainable and optimal use of biomass for energy in the EU beyond 2020".

The result is a corridor of sustainable utilisation options for the following scenarios:

- Restricted scenario:
  - EU wood availability under the condition of stronger utilisation restrictions and larger set-aside areas.
  - Higher global competition for extra-EU solid biomass and lack of investments in infrastructure to mobilise alternative woody biomass.
  - Low export capacity of liquid biofuels outside the EU.
- Reference scenario:
  - EU wood availability is provided under today's circumstances.
  - Extra-EU solid biomass development follows a business as usual trend.
  - Medium export capacity of liquid biofuels to the EU.
- Resource scenario:
  - Maximum possible utilisation of wood in the EU under long-term sustainable conditions.
  - Strong development of supply and infrastructure of extra-EU solid biomass and perennial crops cultivated for export markets.
  - High export capacity of liquid biofuels to the EU.

Figure 32: Overview of estimated biomass potential for bio-energy in the EU28 in 2012, 2020 and 2030 in terms of primary energy*



*Biogas and import of liquid biofuels are shown in final energy units.

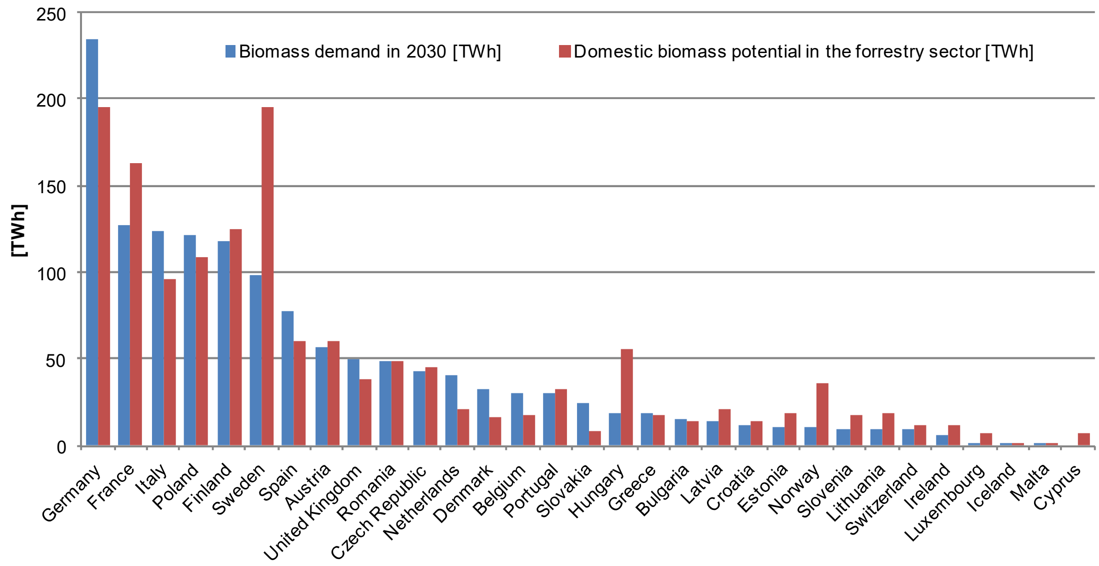
1G: food-based energy crops/biofuels

2G: lignocellulosic energy crops/biofuels

These sustainable utilisation options are then compared to the projected demand of the heating and cooling sector in 2030 for the EU28 member states. In the current policy scenario, total biomass use related to energy demand for heating and cooling (including electricity for heating and cooling and district heating) amounts to 1,049 TWh. Total biomass needs, including the whole electricity sector (excluding transport),are estimated to amount to around 1,364 TWh. Comparing this figure with estimated biomass potentials mainly used for heat and electricity generation (forest residues, stemwood and wood waste make up around 1,436 TWh in the reference scenario described above), we conclude that the range of assumed increase in bio-mass use in the current policy scenario of this project is feasible.

Figure 33 compares estimated biomass demand of the *current policy scenario* with potential in the forestry sector. It can be seen that most countries are able to cover their demand domestically with just the potential provided by the forestry sector. Additional potential from agriculture and biogas are not shown here but could also contribute to biomass supply for heating, cooling and electricity needs. Countries which may not cover their demand domestically may do so by taking European biomass trade into account. From the comparison of potentials and model results we conclude that if biomass trade between member states increases, the assumed increases are feasible from the perspective of limited biomass potential. However, to achieve further renewable shares by 2050 and beyond, biomass potential is highly relevant and will be of limited supply in at least some countries.

Figure 33: A comparison of the domestic biomass demand in the *current policy scenario* with the respective potential in 2030



4.1.7 Investments and costs of heating and cooling supply

An overview of investments and costs related to heating and cooling are given in this section. In general each sector model distinguishes between fuel costs, operation and maintenance costs (O&M) as well as investments in heating and cooling generation and efficiency measures. In the following figures, and in the data sheets provided for downloads, annual supply costs and investments resulting in the scenarios are shown for the periods between 2012 and 2020 and from 2021 to 2030. Within the sector models (Invert/EE-Lab and FORECAST) all costs are implemented as end-user costs and include taxes and all additional charges. Non-discounted real costs are used in this report.

Investments include all additional investments undertaken within the sector models in the respective periods. We distinguish between investments in heating systems, cooling systems and efficiency measures. The investments for efficiency measures in the residential sector shown in this report include only additional costs for thermal retrofitting of existing buildings[22].

O&M costs for heating and cooling systems are interpreted as all related operating expenses excluding costs for fuel and electricity. They mainly include costs for the maintenance and repair of heating and cooling systems whereas, efficiency measures do not exhibit any O&M costs within the simulations. Maintenance of the building envelope is not included in the investments in efficiency measures.

Fuel costs are reported including all taxes and additional charges. From an end-user perspective, costs for electricity and variable costs of district heating are interpreted as fuel costs.

Table 16 illustrates the average annual investments as well as the supply costs for H/C of all sectors for the periods 2012 to 2020 and 2021 to 2030 resulting in the *Current policy scenario*. Annual average investments for the EU28 amount to 110 billion euro in the first period and 123 billion euro in the second period. That is an increase of annual investment by 12% which leads to a decrease in fuel expenditures by 9% despite higher energy prices in the period 2021 to 2030. However, the reduction in fuel costs in the scenario is not only caused by the installation of efficient and RES based heating systems and implementation of efficiency measures but also by the assumed development of climate conditions lowering the heating degree days. For a illustration of investments and costs of each sector, please refer to the annex of this report.

Table 16: Average annual cost for heating and cooling of all sectors [million euros / a]

	Investments		Fuel costs		O&M	
Country	**2012-2020**	**2021-2030**	**2012-2020**	**2021-2030**	**2012-2020**	**2021-2030**
Austria	3,793	4,758	5,671	5,401	342	334
Belgium	3,493	4,523	8,528	7,941	338	396
Bulgaria	983	980	2,193	2,136	158	171
Croatia	506	561	1,455	1,496	108	108
Cyprus	163	222	868	1,089	36	33
Czech Rep.	1,170	1,382	5,569	5,336	245	260
Denmark	1,627	2,018	5,448	5,047	205	217
Estonia	173	229	809	756	28	29
Finland	2,672	2,852	9,205	8,805	309	337
France	12,591	18,399	37,134	34,971	2,045	2,151
Germany	29,040	24,706	49,308	41,602	3,465	3,279
Greece	1,468	1,750	5,721	5,245	390	353
Hungary	1,169	1,477	2,576	2,304	166	189
Ireland	1,352	1,395	3,519	3,110	121	149
Italy	15,566	17,992	35,959	32,859	1,543	1,588
Latvia	321	483	1010	951	45	45

[22] Cost for maintenance of the existing building envelope and the construction of new buildings are not included. Note that this means that costs for increasing the thermal efficiency of new construction compared to a reference case with poorer thermal insulation is not reflected in the cost data.

	Investments		Fuel costs		O&M	
Country	**2012-2020**	**2021-2030**	**2012-2020**	**2021-2030**	**2012-2020**	**2021-2030**
Lithuania	313	330	1,339	1,103	45	45
Luxembourg	162	203	542	457	25	28
Malta	36	39	190	157	6	6
Netherlands	3,805	4,538	11,057	10,751	506	517
Poland	3,060	3,208	25,605	22,193	783	826
Portugal	1,744	2,106	3,250	3,419	201	223
Romania	1,316	1,740	3,408	3,565	476	460
Slovakia	874	1,007	2,314	2,062	92	103
Slovenia	200	208	1083	986	51	51
Spain	7,658	9,355	21,682	20,449	1,028	1,104
Sweden	4,665	4,989	12,820	12,766	386	379
UK	9,963	12,108	22,047	18,213	1,392	1,457
Switzerland	1,860	2,371	3,317	3,395	341	339
Norway	1,639	1,759	4,904	4,211	208	208
Island	253	224	3,341	2,758	15	16
EU28	109,883	123,558	280,310	255,170	14,535	14,838
EU28+3	113,635	127,912	291,872	265,534	15,099	15,401

4.1.8 Import of fossil fuels

In the *current policy scenario* also the shares of fuels imported to the EU28 changes over time. Import shares for each energy carrier are estimated based on Eurostat energy balances. They are calculated as imports minus exports divided by the total gross inland consumption. We assume that import shares of energy carriers used for H/C are equivalent to total import shares for each energy carrier.

Accordingly, 49.2% of total primary energy demand for H/C in the EU28 was supplied by imports in 2012. While relative import shares are highest for fuel oil (88%), absolute imports are highest for natural gas (2,162 TWh).

The future development of imports will among other factors depend on changes in domestic production. Domestic production, however, is determined by multiple factors including e.g. production costs relative to world markets, domestic and foreign resources and exploitation costs, global demand for fossil energy carriers but also political decisions in particular with respect to domestic coal, lignite and shale gas exploration and use. Modelling those developments was not part of this project and is subject to huge uncertainty.

Consequently, we estimate possible changes in future import shares based on simple but transparent assumptions with regard to domestic production. This allows illustrating the impact of changes in demand (e.g. substituting fossil fuels by RES). The following three cases are calculated for the *current policy scenario* based on different assumptions on domestic production.

- Case 1: The import shares remain constant for each energy carrier up until 2030.
- Case 2: Reductions of fossil fuels directly reduce fossil imports, while domestic production stays at 2012 levels.
- Case 3: Reductions of fossil fuels directly reduce domestic production.

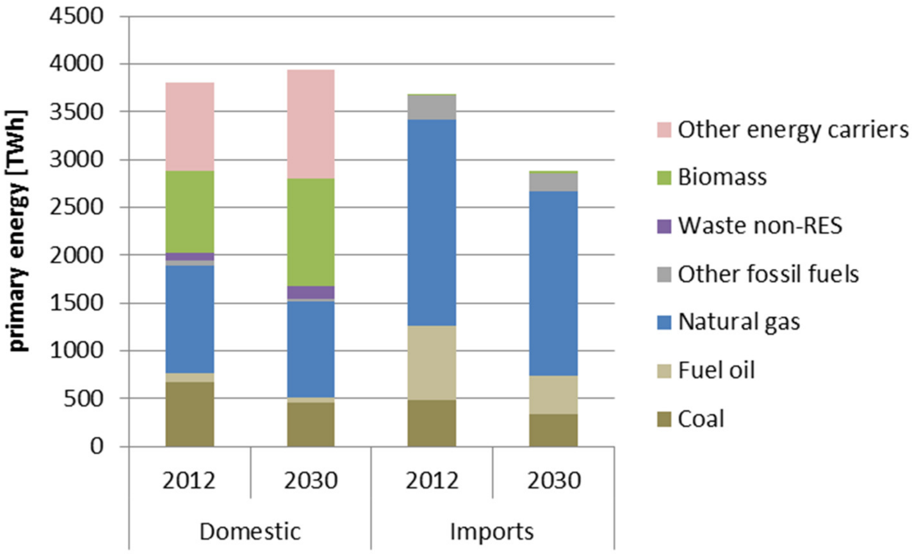
Results for **case 1** are illustrated in Table 17 and Figure 34. Assuming constant import shares imports in 2030 are reduced to 42.3% in the current policy scenario due to a switch of energy carriers towards more RES. Total imports are reduced by 21.7% (802 TWh) from 2012 to 2030 with fuel oil showing the strongest relative reduction (-46%) followed by coal (-31%), while natural gas imports for HC only decrease by 11%.

Principally, the increasing use of biomass can also result in higher biomass import shares (2.7% in 2012). While it was shown in section 4.1.6 that sufficient domestic biomass potentials are available to cover most of the increase in biomass use until 2030 the share of imported biomass could also increase significantly - depending on world markets, production and transportation cost.

Table 17: Domestic production, imports and import shares of primary energy carriers used for H/C in the EU28, *current policy scenario;* case 1: constant import shares by energy carrier

	Domestic		Imports		Import Share	
	2012	**2030**	**2012**	**2030**	**2012**	**2030**
Coal	666	459	482	332	42.0%	42.0%
Fuel oil	105	56	773	410	88.0%	88.0%
Natural gas	1124	1000	2162	1924	65.8%	65.8%
Other fossil fuels	44	33	248	189	85.0%	85.0%
Waste non-RES	82	127	1	2	1.2%	1.2%
Biomass	854	1130	24	31	2.7%	2.7%
Other energy carriers	929	1131	0	0	0.0%	0.0%
Total	3804	3935	3690	2888	49.2%	42.3%

Figure 34: Domestic production, imports and import shares of primary energy carriers in EU28, *current policy scenario;* case 1: constant import shares by energy carrier



The assumptions as in **case 2** would lead to reduction of import of 1190 TWh (-32.3%) and an import share of only 36.6%, which is significantly lower than when assuming constant import shares for each energy carrier as in case 1 (42.3%). This case can be regarded as the minimum import share to be achieved by energy-efficiency improvements and substitution to RES as assumed in the *current policy scenario.* While this assumption might be appropriate for solid fuels (in particular lignite) it does not seem to be realistic for energy carriers like natural gas or fuel oil where other regions in the world show lower production costs than European producers.

In **case 3** the total import share would hardly be affected and stay at around 49% until 2030. Total imports, however, would still be reduced by -8.8% compared to 2012. This scenario represents a maximum import share assuming that demand reductions will mainly affect the exploration of domestic fossil fuel resources.

Table 18: Import shares of primary energy used for H/C in the EU28 for varying assumptions on domestic production in 2030, *current policy scenario*

Domestic production assumption	Import share 2030
Case 1 – constant import shares	42.3%
Case 2 – demand changes affect imports	36.6%
Case 3 – demand changes affect domestic production	49.3%

Consequently, in the *current policy scenario*, the import share of primary energy for H/C can be ranging from 36.6% to 49.3% in 2030 depending on the domestic production[23]. Irrespective of this wide range of potential fossil fuel imports it is very likely

[23] - The overall import reduction will mainly depend on the global market price and European production

that with ambitious implementation of current policies in the H/C sector, EU28 import dependency will decrease substantially. This is driven by both energy efficiency improvements but also a shift towards (domestic) RES.

In monetary terms the amount of imports is subject to high uncertainty as well given the variable nature of international fossil fuel prices. While the effects of import reductions on the economy will be addressed in the WP4 report of this project a first estimate of monetary imports is given here. We assume two price scenarios to value fossil fuel imports and show the monetary value of imports in 2012 compared to 2030. The price scenarios illustrated in Table 19 correspond to average fossil fuel prices for hard coal, fuel oil and natural gas in the EU Reference Scenario 2016 for the years 2015 and 2030 reflecting expectations of significant fossil fuel price increases.

Table 19: Fuel price assumptions used for estimation of monetary imports of fossil fuels in Euro/MWh

Energy carrier	2015	2030
Hard coal	7.9	15.1
Fuel oil	33.0	68.9
Natural gas	26.6	41.7

Source: EU Reference Scenario 2016

Table 20 shows results for monetary imports of hard coal, fuel oil and natural gas for both price scenarios and 3 cases of import shares. Assuming constant prices of 2015 total import costs of fossil fuels are estimated to decrease from around 87 billion euros in 2012 to 67 billion in 2030 for case 1. (61 billion euros in case 2 and 77 billion euros in case 3). The majority of import costs stems from natural gas imports which account for 66% in 2012 and increases to more than 75% in 2030 in all 3 cases. Under the higher price assumptions for prices in 2030 monetary fossil fuel imports are around 70% higher than at constant price assumptions. Despite the significant reduction of fossil fuel energy consumption in the H/C sector of Europe in the *current policy scenario* total monetary imports of fossil fuels would increase because the increase in energy prices exceeds expected energy savings.

Table 20: Monetary fossil fuel imports in 2012 and 2030 valued at international fossil fuel prices

	Monetary Imports – valued at fuel prices 2015 [Billion Euros]			
	2012	**2030 - case1**	**2030 - case2**	**2030 - case3**
Coal	4	3	1	4
Fuel oil	25	14	12	15
Natural gas	57	51	48	57
Total	86	67	61	77

costs. For high prices above marginal production costs in Europe the assumption that reductions in demand for fossil fuels mainly affect imports (case 2) is more justified than in a scenario with low fossil fuel prices in which also domestic producers would be affected by reductions in domestic demand (case 3).

Monetary Imports – valued at fuel prices 2015 [Billion Euros]				
	2012	2030 - case1	2030 - case2	2030 - case3
Monetary Imports - valued at fuel prices 2030 [billion Euros]				
	2012	**2030 - case1**	**2030 - case2**	**2030 - case3**
Coal	7	5	2	7
Fuel oil	53	28	25	32
Natural gas	90	80	75	90
Total	150	113	102	129

Projections of fossil fuel prices in 2030 based on the EU Reference Scenario 2016

4.2 Sector specific energy demand results

This section presents the results for the individual sectors (industry, tertiary, residential) and the transformation sectors (electricity and district heating).

4.2.1 Industry sector

4.2.1.1 Overview

Given the framework conditions and policy assumptions outlined in the preceding chapter, and the technology assumptions shown in WP2, industrial energy demand for H/C develops as follows in the *current policy scenario*.

Total final energy demand (FED) increases by 5% from 2012 to 2030, while the majority of the increase takes place by 2020 as shown in Figure 35 and Table 21. At the same time, the individual H/C end-uses develop very differently up to 2020 and 2030. Space heating decreases by 15% from 2012 to 2030 while all other end-uses increase: process heating by 8%, process cooling by 6% and space cooling by 2%. These changes are driven by changes in macro-economic development, i.e. drivers such as production output and investment in new technologies.

Figure 35: Current policy scenario final energy demand for H/C in industry by end-use in the EU28 [TWh]

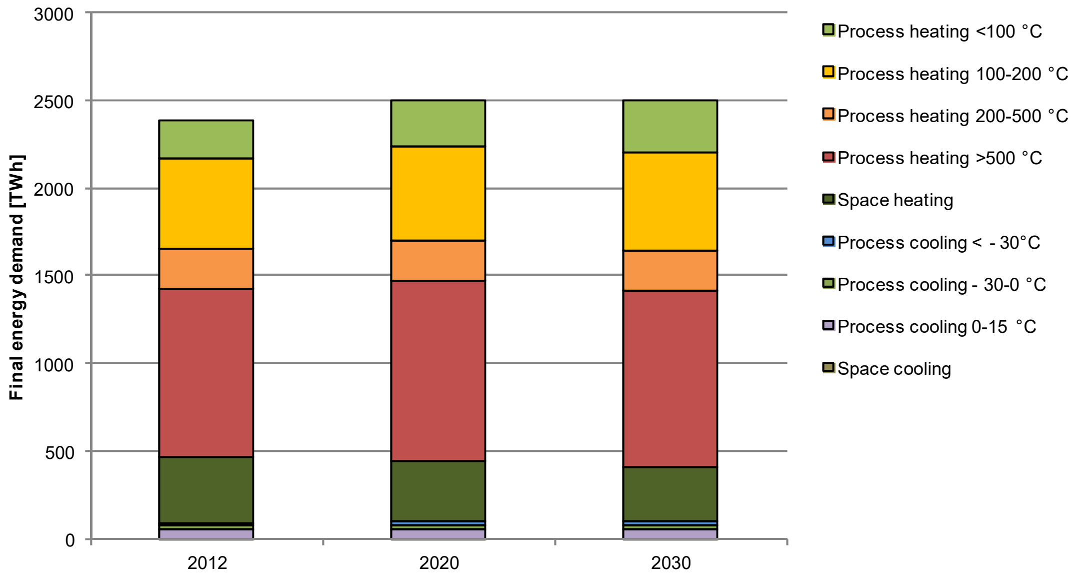


Table 21: Current policy scenario final energy demand for H/C in industry by end-use in the EU28 [TWh]

	2012	2020	2030	Change 2030/2012
Space cooling	16	16	16	2%
Process cooling 0-15 °C	44	46	48	9%
Process cooling - 30-0 °C	19	19	20	7%
Process cooling < - 30°C	20	20	19	-3%
Space heating	370	348	315	-15%
Process heating >500 °C	961	1026	995	4%
Process heating 200-500 °C	224	230	229	2%
Process heating 100-200 °C	524	534	561	7%
Process heating <100 °C	213	260	299	41%
Total	2390	2498	2503	5%
Total process heating	1922	2049	2084	8%
Total process cooling	83	85	87	6%

The structure of individual energy carriers in total FED also changes substantially as shown in Figure 36 and Table 22. While the use of natural gas, waste, biomass, district heating, electricity, ambient heat and solar energy increase up until 2030, others like coal and fuel oil substantially decrease. Across all energy carriers, the use of RES increases by about 41%, while the use of fossil fuels remains more or less constant (-1%).

Figure 36: Current policy scenario final energy demand for H/C in industry by energy carrier in the EU28 [TWh]

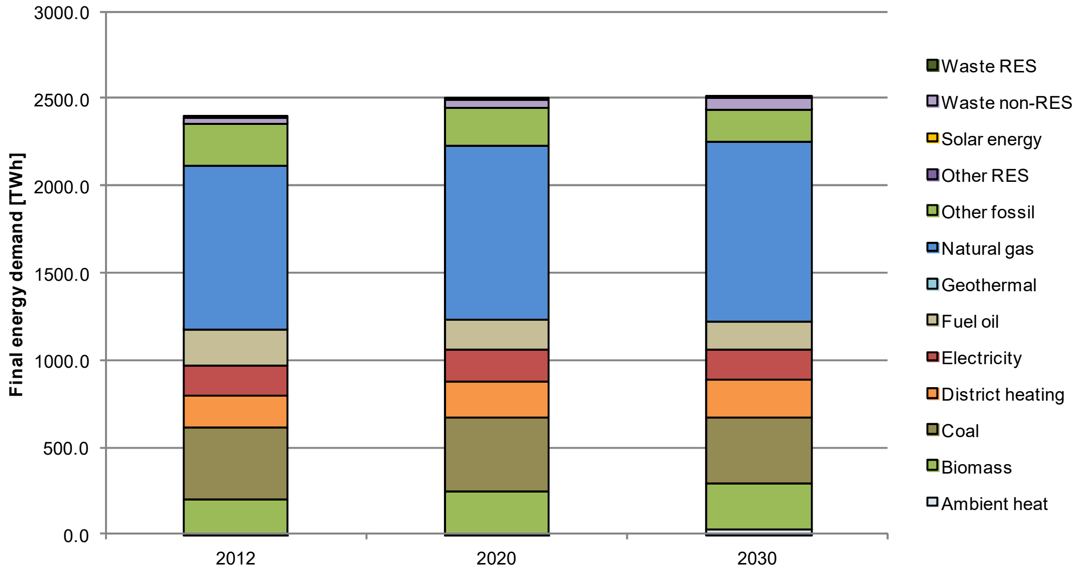


Table 22: Current policy scenario final energy demand for H/C in industry by end-use in the EU28 [TWh]

	2012	2020	2030	Change 2030/2012
Ambient heat	0.4	16.3	31.4	8297%
Biomass	211.7	241.9	264.8	25%
Coal	405.0	419.3	377.0	-7%
District heating	188.1	208.4	215.9	15%
Electricity	170.8	178.1	180.6	6%
Fuel oil	201.8	177.1	156.0	-23%
Geothermal	0.0	0.0	0.0	-81%
Natural gas	935.6	990.2	1024.2	9%
Other fossil	237.0	211.2	185.2	-22%
Other RES	0.0	0.0	0.0	0%
Solar energy	0.0	1.5	2.8	9326%
Waste non-RES	37.2	50.5	61.3	65%
Waste RES	2.5	3.3	3.4	37%
Total	2390.1	2497.8	2502.6	5%
Total RES	214.6	263.0	302.4	41%
Total fossil fuels	1816.6	1848.3	1803.7	-1%
Total secondary energy	358.9	386.5	396.5	10%

The apportionment of the share of energy carriers by country is illustrated in Figure 37 and Figure 38. It can be observed that the share of RES (e.g. mostly biomass and ambient heat) increases in most countries.

Figure 37: Current policy scenario final energy demand for H/C in industry by energy carrier and by country: part I Austria - Latvia [TWh]

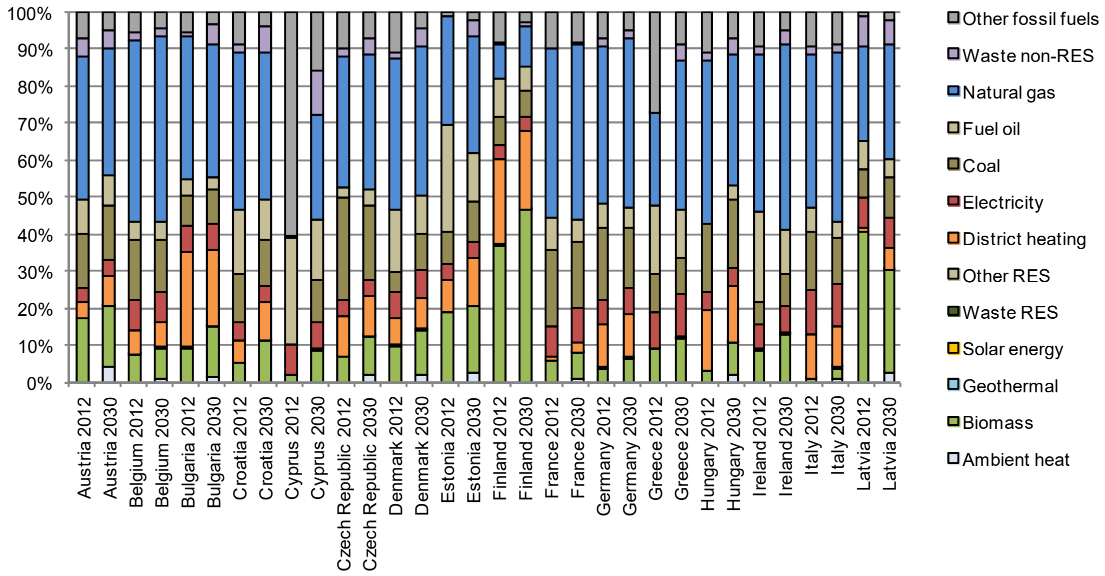
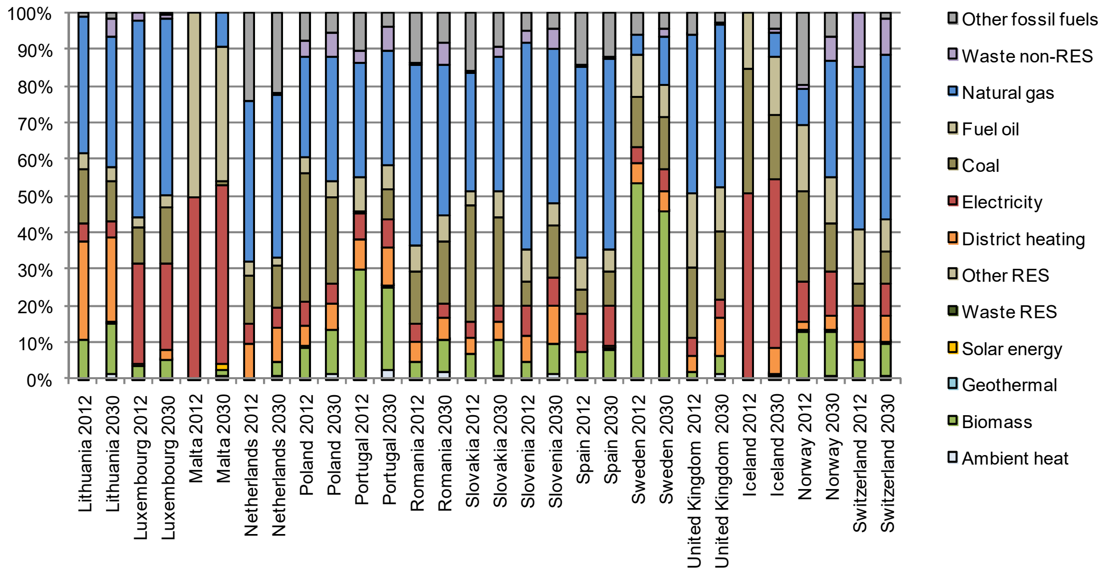


Figure 38: *Current policy scenario* final energy demand for H/C in industry by energy carrier and by country: part II Lithuania - Switzerland [TWh]



Disaggregating FED for H/C by sub-sector reveals structural shifts (see Figure 39 and Table 23). While FED in the iron and steel industry is falling from 2012 to 2030 by about 11%, it is substantially increasing in the petrochemical and the non-metallic minerals sectors, by 9% each.

Figure 39: Current policy scenario final energy demand for H/C in industry by sub-sector in the EU28 [TWh]

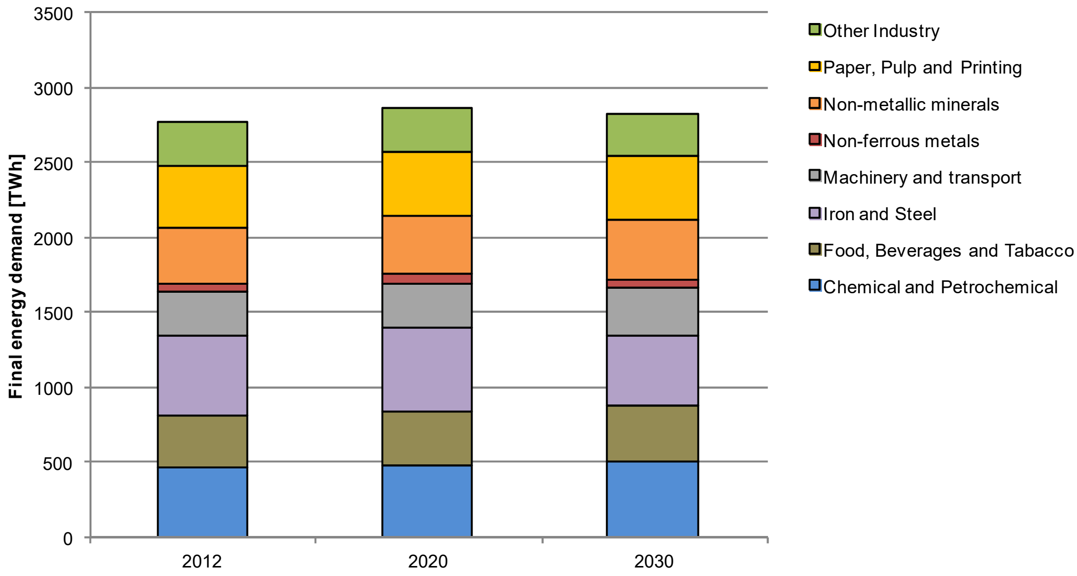


Table 23: Current policy scenario final energy demand for H/C in industry by end-use in the EU28 [TWh]

	2012	2020	2030	Change 2030/2012
Chemical and petrochemical	463	482	505	9%
Food, beverages and tobacco	354	364	372	5%
Iron and steel	535	551	476	-11%
Machinery and transport	288	301	310	7%
Non-ferrous metals	57	60	57	0%
Non-metallic minerals	368	394	402	9%
Paper, pulp and printing	295	288	286	-3%
Other industry	416	422	426	3%
Total industry	2390	2498	2503	5%

While FED for H/C grows slowly within the EU28, on average reaching 5% growth from 2012 to 2030, the development is more dynamic in individual countries (see Table 22). Total growth ranges from +38% (Romania) to -9% (Malta). Driven by higher economic growth assumptions, most of the eastern European countries exhibit more growth than the EU average (e.g. Estonia 20%, Hungary 19%, Latvia 27%, Poland 29% and Slovenia 23%). Conversely, growth in many of the large Western European countries ranges between -6% (Germany) and +5% (United Kingdom).

Table 24 shows the FED for H/C by country and end-use in 2030 compared to 2012. Substantial differences can be observed between countries and end-uses. For example, FED for space heating falls for all countries except Slovakia, driven by more ambitious building standards in combination with quite stable building stock levels (or a slight increase). In most countries demand falls by about 15% between 2012 to 2030.

Table 24: *Current policy scenario* final energy demand for H/C in industry in 2030 by end-use and by country [TWh]

	2030 Final energy demand [TWh]				Change 2030/2012			
	Space heating	Process heating	Space cooling	Process cooling	Space heating	Process heating	Space cooling	Process cooling
Austria	13.0	72.5	0.22	1.93	-17%	11%	2%	9%
Belgium	9.6	80.8	0.11	4.82	-17%	9%	0%	8%
Bulgaria	4.5	21.8	0.19	0.82	-13%	22%	11%	0%
Croatia	2.4	9.7	0.11	0.32	-3%	17%	18%	-1%
Cyprus	0.1	1.4	0.01	0.08	-13%	9%	0%	-2%
Czech Republic	11.0	64.3	0.26	2.09	-16%	19%	0%	0%
Denmark	2.3	19.6	0.01	1.37	-19%	25%	0%	16%
Estonia	0.8	4.6	0.01	0.17	-15%	31%	10%	13%
Finland	21.7	77.5	0.22	2.01	-10%	9%	4%	5%
France	29.7	173.1	1.69	11.15	-17%	0%	2%	14%
Germany	54.3	420.1	0.84	18.31	-16%	-4%	3%	0%
Greece	4.2	18.4	0.69	0.85	-12%	-6%	2%	13%
Hungary	3.3	22.2	0.07	0.82	-15%	27%	1%	4%
Ireland	3.0	16.0	0.02	1.14	-18%	19%	0%	22%
Italy	33.8	208.6	4.83	11.02	-14%	6%	2%	5%
Latvia	1.2	9.3	0.01	0.12	-17%	36%	0%	4%
Lithuania	1.4	8.3	0.02	0.29	-16%	14%	0%	-8%
Luxembourg	0.9	5.0	0.05	0.13	-7%	-2%	24%	38%
Malta	0.1	0.0	0.01	0.01	-9%	-25%	10%	509%
Netherlands	14.1	122.8	0.13	6.07	-18%	10%	1%	5%
Poland	7.0	159.4	0.08	5.32	-15%	33%	4%	9%
Portugal	5.8	38.6	0.51	1.07	-15%	10%	1%	4%
Romania	10.1	73.8	0.14	1.38	-15%	53%	6%	3%
Slovakia	13.0	35.0	0.42	0.75	3%	9%	1%	-2%
Slovenia	1.1	9.5	0.05	0.21	-17%	31%	0%	16%
Spain	24.2	167.3	4.66	6.33	-16%	11%	0%	-1%
Sweden	7.8	77.5	0.06	1.81	-20%	1%	6%	27%
United Kingdom	34.9	166.9	0.38	7.01	-15%	11%	2%	10%
Iceland	1.2	1.8	0.05	0.31	-2%	7%	25%	8%
Norway	3.5	24.7	0.02	1.70	-14%	7%	30%	10%
Switzerland	2.6	21.5	0.03	1.07	-17%	10%	4%	11%
EU28	315	2084	16	87	-15%	8%	2%	6%
EU28+NO+CH+IS	323	2132	16	90	-15%	8%	2%	6%

Other end-uses are more diverse across the countries. For instance, there is also a substantial growth in the EU28 average for process heating (+8%), whereas individual countries show decreases in FED (e.g. Greece and Germany with 6 and 4%, respectively).

4.2.1.2 Process heating

Process heating in industry is very diverse and serves a number of different purposes. Table 25 summarises the FED for process heating analysed by temperature level. Low temperature heat demand (< 100°C) is mostly used in the food industry, but also in the chemical industry. Steam demand (100-500°C) is required by subsectors such as the pulp and paper and chemical industries and high temperature heat demand is used in individual furnaces across different sub-sectors such as the iron and steel industry and cement or glass production.

Changes in FED for process heating are driven by production output (and structural changes) as well as energy efficiency improvement. Low-temperature heat demand increases substantially from 2012 to 2030 in the EU28 (+41%), while there is only a small increase (2-4%) in process heating above 200°C.

Table 25: Current policy scenario final energy demand for process heating in industry in 2030 by temperature level and by country [TWh]

	Final energy demand in 2030				Change 2030/2012			
	<100 °C	100-200 °C	200- 500 °C	>500 °C	<100 °C	100-200 °C	200-500 °C	>500 °C
Austria	10.9	22.9	7.8	30.9	265%	5%	-3%	-5%
Belgium	11.2	18.9	9.8	40.9	43%	19%	3%	0%
Bulgaria	5.7	5.5	2.2	8.5	7%	45%	25%	22%
Croatia	1.7	2.7	1.1	4.2	48%	3%	4%	22%
Cyprus	0.0	0.1	0.1	1.1	-38%	-15%	-21%	21%
Czech Rep.	10.6	15.4	8.1	30.2	63%	29%	14%	7%
Denmark	5.6	6.9	2.4	4.8	63%	15%	19%	11%
Estonia	0.9	1.9	0.6	1.1	146%	15%	14%	24%
Finland	10.0	48.5	6.5	12.6	9%	14%	16%	-9%
France	21.6	40.9	20.7	89.8	86%	-7%	-7%	-5%
Germany	68.4	94.6	42.8	214.4	10%	4%	-10%	-10%
Greece	1.6	4.8	2.0	10.0	-24%	-13%	-11%	3%
Hungary	5.6	3.4	2.3	10.9	34%	30%	18%	25%
Ireland	2.3	5.6	2.1	6.1	77%	14%	14%	13%
Italy	33.4	40.9	25.3	108.9	14%	31%	2%	-3%
Latvia	1.4	3.4	1.4	3.1	177%	12%	19%	48%
Lithuania	2.9	2.1	0.7	2.5	6%	23%	30%	14%
Luxembourg	0.2	0.6	0.9	3.3	144%	24%	-12%	-7%
Malta	0.0	0.0	-	0.0	-53%	-43%	0%	-25%
Netherlands	21.5	26.6	10.6	64.0	29%	26%	3%	0%
Poland	29.3	35.8	17.2	77.0	76%	20%	24%	30%
Portugal	5.9	14.5	3.1	15.1	69%	-7%	4%	16%

	Final energy demand in 2030				Change 2030/2012			
	<100 °C	100-200 °C	200- 500 °C	>500 °C	<100 °C	100-200 °C	200-500 °C	>500 °C
Romania	8.3	11.7	6.9	46.9	132%	52%	45%	45%
Slovakia	1.9	5.2	2.3	25.7	31%	37%	-11%	5%
Slovenia	1.4	2.8	0.8	4.5	118%	16%	14%	28%
Spain	5.8	46.2	19.0	96.3	59%	-4%	3%	20%
Sweden	4.7	45.3	9.7	17.9	1%	-9%	19%	25%
UK	26.6	54.0	22.4	64.0	126%	-1%	-4%	5%
Iceland	0.0	0.0	0.0	1.8	-28%	-28%	-21%	9%
Norway	1.3	5.7	1.4	16.3	142%	2%	-5%	5%
Switzerland	3.5	5.7	2.2	10.2	45%	3%	-1%	8%
EU28	299.4	561.2	228.7	994.9	41%	7%	2%	4%
EU28+NO+CH+IS	304.2	572.6	232.3	1,023.1	41%	7%	2%	4%

4.2.1.3 Process and space cooling

Industrial process cooling is split into three temperature levels (see Table 26). These are low temperature processes, mainly in the chemical industry (e.g. air separation for oxygen production), and refrigeration and cooling (above 0°C) which are primarily used in the food industry. The development of process cooling mainly reflects the economic and production output of the different subsectors and products.

Table 26: *Current policy scenario* final energy demand for cooling in industry in 2030 by temperature level and by country [TWh]

	2030				Change 2030/2012			
	Space cooling	Process cooling < - 30°C	Process cooling - 30-0 °C	Process cooling 0-15 °C	Space cooling	Process cooling < - 30°C	Process cooling - 30-0 °C	Process cooling 0-15 °C
Austria	0.22	0.67	0.43	0.83	2%	-3%	13%	17%
Belgium	0.11	1.56	1.05	2.21	0%	-4%	12%	17%
Bulgaria	0.19	0.26	0.17	0.39	11%	-5%	2%	3%
Croatia	0.11	0.02	0.08	0.22	18%	-2%	-2%	0%
Cyprus	0.01	0.00	0.02	0.06	0%	29%	-1%	-2%
Czech Republic	0.26	0.92	0.36	0.81	0%	-5%	0%	8%
Denmark	0.01	0.03	0.38	0.95	0%	38%	16%	15%
Estonia	0.01	0.01	0.05	0.12	10%	5%	10%	15%
Finland	0.22	0.72	0.35	0.94	4%	-4%	5%	14%
France	1.69	0.70	3.07	7.38	2%	3%	12%	15%
Germany	0.84	5.14	3.98	9.18	3%	-3%	2%	1%
Greece	0.69	0.06	0.24	0.55	2%	-4%	14%	15%
Hungary	0.07	0.15	0.20	0.47	1%	0%	4%	6%
Ireland	0.02	0.04	0.33	0.78	0%	33%	20%	22%

	2030				Change 2030/2012			
	Space cooling	Process cooling < - 30°C	Process cooling - 30-0 °C	Process cooling 0-15 °C	Space cooling	Process cooling < - 30°C	Process cooling - 30-0 °C	Process cooling 0-15 °C
Italy	4.83	3.08	2.12	5.83	2%	-5%	6%	10%
Latvia	0.01	0.00	0.03	0.09	0%	77%	0%	4%
Lithuania	0.02	0.02	0.09	0.19	0%	8%	-7%	-10%
Luxembourg	0.05	0.01	0.04	0.08	24%	49%	45%	34%
Malta	0.01	-	0.00	0.01	10%	0%	279%	533%
Netherlands	0.13	2.19	1.27	2.60	1%	-4%	10%	10%
Poland	0.08	1.37	1.21	2.74	4%	-1%	12%	14%
Portugal	0.51	0.13	0.28	0.66	1%	1%	3%	4%
Romania	0.14	0.35	0.31	0.72	6%	-3%	3%	5%
Slovakia	0.42	0.40	0.12	0.23	1%	-6%	-1%	6%
Slovenia	0.05	0.01	0.06	0.14	0%	21%	13%	16%
Spain	4.66	1.08	1.44	3.82	0%	-6%	-2%	0%
Sweden	0.06	0.10	0.47	1.25	6%	31%	22%	28%
United Kingdom	0.38	0.36	1.88	4.77	2%	19%	9%	9%
Iceland	0.05	-	0.02	0.29	25%	0%	23%	7%
Norway	0.02	0.20	0.55	0.96	30%	21%	11%	7%
Switzerland	0.03	0.08	0.30	0.68	4%	19%	11%	10%
EU28	15.80	19.39	20.01	47.99	2%	-3%	7%	9%
EU28+NO+CH+IS	15.89	19.67	20.88	49.92	2%	-2%	7%	9%

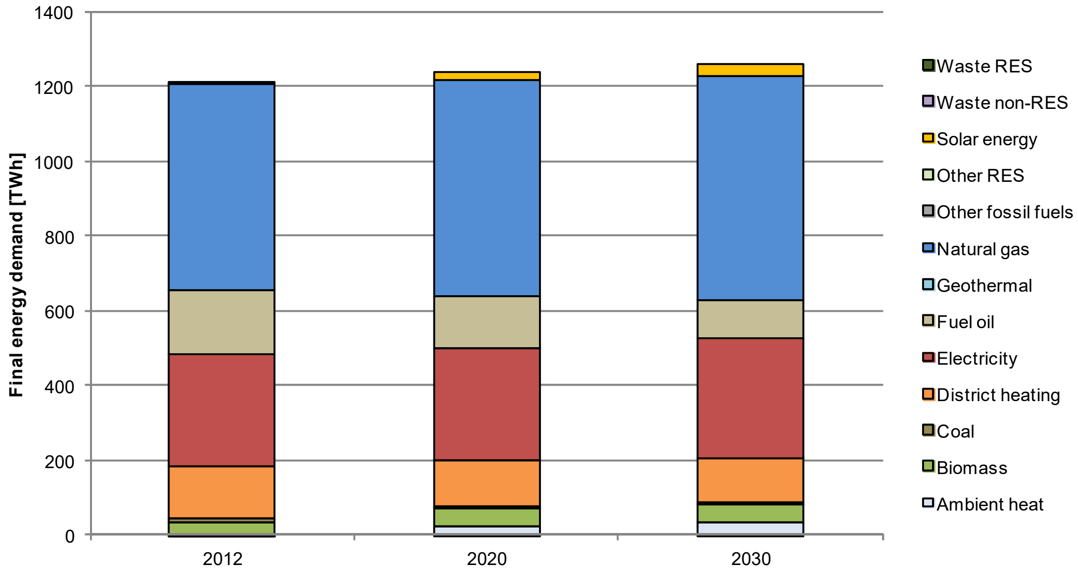
4.2.2 Tertiary sector

Overview

In the tertiary sector, the final energy demand for H/C develops in line with the given framework conditions and policy assumptions outlined in the preceding chapter, and the technology assumptions described in WP2. Total final energy demand (FED) increases by 4% from 2012 to 2030 in the *current policy scenario* (see Figure 40).

Natural gas remains the major fossil energy carrier providing final energy demand (between 500 TWh in 2012 and 598TWh in 2030, see Table 27) in the tertiary sector throughout the years. The contribution of RES, however, increases by approx. 80 TWh in total. This means that the proportion of renewable energy increases from approx. 3% in 2012 to 9% in 2030.

Figure 40: Current policy scenario final energy demand for H/C in the tertiary sector by energy carrier in the EU28 [TWh]



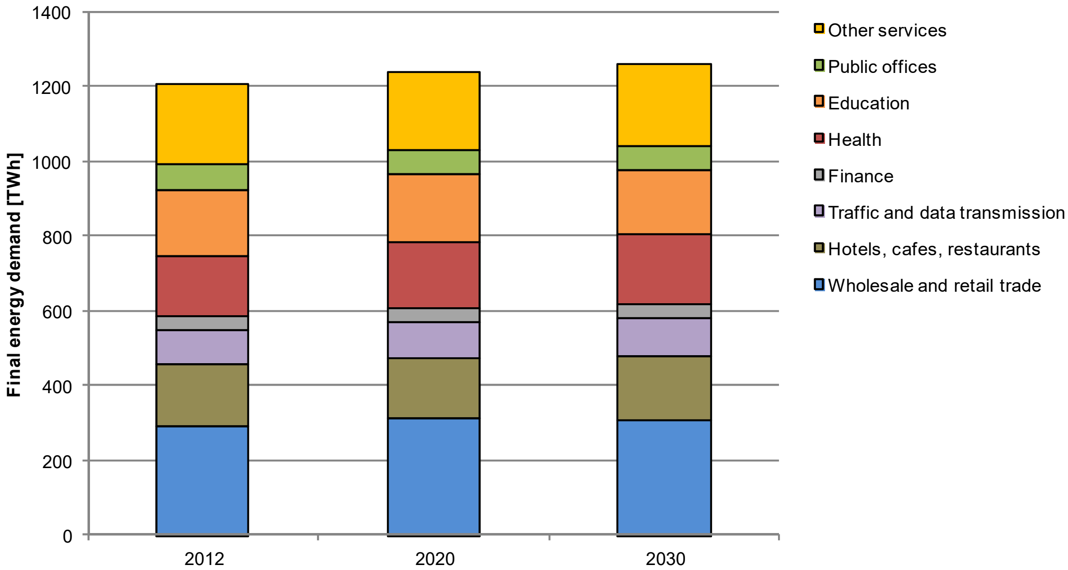
The growth of renewable energy compensates for the reduced energy demand from other fossil energy carriers such as fuel oil and coal, which are down from 15% in 2012 to 8% in 2030. The overall demand increase is mainly covered by additional natural gas consumption. Electricity demand increases during the years is closely related to the growing demand for ambient heat (based on the use of heat pumps) whereas the contribution of district heating declines.

Table 27: Current policy scenario, final energy demand for H/C in the tertiary sector by energy carrier in the EU28 [TWh]

	2012	2020	2030	Change 2030/2012
Ambient heat	8	28	36	352%
Biomass	30	48	52	70%
Coal	13	7	3	-79%
District heating	135	123	119	-12%
Electricity	301	299	317	5%
Fuel oil	168	138	101	-40%
Natural gas	550	576	598	9%
Other RES	0	0	0	0%
Solar energy	2	22	33	1227%
Total	1208	1240	1258	4%
Total RES	41	98	120	195%
Total fossil fuels	731	721	702	-4%
Total secondary energy	436	421	436	0%

In terms of sub-sectors, no relevant structural shift is expected, although some demand increase for H/C is expected from the health and the ICT (traffic and data transmission) sectors (see Figure 41 and Table 28).

Figure 41: *Current policy scenario*, final energy demand for H/C in the tertiary sector by sub-sector [TWh]



Other sectors, such as wholesale and retail trade and the financial sector, also show slight energy demand increases up to 2030 while energy consumption in sectors such as education, and the public office sector in particular, declines (-11% by 2030 compared to 2012). These changes are mainly based on the changing demand for specific floor area, combined with some cost effective energy efficiency improvements available in the current policy scenario.

Table 28: Current policy scenario, final energy demand for H/C by tertiary sub-sector [TWh]

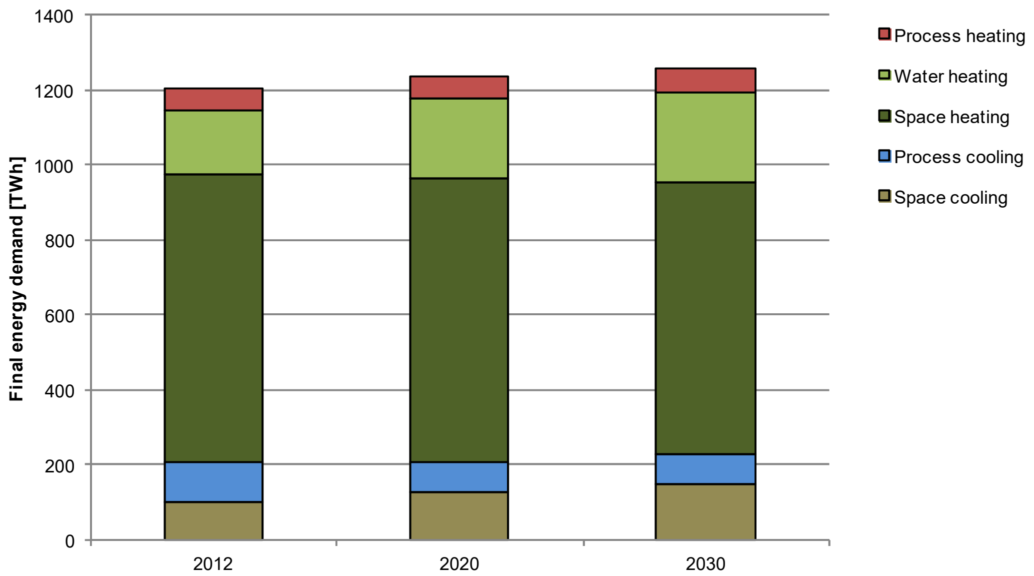
	2012	2020	2030	Change 2030/2012
Wholesale and retail trade	292	313	310	6%
Hotels, cafes, restaurants	170	163	169	0%
Traffic and data transmission (ICT)	91	97	103	13%
Finance	36	37	38	6%
Health	161	174	182	13%
Education	176	179	174	-1%
Public offices	69	66	61	-11%
Other services	214	211	220	3%
TOTAL Services	1208	1240	1258	4%

4.2.2.1 Heating and cooling

The final energy demand by end-use is show in Figure 42 for the scenario period. The main end-use demand in the tertiary sector is space heating, with a share of 63% in 2012 and 57% in 2030. Water and process heating make up approximately 19%

(2012) and 24% (2030) respectively.

Figure 42: Current policy scenario, final energy demand for H/C in tertiary sector by end-use in the EU28



The increasing demand for hot water is mainly driven by the growing floor area as only minor efficiency improvements are expected for this end-use. Additionally, the demand growth of water heating is similar in all sectors and countries and therefore not linked to any specific measures or specific structural shifts of the tertiary sector.

Table 29: Current policy scenario, final energy demand for H/C by end-uses [TWh]

	2012	2020	2030	Change 2030/2012
Space cooling	101	128	149	47%
Process cooling	110	82	81	-27%
Space heating	765	758	725	-5%
Water heating	169	209	241	43%
Process heating	63	63	63	0%

Figure 43 and Figure 44 provide the country specific distribution of energy carriers used for the different end-uses. In some countries, such as the United Kingdom (UK), the Netherlands (NL) or Belgium (BE), natural gas covers more than 50% of heating demand (Figure 43 and Figure 44) both now and in 2030. However elsewhere, especially in the Nordic countries such as Denmark (DK), Finland (FI) and Sweden (SE), there is more reliance on secondary heat sources such as district heating and electricity in combination with ambient heat.

Figure 43: Current policy scenario, final energy demand from heating end-uses in the tertiary sector by energy carrier and by country part I Austria to Ireland [TWh]

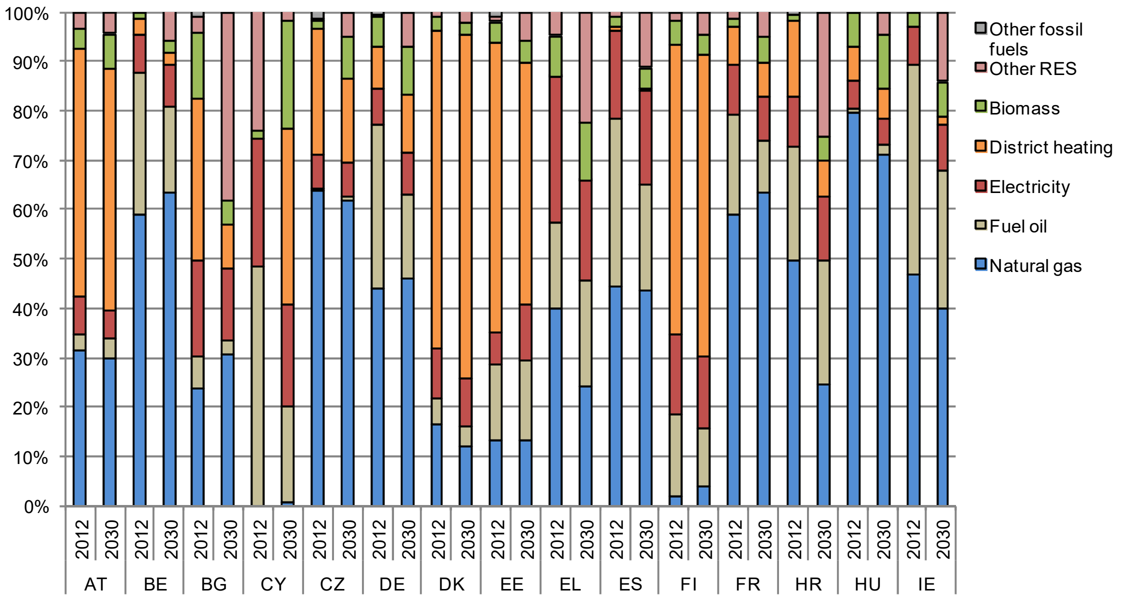


Figure 44: Current policy scenario, final energy demand from heating end-uses in the tertiary sector by energy carrier and by country part II Italy to the UK [TWh]

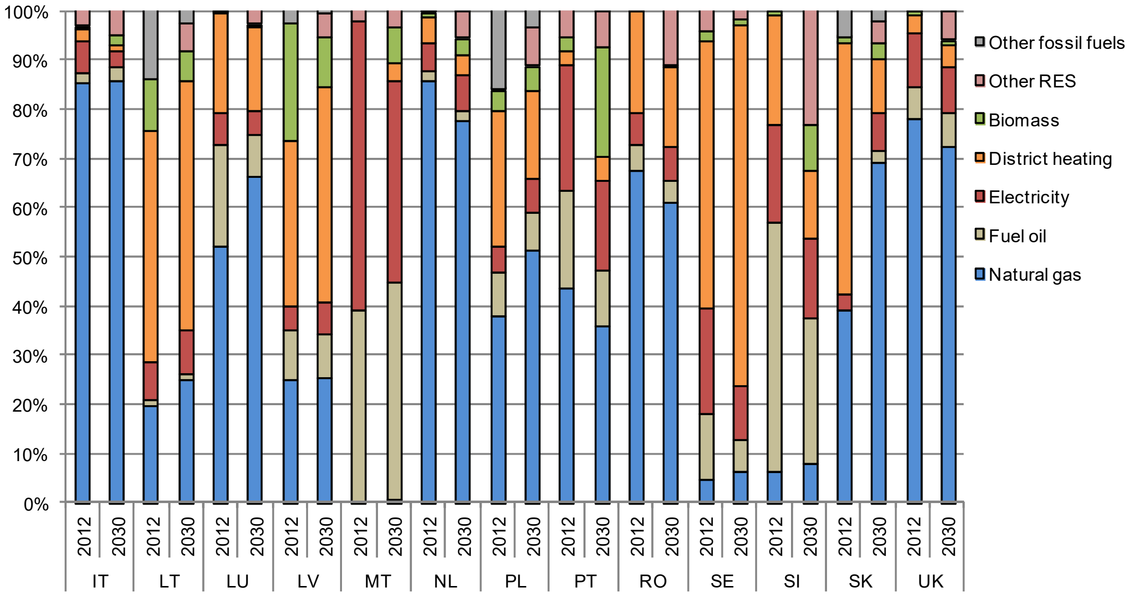


Figure 43 and Figure 44 provide the relative distribution of energy carriers, while the absolute figures by country are shown in the annex. It is noteworthy that fuel oil is not only replaced by natural gas but also by renewable energy carriers, such as ambient heat (e.g. Belgium), biomass (e.g. Germany) or solar energy (e.g. Greece in combination with natural gas).

4.2.3 Residential sector

The following tables and figures represent an extract of the detailed results of the data analysis which is provided in the additional datasets. The proportions of heating and cooling end-uses, together with the applied energy sources, are shown as cumulative final and useful energy demand for space heating, water heating and space cooling for the residential sector. A comparison of all countries within the scope of this study is also provided.

4.2.3.1 Overview

Figure 45 and

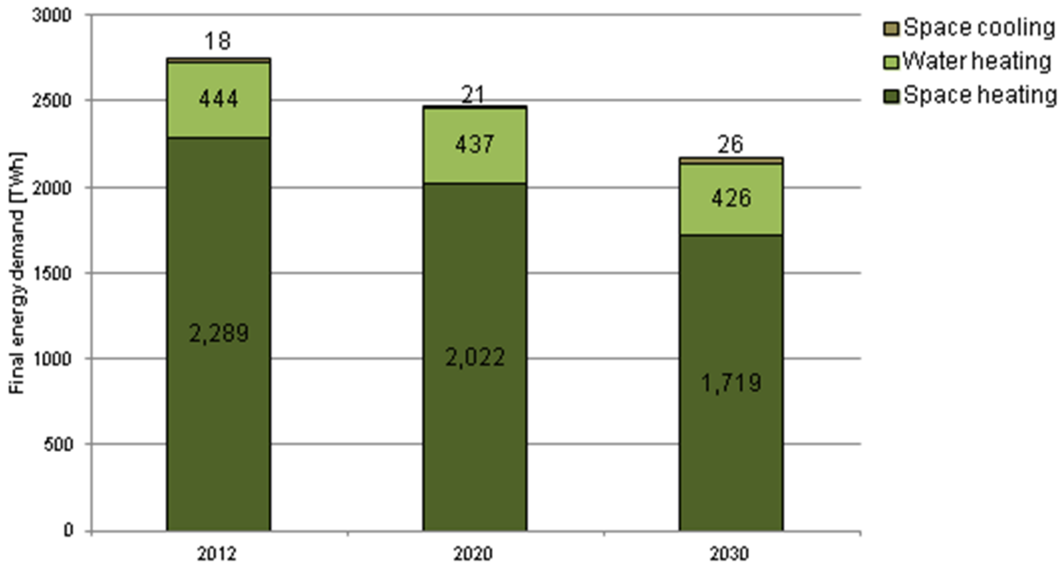


Table 30 show the total final energy demand in the EU28, Norway, Switzerland and Iceland for heating and cooling end-uses in the residential sector. Up to 2030 there is a decrease of 21% in the total final energy demand for the end-use sectors considered. Space heating remains the dominant end-use of the residential sector, although the proportion of space heating in total final energy demand slightly decreases. The share of space cooling increases from 0.63% to 1.15% and as such becomes a more relevant end-use category, especially for southern European countries. The relative growth of cooling far exceeds expected developments of energy demand in other sectors and end-uses. However, in the residential sector, space cooling in the aggregate of EU28 countries remains almost negligible compared to the overall energy demand, even though it might lead to considerable peak loads. This, however, was not part of this study.

Table 31 shows the total useful energy demand for heating and cooling end-uses in the residential sector. The development of the total useful energy demand follows the same trends as the total final energy demand. Up until 2030, total useful energy demand decreases by 21%. The shares of space heating and cooling in the total useful energy demand are higher than the corresponding shares within the final energy demand. This indicates that there are higher efficiency losses in the supply of domestic hot water.

Figure 45: Total final energy demand for space heating, water heating and space cooling end-uses for 2012, 2020 and 2030

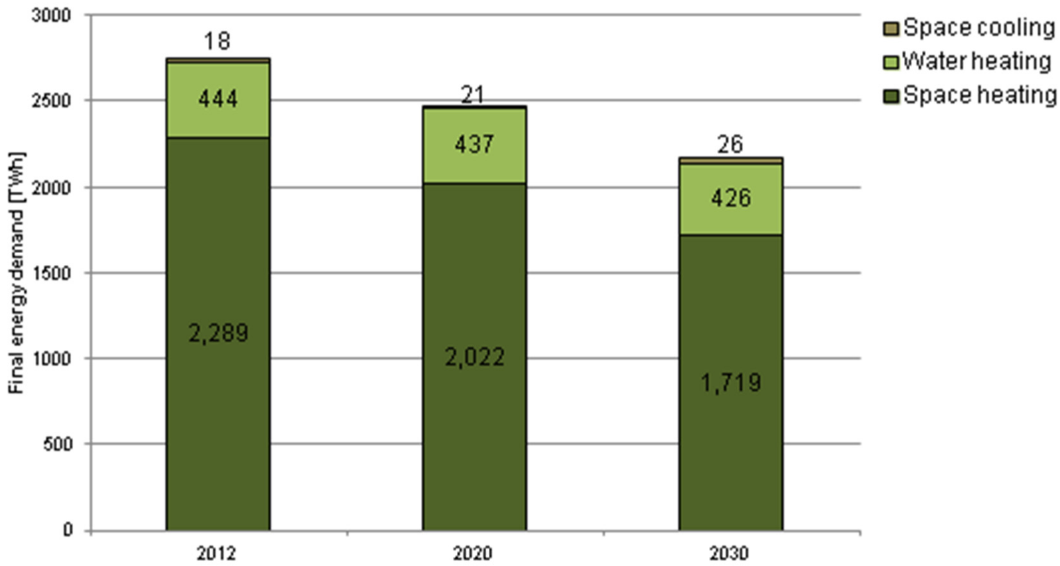


Table 30: Total final energy demand for space heating, water heating and space cooling in residential buildings in 2012, 2020 and 2030 [TWh]

	2012	2020	2030	Change 2030/2012
Space cooling	18	21	26	45%
Space heating	2289	2022	1719	-25%
Water heating	444	437	426	-4%
Total	2751	2480	2170	-21%

Table 31: Total useful energy demand by end-use in residential buildings for 2012, 2020 and 2030, EU28+CH, IS, NO, current policy scenario [TWh]

	2012	2020	2030	Change 2030/2012
Space cooling	49	61	82	68%
Space heating	1859	1647	1400	-25%
Water heating	212	224	208	-2%
Total	2120	1932	1690	-20%

Figure 46 and Figure 47 compare the shares of end-uses of the total heating and cooling demand in all countries within the scope of the study. The black line represents the absolute level of the total final energy demand by country. Space heating still represents the greatest end-use in almost all countries. In Cyprus and Malta however, in comparison to the other countries, there is a significant proportion of space cooling. Water heating and space cooling demand account for about half of the total final energy demand for these two countries. The average share of the total heating and cooling demand, taken by the final energy demand for water heating, slightly increases from 17% in 2012 to 19% in 2030.

Figure 46: Share of end-uses in FED in the residential sector by country for 2012 and 2030, current policy scenario, Austria-Ireland

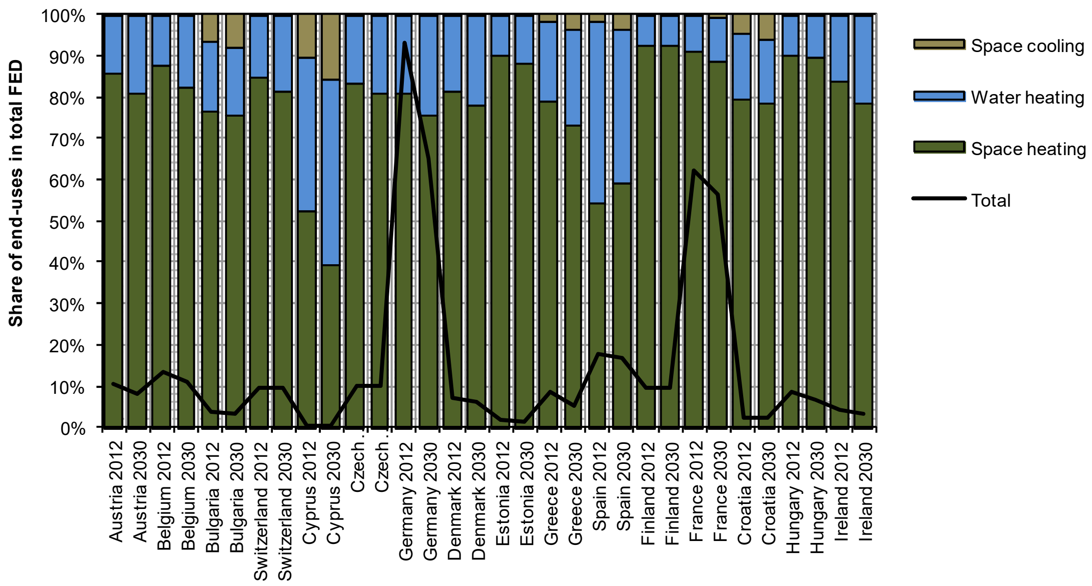


Figure 47: Share of end-uses in FED in the residential sector by country for 2012 and 2030, current policy scenario, Iceland-United Kingdom

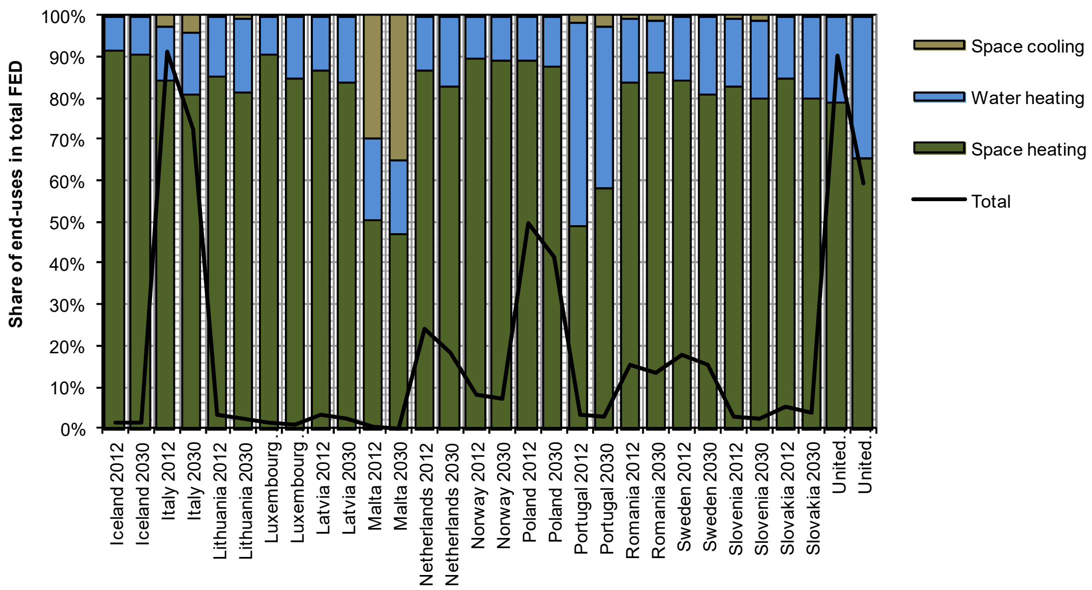


Figure 48 and Table 32 present the 2012-2030 development of the total final energy demand for space heating, hot water and cooling in residential buildings of the EU28 by energy carrier. Natural gas remains the energy carrier with the highest share. However, together with its decreasing absolute demand, there is a decrease in the proportion of fossil fuels, such as natural gas, fuel oil and coal, included in the total final energy demand from 61% to 51% in this scenario. The increase in the use of

RES-H/C technologies is dominated by biomass, even though relative growth rates are much lower than those of solar and ambient heat.

Figure 48: Final energy demand for heating and cooling in the residential sector, EU28 in 2012, 2020 and 2030 by energy carrier, current policy scenario

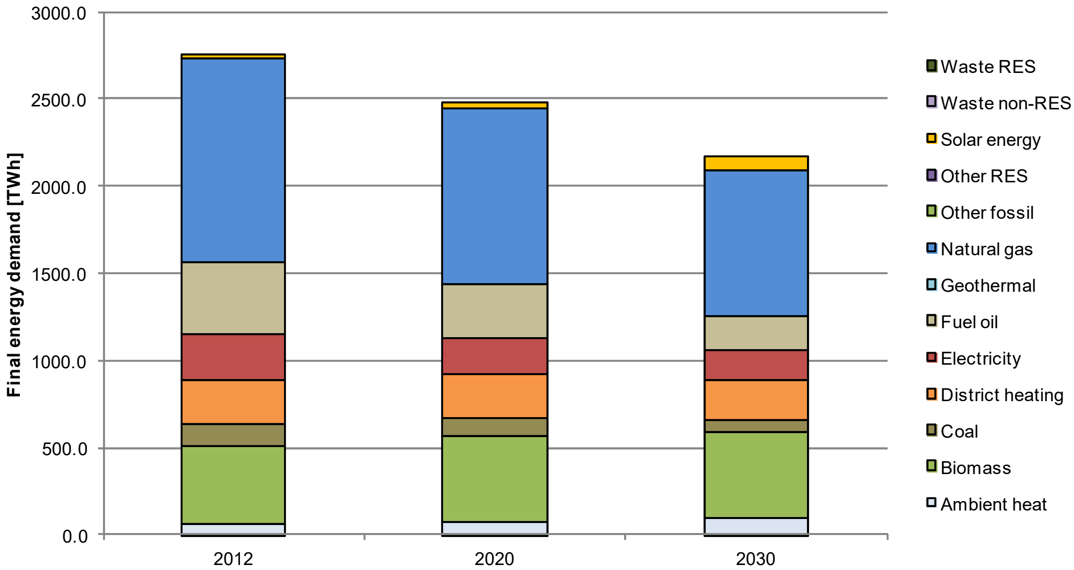


Table 32: Final energy demand for heating and cooling in the residential sector by energy carrier for 2012, 2020 and 2030, current policy scenario [TWh]

	2012	2020	2030	Change 2030/2012
Ambient heat	71	81	101	42%
Biomass	449	496	496	10%
Coal	119	97	68	-43%
District heating	254	247	223	-12%
Electricity	256	212	178	-30%
Fuel oil	411	306	190	-54%
Geothermal	0	0	0	0%
Natural gas	1171	1001	838	-28%
Other fossil	0	0	0	0%
Other RES	0	0	0	0%
Solar energy	17	36	72	327%
Waste non-RES	0	0	0	0%
Waste RES	0	0	0	0%
Total	2751	2479	2170	-21%
Total RES	538	614	670	25%
Total non-RES	1702	1405	1097	-36%
Total secondary energy	510	459	401	-21%

Figure 49 and 48 compare the proportions of energy carrier within the final energy demand for heating and cooling in all countries within the scope of the study. They show the considerable differences between countries regarding the energy carrier mix. In general, the existing policy framework leads to a growth of RES-H technologies (and, to a certain extent, district heating) and a decreasing share of oil boilers. However, the decreasing market shares of oil boilers are not only compensated for by RES-H, but also, to a significant extent in some countries, by natural gas. The model results indicate a significant growth of biomass in countries such as Croatia, Czech Republic, Romania and Spain whereas a declining market share results, for instance, in Latvia, Lithuania and Switzerland. The decrease of biomass heating in general is due to the replacement of old biomass systems by other heating systems, but also by more efficient, modern central biomass boilers. The growth of biomass heating in some countries may give rise to challenges regarding acceptance, stability and maturity of biomass fuel markets and air-borne emissions.

Figure 49: Share of energy carriers of total final energy demand by country for 2012 and 2030, Austria-Latvia

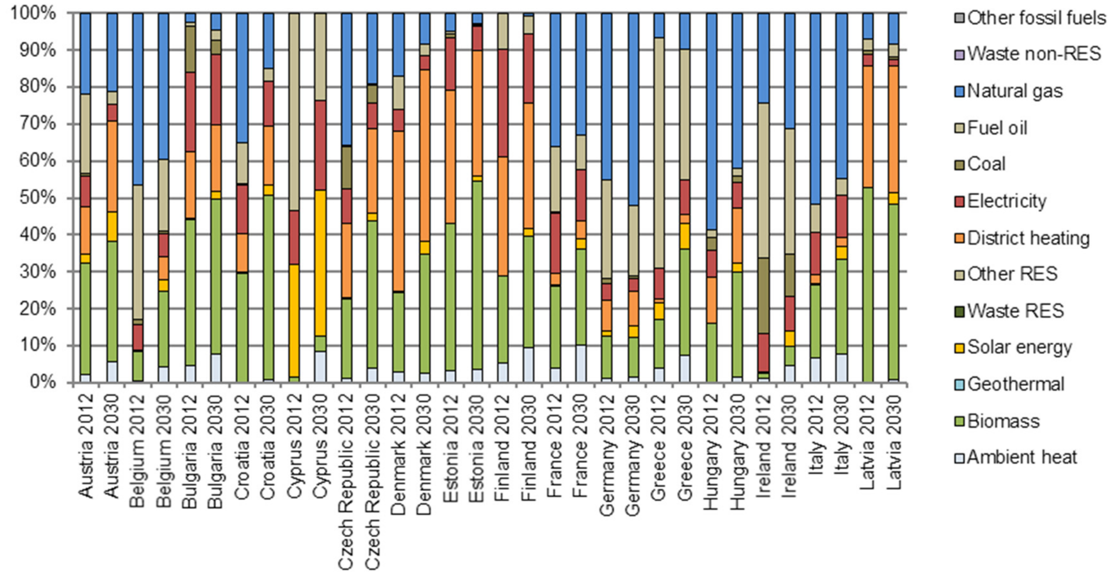
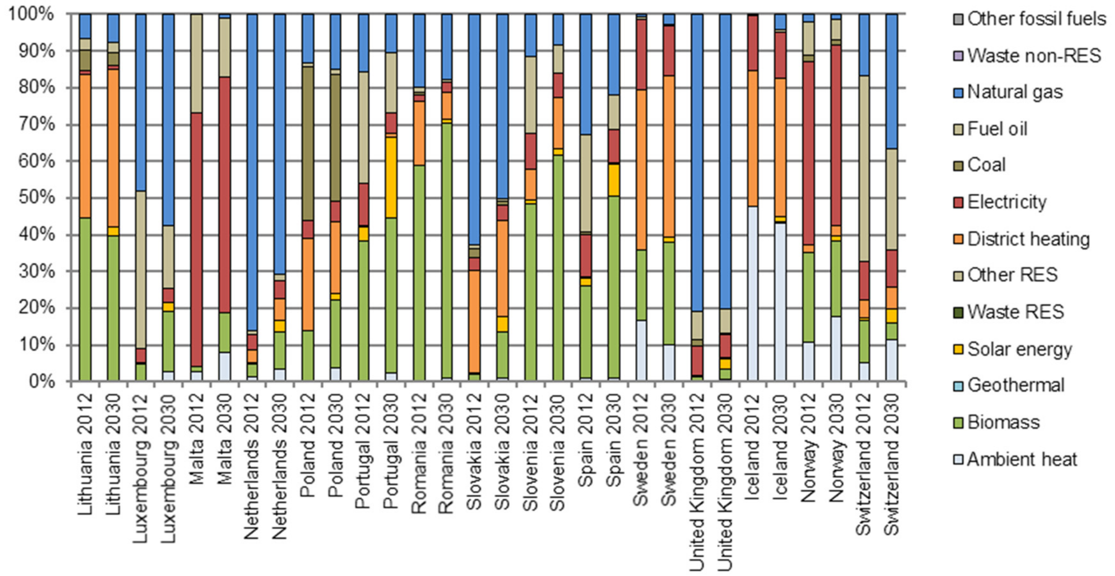


Figure 50: Share of energy carriers of total final energy demand by country for 2012 and 2030, Lithuania-Switzerland



4.2.3.2 Space heating and water heating

Table 33 and Figure 51 show the development of the final energy demand by energy carrier for space heating from 2012 to 2030. The energy mix is very similar to the mix of the overall heating final energy demand, whereby biomass shows a strong increase and solar energy is virtually negligible.

Figure 51: Final energy demand for space heating for all countries in 2012, 2020 and 2030

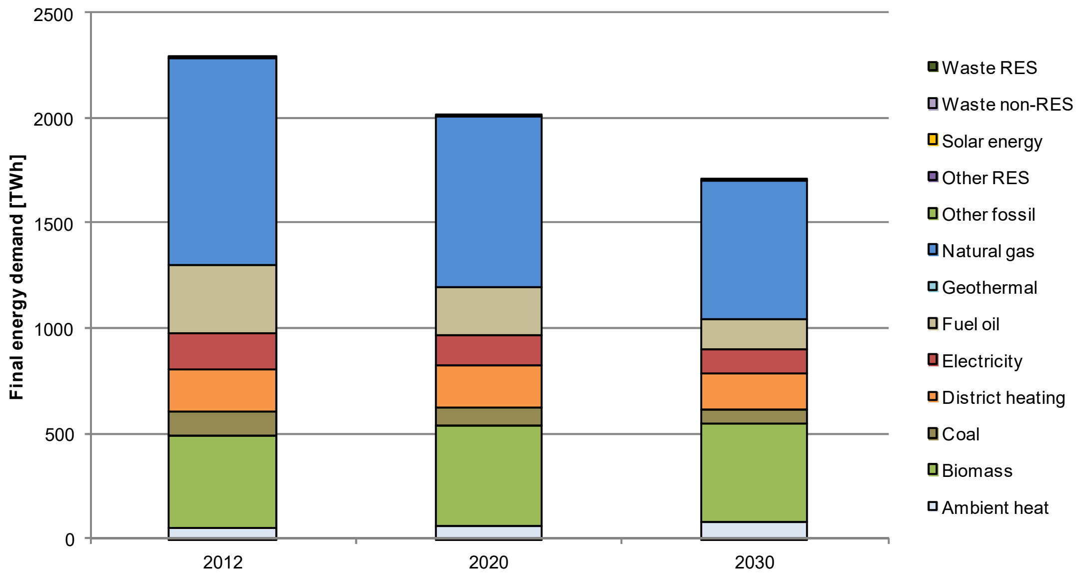


Table 33: Final energy demand for space heating for all countries for 2012, 2020 and 2030 [TWh]

	2012		2020		2030	
Natural gas	985	42%	820	39%	670	37%
Coal	113	5%	92	4%	64	4%
Fuel oil	354	15%	261	12%	161	9%
Electricity	188	8%	156	7%	133	7%
District heating	212	9%	204	10%	180	10%
Biomass	447	19%	484	23%	476	27%
Geothermal	0	0%	0	0%	0	0%
Solar energy	3	0%	9	0%	17	1%
Ambient heat	69	3%	77	4%	95	5%
Other RES	0	0%	0	0%	0	0%

Figure 52 and Table 34 summarises the development of the final energy demand by energy carrier for water heating from 2012 to 2030. The slight decrease in the energy demand is mainly due to the installation of more efficient boilers and water heaters. However, the relative decrease within the scenario period is far below that of space heating. As with space heating, natural gas remains the dominating energy carrier. Solar energy, however, plays a much more significant role, accounting for 13 % of the final energy demand for water heating in 2030.

Figure 52: Final energy demand for water heating for all countries in 2012, 2020 and 2030

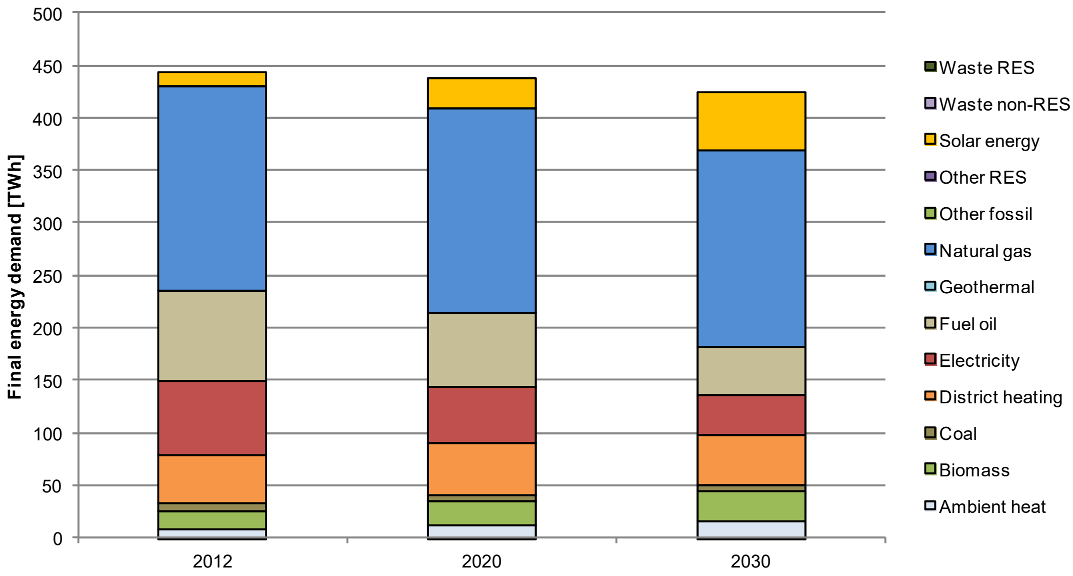
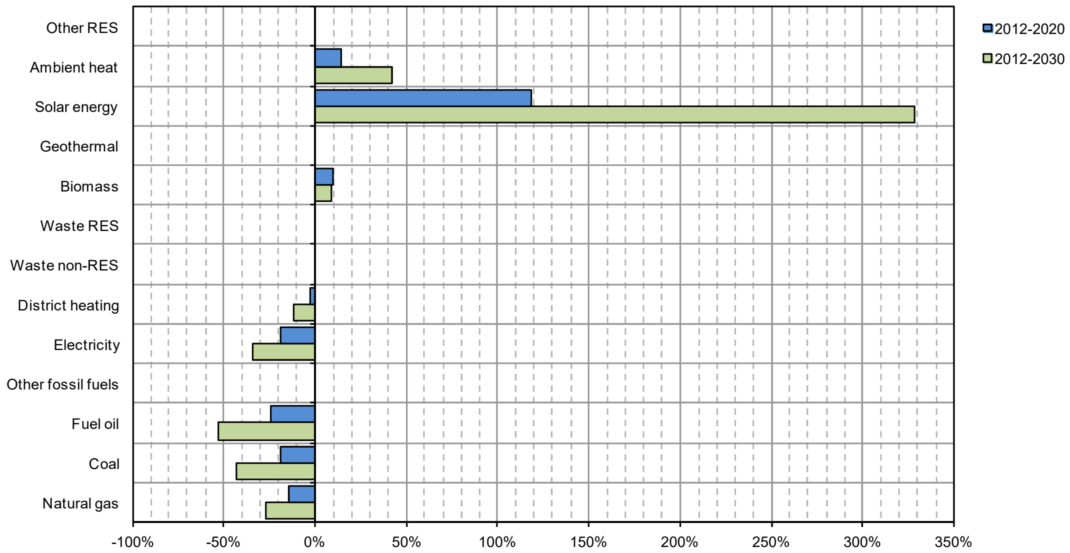


Table 34: Final energy demand for water heating for all countries for 2012, 2020 and 2030 [TWh]

	2012		2020		2030	
Natural gas	196	43%	196	43%	190	43%
Coal	7	2%	6	1%	5	1%
Fuel oil	90	20%	74	16%	49	11%
Other fossil fuels	0	0%	0	0%	0	0%
Electricity	74	16%	58	13%	40	9%
District heating	47	10%	50	11%	50	11%
Waste non-RES	0	0%	0	0%	0	0%
Waste RES	0	0%	0	0%	0	0%
Biomass	17	4%	24	5%	29	7%
Geothermal	0	0%	0	0%	0	0%
Solar energy	14	3%	29	6%	57	13%
Ambient heat	11	2%	15	3%	20	4%
Other RES	0	0%	0	0%	0	0%

Figure 53 illustrates the changes in the deployment of different energy carriers from 2012 to 2020 and 2012 to 2030. The proportion of solar energy exhibit the highest growth, whereas the fossil energy carriers clearly decline under the assumptions of the current policy scenario.

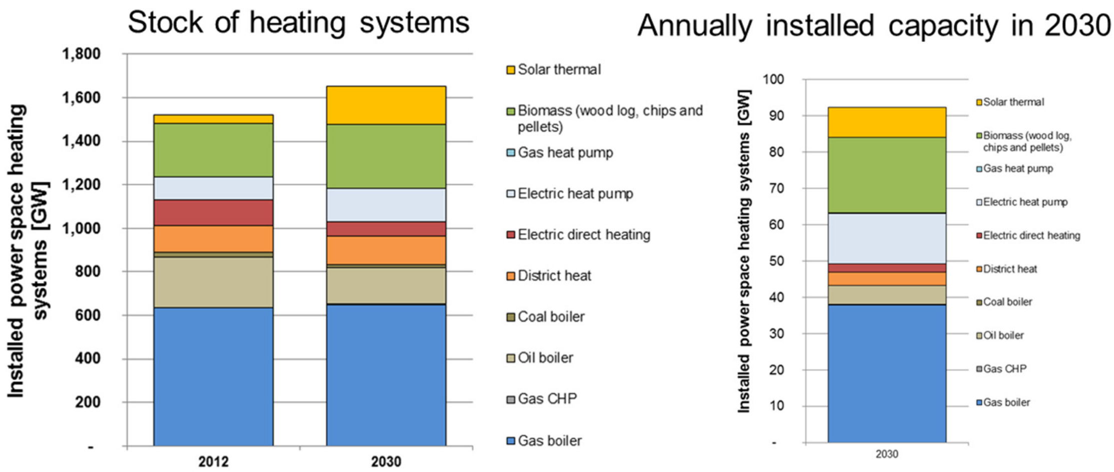
Figure 53: Growth of final energy demand for space and water heating for EU28 + CH, IS, NO by energy carrier in 2020 and 2030, current policy scenario



4.2.3.3 Development of installed capacities in the residential sector

In this chapter presents a brief analysis of the technology stock development for space heating in the residential sector. Figure 54 compares total installed capacities for space heating systems in 2012 and 2030. It can be seen that while the final energy demand decreases total installed capacities are less affected. The increase shown in Figure 54 (left) is a result of increasing installations of solar thermal systems which are usually installed as complementary technologies requiring backup systems covering the full heat loads of buildings. While installed capacities of gas fired heating systems (individual boilers and central heating systems) are constant throughout the simulation period, installed capacities of oil fired systems and direct electric heaters decreases significantly. Electrical heat pumps and biomass fired heating systems (wood log, wood chips and pellets) increases from 246 GW in 2012 to 294 GW in 2030. Gas fired heat pumps and micro CHPs still play a minor role under the assumptions of the current policy scenario. Figure 54 (right) shows new installations for year 2030. It can be seen that in 2030 around 50% of installed heating systems will be fossil fuel based. While new installations of oil boilers decrease, gas fired heating systems still make up for the largest share of installed heating systems. The main renewable heating systems are biomass fired boilers (23%) and electrical heat pumps (15%). Those figures also illustrate that the transformation speed from fossil to renewable heating systems is limited due to relatively low annual exchange rates of heating systems in buildings.

Figure 54: Technology stock of installed capacities of space heating systems EU28 + CH, IS, NO in 2012 and 2030 and annually installed ca-pacity in 2030, residential sector, *current policy scenario*



Heating systems are modelled in more detail in the INVERT/EELab (see 2.4). For illustration, exemplary results for the residential heating system stock of France are presented below (Figure 55).

Figure 55: Development of technology stock of space heating systems in France from 2012 to 2030, residential sector, *current policy sce-nario*

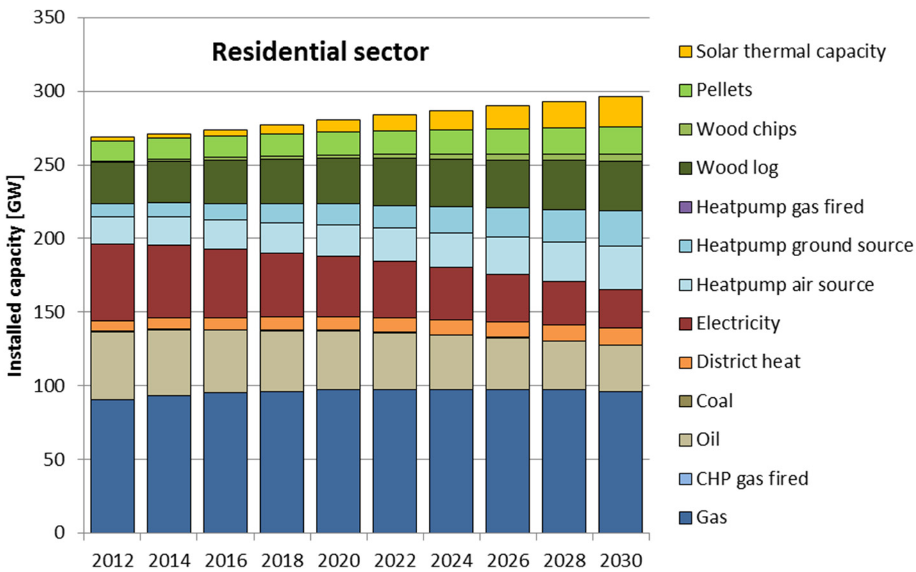
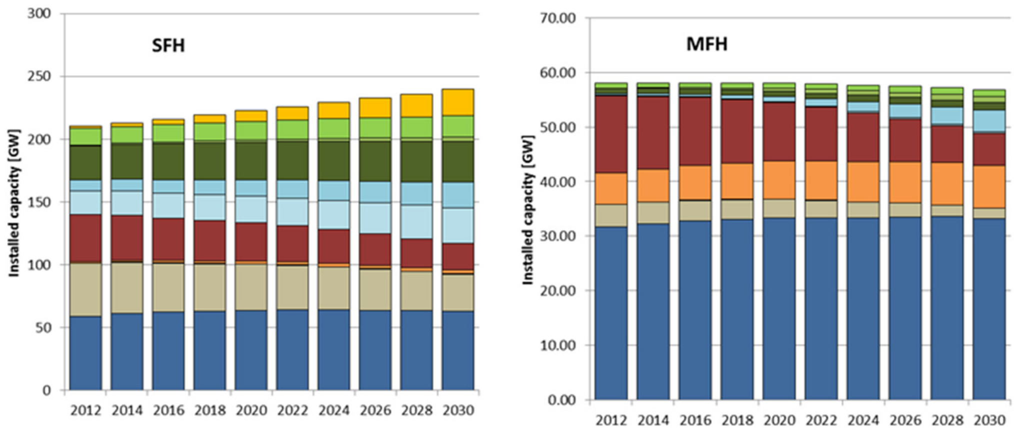


Figure 56 illustrates different developments in multi- and single family buildings in France within the scenario period. Most of solar thermal, biomass and heat pump systems are installed in single family house. Multifamily houses are dominated by gas fired heating systems, district heating and electric heating systems (direct and heat pumps).

Figure 56: Development of technology stock of space heating systems in France from 2012 to 2030, single family (SFH) vs. multi family houses (MFH), *current policy scenario*

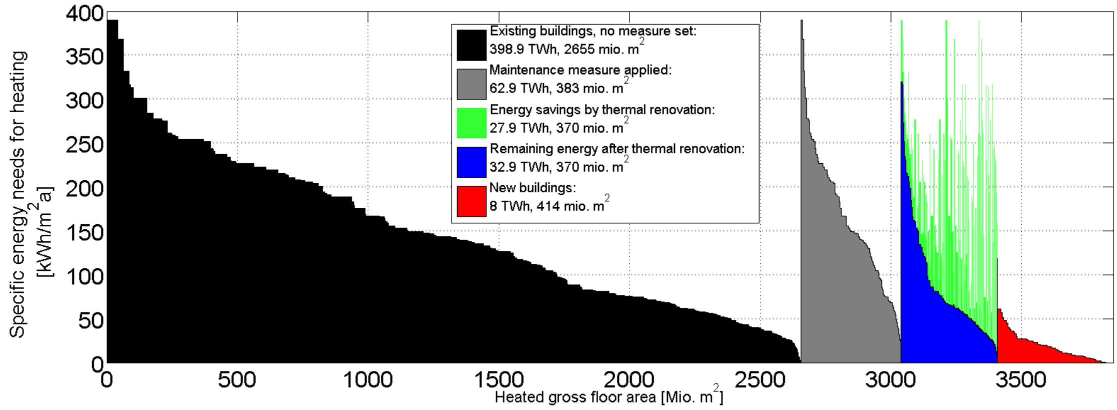


4.2.3.4 Development of specific heat demand in residential buildings

The average specific heat demand in buildings decreases from 126 kWh/m^2 in 2012 to around 94 kWh/m^2 in 2030 in the calculated scenario. Around 20% of this decrease is attributed to warmer temperatures, while the rest is due to thermal building renovations as well as an increasing share of new buildings with lower average heat demands. The average specific heat demand of multifamily houses across the EU decreases from around 100 kWh/m^2 in 2012 to around 76 kWh/m^2 in 2030 while the average specific heat demands of single family houses decreases from 180 kWh/m^2 to around 140 kWh/m^2 in 2030.

Figure 57 presents an example for France which illustrates the level of detail of our analysis. The black area represents the gross floor area of existing reference buildings in the model in which no efficiency measures are implemented within the scenario period structured according to their specific energy needs for heating. The grey area shows the gross floor areas of reference building in which only maintenance measures without efficiency improvements have been applied. The blue area shows buildings, which are thermally renovated between 2015 and 2030. The achieved energy savings are depicted by the green bars for each considered reference building. Specific energy needs of new buildings – marked in red – are significantly lower than existing buildings. The results presented in Figure 57 illustrate that the main share of total energy demand for heating in 2030 still consist of the non-renovated buildings stock. This highlights the importance of thermal renovation to increase the energy efficiency of the European building stock.

Figure 57: Details on the specific heat demand including changes through renovation activities and new buildings in France between 2015 and 2030



Source: www.invert.at

4.2.3.5 Space cooling

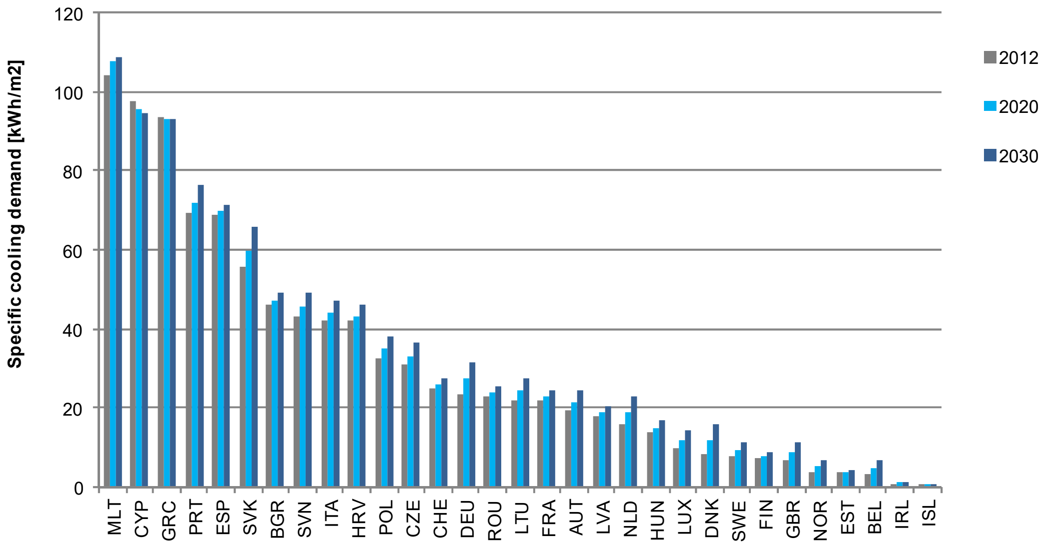
We distinguish between electricity demand for cooling (final energy), useful energy demand for cooling and theoretical cooling needs. The latter is the total theoretical energy demand of the *whole residential building stock.* This is the level of energy required to keep the indoor temperature within certain thresholds (thresholds in the model are typically between 22° and 25°). It is important to note that this is a theoretical figure since only a small percentage of those needs are actually satisfied in reality. The difference between real consumption and calculated cooling needs is mainly due to the fact that 1) only a certain percentage of households are equipped with air conditioning systems , and 2) even if a household owns an AC unit, user behaviour affects the needs supplied. These factors are considered in the calculation of useful energy demand for cooling and the resulting electricity demand in the model.

Theoretical cooling needs of residential buildings

The theoretical cooling needs are calculated using the building stock data in INVERT/EE-Lab, taking into account geometry, thermal condition of the building stock, estimated indoor temperatures as well as climate condition of each country. The model assumes that ambitious renovation activities also include shading and night ventilation to reduce cooling needs in countries. Buildings that are more efficient in terms of lower space heating energy demand might also generate a higher cooling demand, if passive measures like shading are not fostered.

The model results suggest that total theoretical cooling needs in EU28 (+CH, IS, NO) would rise from around 650 TWh/a in 2012 to 710 TWh/a in 2020 and 785 TWh/a in 2030 which corresponds to a 21% increase to keep the building stock at a desired temperature level. More than half of the increase results from theoretical cooling needs in Spain (+7%), Italy (+19%), Germany (+29%) and France (+24%). As shown in Figure 58 the relative increase of specific cooling needs is higher in countries with colder climates because the relative increase of cooling degree days is greater when starting from low numbers of days in the year where indoor temperatures are higher than desired levels. Furthermore the thermal building envelope in countries with high cooling needs are already designed to reduce the cooling required and further measures are assumed to be taken in the period to 2030. Therefore, the model results suggest that a stronger focus on shading and ventilation measures is also needed for countries with initially low cooling needs in the residential sector.

Figure 58: Specific cooling needs in the residential building stock by country for the years 2012, 2020 and 2030



Useful and final energy demand cooling

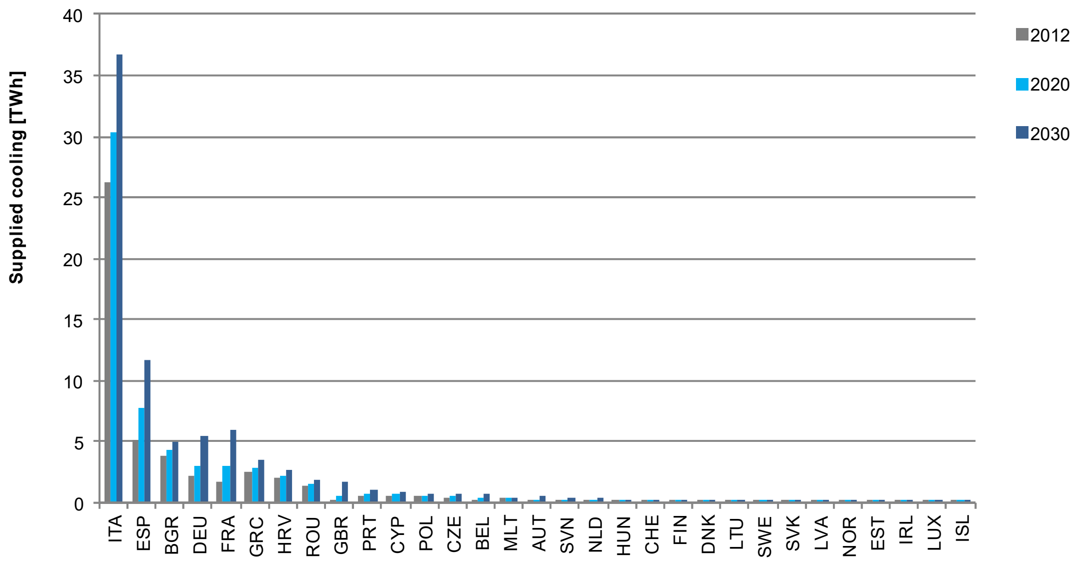
Based on the theoretical cooling needs developments of actual useful and final energy demand for cooling are derived. From empirical data collected in work package 1 of this study and additional literature on diffusion of air conditioning systems (Werner 2015, Pout et al. 2012, Dalin et al. 2006) we estimate the current share of effectively cooled living space and maximum saturation rates. In our model, the diffusion speed of AC systems increases with increasing specific cooling demands for each country.

After calibration to data of WP1 the supplied useful energy demand for cooling amounts to around 49 TWh in 2012. This means that only 7.5% of the theoretical demand is actually satisfied. The model results suggest that final energy demand cooling rises to 61 TWh in 2020 and 82 TWh in 2030. This corresponds to a share of around 10% of the theoretical cooling needs being satisfied by 2030. The 67% increase of supplied cooling needs is, to a greater extent, driven by the diffusion of air conditioning, rather than being due to the increase in total theoretical cooling needs which only account for about 25% of the increase in delivered useful energy demand. It should also be stressed that the underlying diffusion curves bear great uncertainties as consumer choices, and user behaviour, with respect to cooling systems, depend on a number of highly uncertain variables which could not been fully taken into account in this study.

Figure 59 illustrates the results by member state. The surprisingly large difference between Italy and Spain, compared to theoretical cooling demands, are due to the calibration of market shares to the current deployment of cooling systems in these countries. Referring to the statistical data compiled in WP1 reveals the significant difference in the final energy demand for cooling (26 TWh in Italy and. 5 TWh in Spain). This translates into lower market diffusions of cooling systems in Spain than in Italy. However, there are considerable uncertainties in the reported cooling energy demand data in the literature.

In absolute figures the majority of the increase in useful energy demand can be attributed to Italy, Spain, Germany and France that account for about 75% of total useful energy demand related to cooling in the residential sector. In relative terms, model results suggest sharp increases in most countries, doubling in more than 10 countries by 2030..

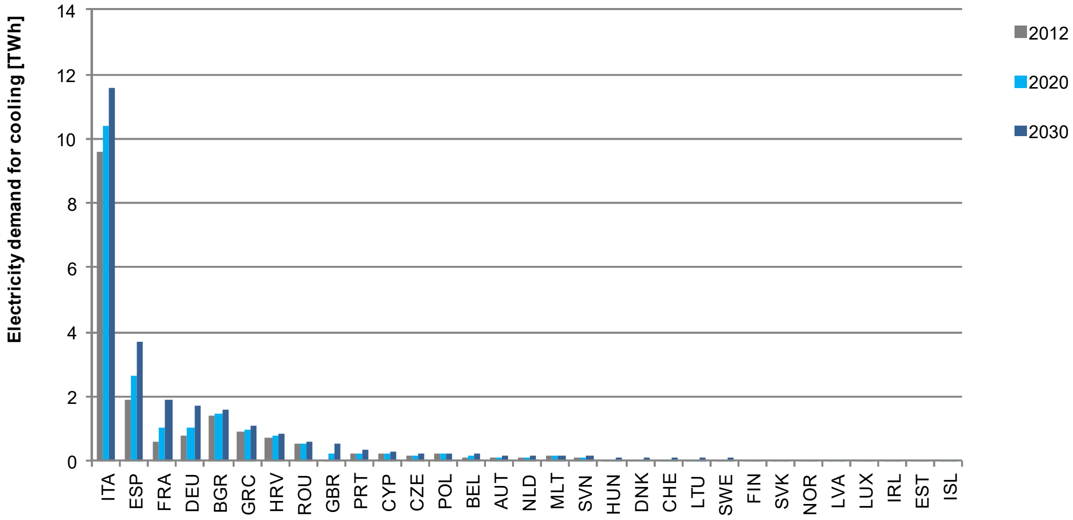
Figure 59: Effectively supplied useful energy demand for cooling from 2012 to 2030 [TWh]



Electricity demand for cooling is calculated with an estimated average Seasonal Energy Efficiency Ratio (SEER) of installed air conditioning systems starting from 2.7 in 2012 rising to 3.1 by 2030 due to technological progress and replacement of existing air conditioning systems. In our scenario, we assume that additional cooling needs would be delivered by electrically driven air conditioning systems due to substantial dominance of this technology in residential buildings. Therefore, the additional total final energy demand for cooling in the residential sector is provided by electricity. However, there are high uncertainties involved in the development of the technology mix,

Under these assumptions, total electricity demand for cooling increases from 17.9 TWh in 2012 to 21 TWh in 2020, and almost 26 TWh in 2030. Figure 60 shows the cumulative demand curve for all countries. The results show that 7 countries – Italy, Spain, France, Germany, Bulgaria and Greece – make up for more than 80% of cooling needs in 2030.

Figure 60: Final energy demand for cooling in residential buildings by country, current policy scenario [TWh]



Finally, the calculation of installed capacities is based on estimated full load hours by country. Data from previous studies (Werner 2015, Pout et. Al 2012, Pär Dalin 2006) are used to perform regressions on the relationship between full load hours and the climate conditions using the European climate index (ECI) as a proxy. The result of the regression analysis is needed to fill gaps in market data on full load hours in certain countries. The resulting assumption of full load hours ranges from 70 h/a in the northern countries to 550 h/a in Cyprus.

Under these assumptions, the installed capacity is estimated to rise from 55 GW in 2012 to 68 GW and 94 GW by 2030. Although strong increases of installed capacities are to be expected, the model results might overestimate this effect as full load hours do not increase. However, installed capacities of more than 10 GW in France and Germany by 2030 and sharp increases in many other countries are likely if warmer climates result in stronger diffusions of cooling technologies as implemented in the model. Installed capacity and resulting electricity consumption is of special concern for countries with electricity demand peaks caused by cooling demand..Such peaks in electricity could be very expensive from an electricity system perspective if they are not tackled by an increase in installed power production capacity, demand response or by measures to reduce cooling demand in the first place.

4.2.4 District heating sector

For the EU28 the district heating supply mix shows a steady shift from fossil fuel based technologies in 2012 to RES based technologies in 2030. While about 75% of the district heating demand is produced by fossil fuels in 2012, the projections for 2030 predict that 46.5% of the district heating demand will be provided by RES technologies, as can be seen in Figure 61.

Figure 61: The technology mix for the district heating demand in the EU28 for the year 2012, 2020, and 2030

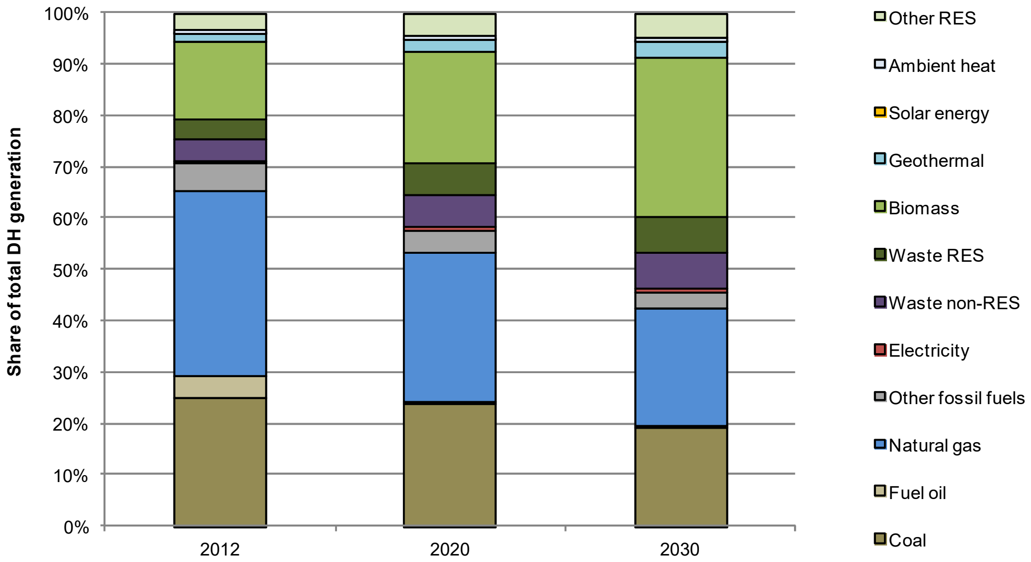


Figure 62 depicts the technology mix for the district heating demand in the EU member states, Norway, Switzerland, and Iceland for 2012. The share of technologies based on RES spreads from 0.5% in Spain and 15% in Greece to nearly 100% in Iceland. Iceland, though, has an unmatched potential source of geothermal energy. The EU member states with the highest shares of RES in the district heating sectors are Italy, France, and Sweden.

Figure 62: Technology mix for the district heating supply in the EU member states, Norway, Switzerland, and Iceland for the year 2012

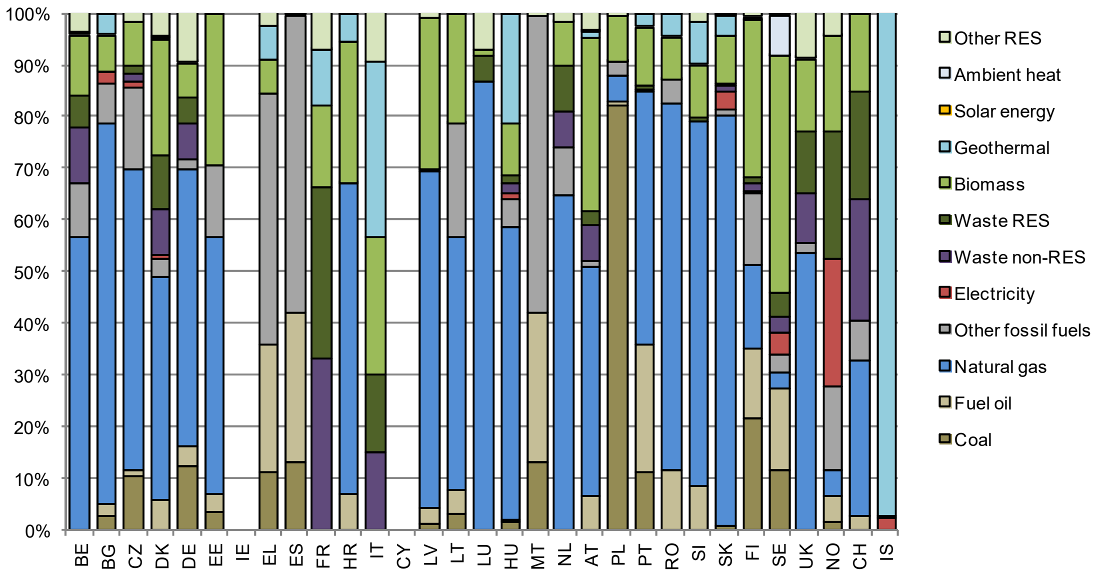
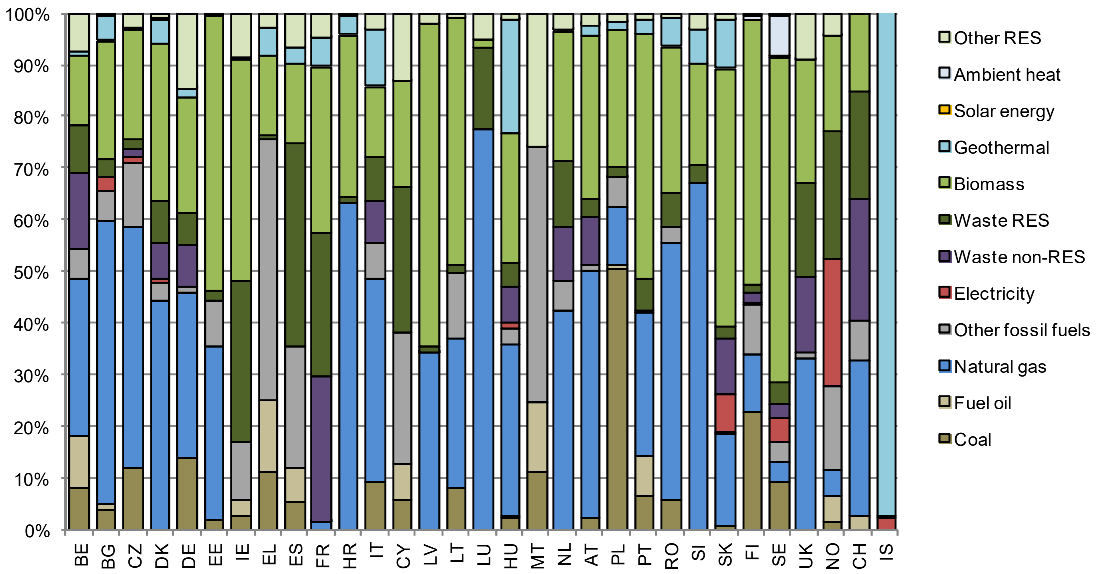


Figure 63: The technology mix for the district heating demand in the EU member states, Norway, Switzerland, and Iceland for the year 2030

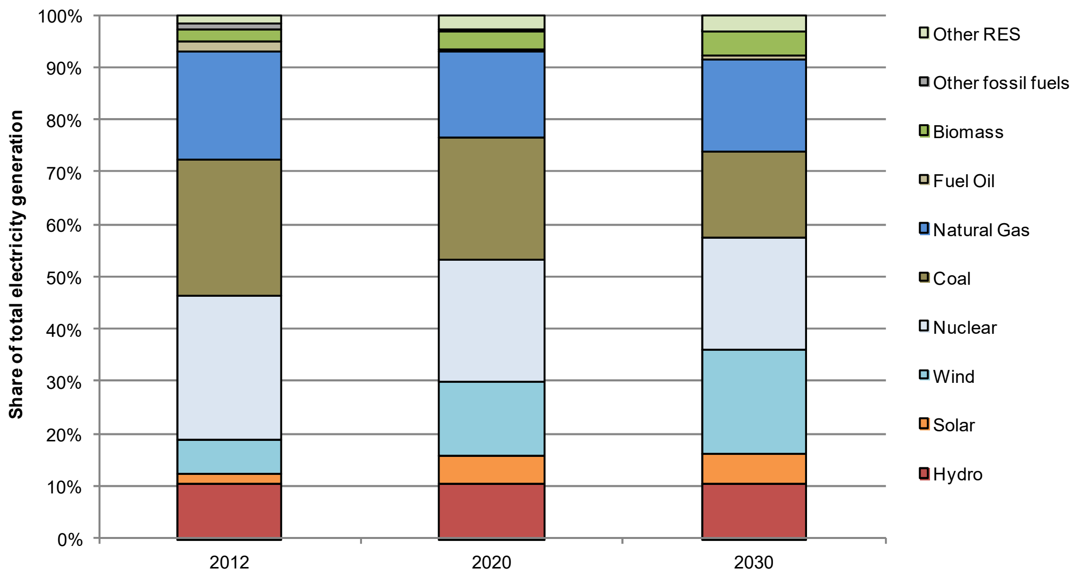


The projected share of RES in the district heating sector for 2030 is higher than 2012 for nearly all countries examined, as can be seen in Figure 63. The biggest growth for RES technologies can be seen in Spain, Slovakia, Estonia, and Sweden.

4.2.5 Electricity sector

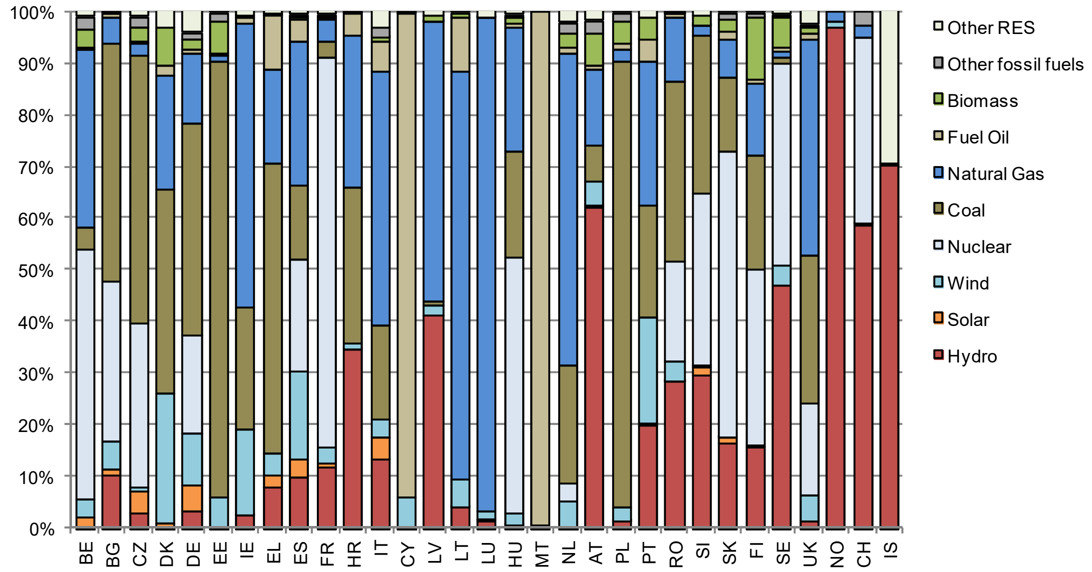
The electricity generation mix for the EU28 countries in 2012, 2020, and 2030 is shown in Figure 64. The fastest growing technology in this mix is wind technology which includes on- and offshore wind power plants. In contrast, the proportions of nuclear and coal technologies show the greatest reduction when comparing 2020 with 2012.

Figure 64: The technology mix for the electricity demand in the heating and cooling sector in the EU28 for 2012, 2020, and 2030



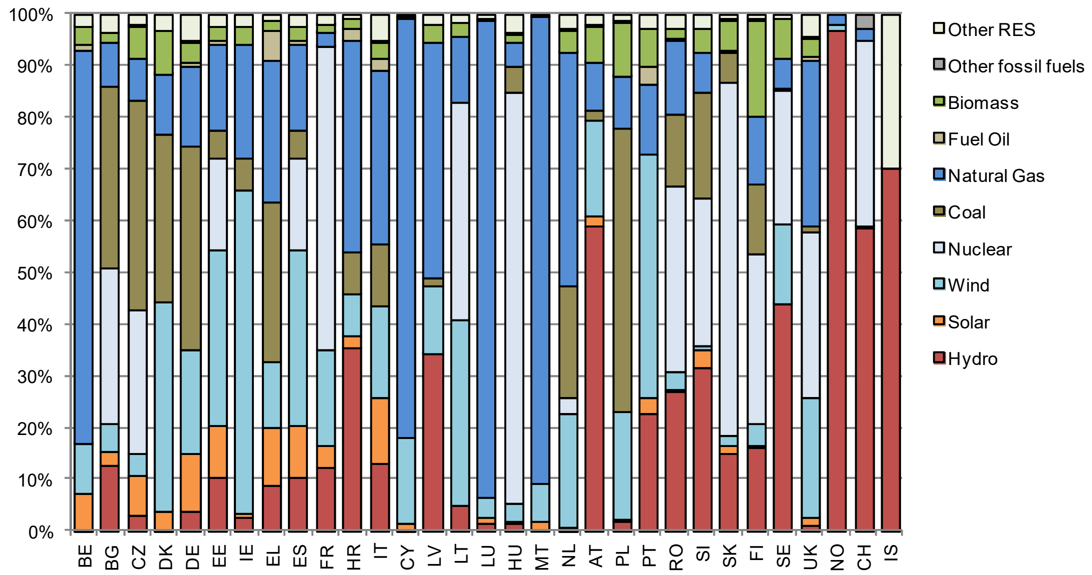
The electricity generation mix at country level in 2012 (Figure 65) is very diverse. The fossil fuel generation technologies are dominated by coal and natural gas based technologies with the exception of Cyprus and Malta. These insular states are very much dependent on fuel oil with shares of 93.5% and 99.1%. The most dominant electricity generation technologies based on renewable energy, in the year 2012, are hydro and wind. Norway and Iceland have a RES-E share of nearly 97.7% and 100% respectively.

Figure 65: The technology mix for the electricity demand in the heating and cooling sector in the EU member states, Norway, Switzerland, and Iceland for the year 2012



The fuel oil use in electricity generation in Cyprus and Malta is substituted by natural gas and wind by 2030, as can be seen in Figure 66. The highest share of RES-E technologies in 2030 in the EU is achieved by Austria (79.3%), Portugal (72.9%), Ireland (65.8%), and Sweden (59.5%).

Figure 66: The technology mix for the electricity demand in the heating and cooling sector in the EU member states, Norway, Switzerland, and Iceland for the year 2030



5 Results of RES-H/C obligation scenarios

RES-HC supplier obligations can be a way of promoting the use of RES at low cost, depending on the design of the obligation system. In order to assess the impact of such an obligation system, different design alternatives are compared to the *current policy scenario*. One crucial design element is if the quota is imposed either on a yearly basis in terms of an annual increase (gradual obligation), or set as RES-HC share which suppliers are required to achieve in the year 2030 (universal obligation). Therefore, we analyse the following scenarios:

- RES-HC supplier obligation with a quota for 2030 on EU level and EU wide trade between suppliers of different member states
- RES-HC supplier obligation with an annual increase of the quota on Member State level

For each scenario we assume that the obligation system is implemented by 2020 and remains active at a similar level until 2030. Furthermore, it is assumed that other RES-H/C subsidies are ceased by 2020 in order to avoid double subsidies. Also subsidies for fossil fuel technologies are ceased (e.g. for natural gas condensing boilers). A detailed description of the scenario assumptions can be found in 3.2.

The scenarios are compared to the *current policy scenario*. A particular focus is put on the resulting RES share, energy carrier mix and cost. For a definition of the RES-H/C share please see section 8.1.5.

The calculation of the obligation scenarios is based on a least cost approach, which assumes sequential implementation of RES options beginning with the "cheapest" (also considering future technology learning). In order to determine the least cost option, a marginal cost curve for RES deployment is calculated for each sector and member state. The cost curve is determined based on individual scenarios of RES certificate prices. Each step of the cost curve represents one scenario in one sector and country. The final marginal cost curve is derived by calculating several scenarios with varying subsidy levels for RES-H/C installations (= certificate price).

The results represent a least cost allocation of additional RES-H/C quantities needed to reach the quota target. Moreover, the application of detailed bottom-up simulation sector models enables us to derive realistic results for the additional financial support needed to increase the RES-HC share to the target level. Thereby, the potential certificate price for each member state, as well as at EU level, can be determined.

Furthermore, the marginal cost curve is used to derive support levels needed of the so called "EUCO27" scenario. The *EUCO27* scenario has been calculated applying the PRIMES modelling framework within another contract for the European Commission. It assumes the introduction of an obligation on fossil fuel suppliers to reach 27% RES-HC in their individual sales portfolio by 2030.

The calculated scenarios complete the assessment for the design of an RES-HC obligation scheme as it proposed in the impact assessment of the *Proposal for Renewable Energy Directive r*ecast [24]. However, the design of the RES-HC supplier obligation assumed in our scenarios is not exactly in line with the design options described in the Impact Assessment since the modelling activities of work package 3 have been conducted at an early stage of the discussion on the instrument design.

[24] COM (2016) 767 final. Commission Staff Working Document - Impact Assessment accompanying the document Proposal for the Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast)

5.1 RES-H/C supplier obligation with a quota for 2030 and EU wide trade mechanism

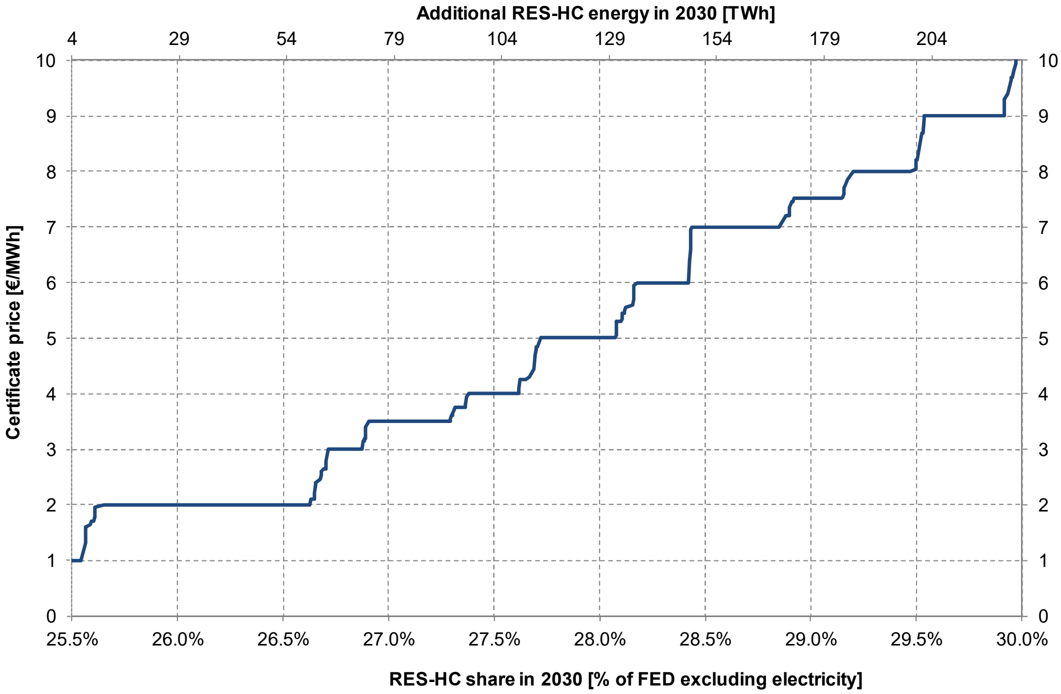
Following the concept of least cost RES-H/C deployment, the *2030 Quota EU scenario* assumes a single EU wide quota for 2030, namely the achievement of a share of at least 27% RES-H/C in total FED (excluding electricity). There are no additional restrictions on annual minimum increases and no specific quota for each member state.

The scenario serves as a theoretical economic assessment assuming a system which guarantees a cost optimal allocation of RES deployment. The technical implication of such a scenario is rather complex and the overall RES-H/C quota of 27 % on EU level would need to be transformed in a corresponding quota level for all suppliers reflecting the overall increase needed. By considering a trade mechanism among obliged suppliers of different Member States, the theoretical overall certificate price required to achieve the RES-H/C share of 27 % on EU28 level can be modelled. Thus, the results provide a valuable input for the definition of such a quota as well as the potential cost optimal allocation of RES-H/C installation and the needed support level.

The results of the analysis are summarised in Figure 67. This depicts the support level/certificate price needed to reach a certain RES-H/C share and a certain quantity of additionally implemented RES-H/C energy starting from a certificate price of zero euros per MWh. Each step of the cost curve shows additional RES deployment in a specific member state and sector (industry, tertiary, residential and district heating). Note that the individual steps consist of numerous smaller steps at the same price. This is a direct result of the modelling approach assuming similar price steps in all countries and sectors. In real-life, the curve would be more continuous. However, given the uncertainty of the assumptions, the resulting curve is sufficiently detailed for the analysis.

As Figure 67 shows, a certificate price of 3.5 €/MWhth is need in order to reach the 27% RES-H/C share at EU28 level. Compared to a scenario with a certificate price of zero euros/MWh, and no other RES subsidies, this would amount to an increase of about 91 TWh RES in 2030 induced by the certificate price. Note that the zero euro/MWh case is different to the *current policy scenario*, which assumes current RES subsidies in individual member states.

Figure 67: RES-H/C cost deployment curve: RES-H/C certificate prices, RES-H/C share and additional quantities for the EU28; all sectors



Key scenario results are summarised in Table 35. The scenario achieves a **27.2% EU28-wide RES-H/C share** by 2030 reflecting the fact that the entire cost-step of the 27% target is included in the scenario.[25] This equates to an average **annual increase of 0.58%** between 2020 and 2030. During these 10 years, an additional 250 TWh/a of RES energy are deployed, of which, however, about 91 TWh/a is induced by the obligation scheme. In some countries (e.g. Denmark) the RES increase over the period is lower than the RES increase induced by the certificate price. This simply means that without the certificate price, the RES share would fall between 2020 and 2030.

The **annual cost to induce the additional RES-H/C deployment (i.e. additional system cost[26]),** in this scenario, totals about 209 million euros in the year 2030. These costs are represented by the area below the cost curve in Figure 67 and to the left of the resulting RES share of 27.2%.

Assuming that all new RES deployment from 2020 onwards will receive the marginal costs (i.e. through the market price of certificates), **additional consumer expenditure** would amount to about 0.87 billion euros by 2030. Under this assumption, all RES installations that would have been installed without the certificate price will also receive certificates (becoming free-riders). Alternatively, additional consumer expenditure would be 0.32 billion euros assuming no free-riders. However, it is unclear what this means for spending/costs of obliged suppliers, as the certificates may be

25 Due to the step-wise character of the cost curve, the resulting RES-H/C share is not exactly 27%, but 27.2%.

26 Additional system costs refer to the total support provided within the obligation scheme in order to fulfil the quota. That is the value of the issued certificates. It does not represent the total costs of the heating and cooling supply.

generated as a one-time payment when a new RES-installation is installed. In this case, payments would be higher in earlier years and lower in later years.

It is very likely that the obliged suppliers will refinance these costs via the sales price of fossil fuels (or all non-RES fuels including electricity and heat). This **surcharge on non-RES fuels** for H/C would amount to about 0.23 €-cent/kWh in 2030 (assuming 100% free-riders). It is important to note, however, that these figures do not represent the total costs of the heating and cooling supply. The total costs of the scenarios are more likely to be determined by the overall energy and maintenance costs as well as the capital costs of the investments in heating and cooling supply and energy efficiency measures.

A look at the individual countries reveals huge diversity. While the certificate price of 3.5 uros/MWh results in more than a 1% annual average increase in RES share in some countries, the full range extends from -0.03% to 1.19%/a compared to 2020.

Table 35: Summary of results for the *Quota EU 27% scenario* for 2030 (all figures relate to 2030 if not otherwise stated)

	FED (excl. Elec.) [TWh]	RES total [TWh]	RES increase compared to 2020	RES increase induced by certificate price[1] [TWh]	RES-H/C share	Annual RES increase from 2020	Certificate price [euro/MWh]	Additional system cost[2] [million euros]	Additional consumer expenditure (0% freeriders) [3] [million euros]	Additional consumer expenditure (100% freeriders)[4] [million euros]	Surcharge on non-RES energy supply [5] [euro/MWh]
Austria	155	58	5	5	37.4%	0.47%	3.5	9	17	18	0.18
Belgium	179	39	10	3	21.7%	0.64%	3.5	6	9	35	0.25
Bulgaria	49	22	4	1	44.9%	0.58%	3.5	2	3	13	0.48
Croatia	28	13	2	1	45.1%	1.19%	3.5	2	2	8	0.51
Cyprus	4	1	0	0	33.6%	0.07%	3.5	0	0	0	0.14
Czech Republic	152	52	17	6	34.3%	1.08%	3.5	12	20	60	0.60
Denmark	69	30	-1	1	42.8%	-0.03%	3.5	3	4	-3	-0.08
Estonia	15	9	1	1	58.3%	0.58%	3.5	1	2	2	0.35
Finland	155	94	9	3	60.8%	0.60%	3.5	7	11	30	0.50
France	618	198	39	13	32.0%	0.76%	3.5	30	44	136	0.32
Germany	1,036	191	18	16	18.4%	0.33%	3.5	37	57	61	0.07
Greece	57	21	5	1	37.6%	1.10%	3.5	1	2	16	0.45
Hungary	83	28	6	3	33.3%	0.90%	3.5	7	11	20	0.36
Ireland	45	9	3	1	19.8%	0.69%	3.5	2	2	10	0.27
Italy	653	149	20	8	22.8%	0.32%	3.5	19	28	69	0.14
Latvia	23	13	-1	1	56.3%	0.15%	3.5	2	3	-2	-0.22
Lithuania	22	10	-0	1	45.5%	0.52%	3.5	1	2	-0	-0.01
Luxembourg	11	2	0	0	13.8%	0.48%	3.5	0	0	2	0.18
Malta	0	0	0	0	41.5%	2.33%	3.5	0	0	0	1.12
Netherlands	249	44	18	6	17.8%	0.76%	3.5	13	20	63	0.31
Poland	367	86	17	6	23.3%	0.50%	3.5	14	22	61	0.22

	FED (excl. Elec.) [TWh]	RES total [TWh]	RES increase compared to 2020	RES increase induced by certificate price[1] [TWh]	RES-H/C share	Annual RES increase from 2020	Certificate price [euro/MWh]	Additional system cost[2] [million euros]	Additional consumer expenditure (0% freeriders) [3] [million euros]	Additional consumer expenditure (100% freeriders)[4] [million euros]	Surcharge on non-RES energy supply [5] [euro/MWh]
Portugal	59	24	3	2	40.3%	0.41%	3.5	3	5	11	0.30
Romania	149	56	7	2	37.2%	0.39%	3.5	4	6	24	0.25
Slovakia	71	17	7	2	24.4%	1.06%	3.5	5	8	25	0.47
Slovenia	22	10	2	1	44.7%	0.72%	3.5	2	3	7	0.57
Spain	322	92	22	5	28.5%	0.61%	3.5	11	17	79	0.34
Sweden	157	106	10	2	67.2%	0.80%	3.5	4	6	34	0.65
UK	526	65	28	4	12.3%	0.60%	3.5	10	15	97	0.21
EU28	5,280	1,437	250	91	27.2%	0.58%	3.5	209	320	874	0.23

[1] Total RES energy use in 2030 compared to the case with a certificate price of zero euros

[2] Cost to induce the required RES deployment compared to the case with a certificate price of zero euros (equal to the area below the cost curve and left of the resulting target RES share)

[3] Certificate price multiplied by the RES increase induced by the scheme via comparison to zero euro/MWh in 2030 (also named market value of system)

[4] Certificate price multiplied by the total RES increase since 2020

[5] Assuming that the entire certificate price a supplier theoretically needs to pay will be added to the non-RES supply due to the opportunity cost character of the certificate price.

5.2 RES-H/C supplier obligation annual increase on member state level

This scenario assumes that each member state achieves an increase in their RES-H/C share of at least 0.55% per year from 2020 to 2030 (*Quota MS 0.55 scenario*). Thus, the quota is imposed on all fuels used for H/C. With regard to the induced additional RES-HC deployment, the scenario is comparable to the design of the gradual obligation as it is presented in the impact assessment for the proposal of the RED recast[27] where an annual quota of 1 % on 50 % of the suppliers accounting for exemptions of small size companies and RES fuel suppliers.

The scenario begins with a certificate price of zero euros, and the assumption that technology subsidies for RES and fossil fuel technologies are phased out. In some countries the RES increase generated will already be higher than 0.55% per year. For these countries a certificate price of zero is assumed. For the others, the price is increased incrementally until at least 0.55%/a is reached.

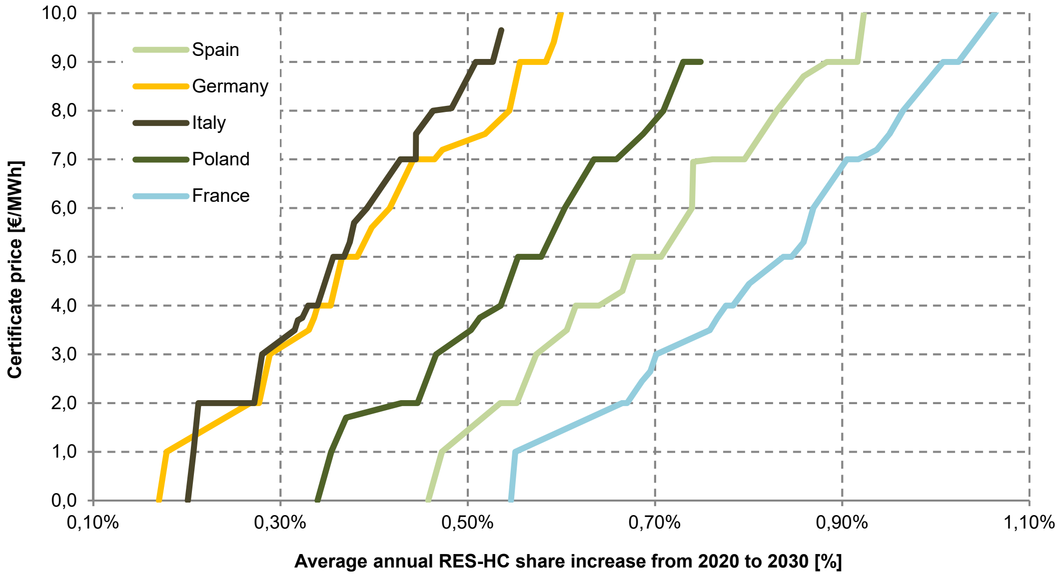
The scenario has no further limitations on minimum total RES-share by country or EU wide. Trade in certificates is only allowed within a country, not between countries.

As with all obligation scenarios, the RES deployment is calculated based on a least-cost approach using marginal RES-H/C cost deployment curves. Figure 68 shows the cost curves for selected countries where the certificate price is shown in relation to the annual average RES-H/C share increase from 2020 to 2030. The RES-HC certificate price can be identified from the intersection point with the required RES share increase.

Note that the certificate price reflects the financial support level needed to convince an investor to implement a RES-H/C technology and to sell the corresponding certificates to the obliged H/C supplier. It represents the annual cost of implementing a MWh RES-H/C energy, that is the support required to cover the cost difference between RES and conventional fossil fuel based heating generation. For instance, an installation which is implemented in the year 2020 would receive the support level, per MWh RES-H/C energy, depicted on the y-axis of Figure 67 (or Figure 68 for 2040) assuming a typical lifetime of 20 years. Since the quota is defined as additional RES-H/C share increase per year, the same support level is needed for additional RES-H/C generators implemented in 2021, and so on. Therefore, the total annual costs required to achieve the quota will increase gradually from year to year in line with the increase of the number of certificates needed for quota fulfilment. Since RES-H/C generators are mostly small-scale applications, it is more likely that the support is provided as a one-time payment to the investor, enabling the obliged supplier to immediately receive all eligible certificates which would be generated over the lifetime of a RES-H/C generator.

27 The level of the gradual obligation derived in the impact assessment is based on the assumption that 50% of the suppliers could be exempted. The eligible suppliers would need to increase their RES-H/C share by 1% per year in the period 2021 to 2030.

Figure 68: RES-H/C cost deployment curve for selected countries including average annual increase in RES-H/C share from 2020 to 2030



The scenario results and key performance indicators are shown in Table 36. The diversity across countries is huge and represents different economic frameworks, trends, technology stock costs and price levels. It can be seen that the **annual average RES-H/C share increase** of at least 0.55%/a is achieved in all countries except Cyprus (0.1%/a) and Italy (0.54%). In both these countries the available technology options in the marginal cost curve do not allow the targeted annual RES deployment to be achieved. The very low RES deployment achieved in Cyprus is subject to the high uncertainty associated with low data availability in very small countries. In Italy, which achieves an annual RES increase of 0.54%/a, the target can be judged as achieved - given the uncertainty of the assumptions. Also note that more expensive technical options are certainly available beyond that considered in this model analysis. Furthermore, the industry sector might show more potential by including heat demand in industrial furnaces into the scope of the obligation scheme (it is excluded by definition in the scenario analysis, because most furnaces face very specific restrictions for the use of RES). Similarly, Denmark is remarkable as it requires a very high certificate price to reach the target.

Some countries, namely the Czech Republic, Greece, Croatia, Malta, Sweden and Slovakia achieve the target without including a RES certificate price, and many of these countries substantially exceed the target. The remaining majority of countries show a resulting RES-H/C share between 0.55%/a and 0.60%/a.[28] However, the respective certificate price varies strongly and reflects the level of ambition in each country.

On average, the EU28 achieves an annual average RES-H/C increase of 0.61%. This is above the countries' individual target of 0.55%/a, because some countries substantially overachieve the target. In total, a RES-H/C share of 27.6% is achieved for the EU28.

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[28] The fact that these countries do not exactly meet the 0.55% obligation is a result of the approach used. More precisely, it comes from the fact that the RES cost deployment curves are based on step functions.

The **total RES increase** from 2020 to 2030 amounts to 267 TWh, of which about 109 TWh are induced by the certificate price/ support provided by the obliged suppliers at member state level.

While the **certificate price** varies substantially across countries from zero to nearly 20 euros/MWh, the weighted EU28 average price equals about 7.7 euros/MWh. Note that this is only a theoretical price as trading between suppliers of different countries is not allowed and an EU-wide market is not considered in this scenario.

Total **annual cost for inducing the additional RES-H/C deployment** (i.e. system cost compared to a case with zero euros certificate price) amounts to about 0.45 billion euros, while the **additional consumer expenditure** ranges between 0.85 and 1.21 billion euros in 2030 assuming 0% and 100% free-riders, respectively. If suppliers refinance all the price certificates (with 100% free-riders) via a mark-up on the sale of non-RES fuels, the average non-RES fuel price would increase by 0.32 euros/MWh in 2030.

The distribution of costs among the countries varies not only according to the difference in country size but also due to different ambition level across countries, as well as across the different trends in the current policy scenario. For example, Germany bears close to half of the entire RES deployment cost in the system at nearly 200 million euros in 2030 whereas in other countries quota fulfilment is achieved without any additional support representing a certificate price of zero.

Table 36: Summary of results for the *Quota MS 0.55 scenario* for 2030 (all figures relate to 2030 if not otherwise stated)

	FED (excl. elec) [TWh]	RES total [TWh]	RES increase compared to 2020	RES increase induced by certificate price[1] [TWh]	RES-HC share	Annual RES increase from 2020	Certificate price [euro/MWh]	Additional system cost[2] [million euros]	Additional consumer expenditure (0% freeriders) [3] [million euros]	Additional consumer expenditure (100% freeriders)[4] [million euros]	Surcharge on non-RES energy supply [5] [euro/MWh]
Austria	155	59	6	6	38.2%	0.56%	5.0	13	30	31	0.33
Belgium	179	38	9	1	21.0%	0.56%	2.0	2	3	18	0.12
Bulgaria	49	22	4	1	44.8%	0.57%	3.0	2	3	11	0.40
Cyprus	4	1	0	0	34.0%	0.10%	9.0	0	1	1	0.39
Czech Rep.	151	47	12	-	30.8%	0.73%	-	-	-	-	-
Germany	1,026	215	42	40	21.0%	0.58%	9.0	199	363	375	0.46
Denmark	68	33	3	5	48.6%	0.55%	9.7	28	45	26	0.73
Estonia	15	9	1	1	58.3%	0.58%	3.5	1	2	2	0.35
Greece	57	21	4	-	36.8%	1.02%	-	-	-	-	-
Spain	323	90	21	3	27.9%	0.55%	2.0	6	6	41	0.18
Finland	155	94	8	3	60.4%	0.57%	3.0	5	8	25	0.40
France	620	186	26	0	30.0%	0.55%	1.0	0	0	26	0.06
Croatia	28	12	2	-	43.3%	1.01%	-	-	-	-	-
Hungary	83	25	3	0	29.8%	0.55%	1.9	0	0	6	0.10
Ireland	45	9	3	1	19.3%	0.64%	2.0	1	1	5	0.14
Italy	650	163	33	22	25.0%	0.54%	9.7	113	211	322	0.66
Lithuania	22	10	0	1	45.9%	0.56%	4.0	2	3	0	0.02
Luxembourg	11	2	1	0	14.7%	0.57%	5.8	1	1	3	0.35
Latvia	23	14	0	2	61.1%	0.63%	8.2	9	15	3	0.35
Malta	0	0	0	-	38.6%	2.05%	-	-	-	-	-
Netherlands	250	42	16	4	17.0%	0.68%	2.0	7	8	32	0.15

	FED (excl. elec) [TWh]	RES total [TWh]	RES increase compared to 2020	RES increase induced by certificate price[1] [TWh]	RES-HC share	Annual RES increase from 2020	Certificate price [euro/ MWh]	Additional system cost[2] [million euros]	Additional consumer expenditure (0% freeriders) [3] [million euros]	Additional consumer expenditure (100% freeriders)[4] [million euros]	Surcharge on non-RES energy supply [5] [euro/MWh]
Poland	367	88	20	9	24.0%	0.58%	5.0	25	44	100	0.36
Portugal	60	25	4	2	41.7%	0.55%	6.0	8	15	24	0.70
Romania	149	59	10	5	39.5%	0.62%	7.0	20	34	69	0.77
Sweden	158	104	8	-	65.7%	0.66%	-	-	-	-	-
Slovenia	22	9	2	1	43.5%	0.61%	2.0	1	1	3	0.27
Slovakia	71	15	5	-	21.3%	0.75%	-	-	-	-	-
UK	529	64	26	3	12.0%	0.57%	2.0	5	6	53	0.11
EU28	5,269	1,455	267	108	27.6%	0.61%	7.8	450	799	1,150	0.30

1 Total RES energy use in 2030 compared to the case with a certificate price of zero euros

2 Cost to induce the required RES deployment compared to the case with a certificate price of zero euros (equal to the area below the cost curve and left of the resulting target RES share)

3 Certificate price multiplied by the RES increase induced by the scheme via comparison to zero euro/MWh in 2030 (also named market value of system)

4 Certificate price multiplied by the total RES increase since 2020

5 Assuming that the entire certificate price a supplier theoretically needs to pay will be added to the non-RES supply due to the opportunity cost character of the certificate price.

5.3 Derivation of certificate prices for the for the EUCO27 scenario (universal obligation)

In addition to the scenarios calculated within this study, a comparison to the *EUCO27 scenario* is presented in the following[29]. The *EUCO27* scenario has been modelled within another contract for the European Commission applying the PRIMES model. The PRIMES model is also used to calculate the Reference scenario of the European Commission (European Commission 2016).

The *EUCO27* scenario assumes that all obliged suppliers of H/C cooling energy achieve a RES-H/C share of 27 % by 2030. Thereby, only 50 % of the total H/C energy is addressed by the universal obligation due to exemptions of small scale and RES suppliers. The obligation scheme in this scenario is implemented on Member States level, that is EU-wide trade of certificates among suppliers of different Member States is not foreseen.

The PRIMES model calculates the development of RES-H/C and total final energy demand. The corresponding costs to achieve the quota in the Member States are not calculated. Therefore, the comparison with our study aims in providing support levels / certificate prices needed to achieve the suggested RES-HC deployment levels of the *EUCO27* scenario in each of the member states[30].

Results of the EUCO27 scenario in terms of RES-H/C quantities and shares for each Member States are shown in the first two columns of Table 37. The third column presents the certificate prices corresponding to the respective quantities in our model. The certificate prices are derived from the country specific cost curves determined by the MAPPING-HC model framework.

However, a combination of EUCO27 and the cost curve results are only partly possible since the achieved RES-H/C quantities for 2030 suggested in the EUCO27 scenario are not fully covered by our analysis[31]. For instance, the results of *EUCO27* scenario suggest a total RES-H/C deployment of 37.8 TWh for Denmark in 2030 whereas in our analysis the scenario with the highest RES-H/C share in Denmark results only in 33.8 TWh in 2030. On the other hand, there are quite a few countries with certificate price of zero for RES-H/C quantities calculated in *EUCO27* for 2030. That is, corresponding RES-H/C quantities suggested in the EUCO27 scenario are achieved without additional support.

Thus, certificate prices assigned to RES-H/C quantities should be interpreted as indicator. Another reason is that the absolute RES-H/C deployment does not indicate the amount of additional RES-H/C installations in the period 2020 to 2030. A calculation of overall consumer expenditures for the *EUCO27* scenario based on the certificate

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[29] see COM (2016) 767 final. Commission Staff Working Document - Impact Assessment accompanying the document Proposal for the Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast)

[30] Please consider that the overall methodology of PRIMES is different to the MAPPING-HC model framework used in this study. A combination of results in terms of RES-HC quantities and support levels is not necessarily consistent.

[31] In order to extend the cost curve and fully cover the EUCO27 quantities, additional scenarios need to be calculated with the MAPPING-HC model framework. The comparison with the EUCO27 was conducted after the modelling work at the end of the project. A calculation of additional scenarios was not possible within the foreseen timeframe of this project.

prices is not possible since the additional induced RES-H/C quantities cannot be derived from the results of the EUCO27 scenario.

Table 37: RES-H/C deployment in the EUCO27 scenario and corresponding certificate prices

	EUCO27 RES-H/C deployment 2030 [TWh]	EUCO27 RES-H/C share	MAPPING-HC certificate price/ support level [EUR/MWh]
Austria	57.0	37.7%	3.4
Belgium	28.1	14.2%	0.0
Bulgaria	17.2	38.8%	0.0
Croatia	7.4	24.7%	0.0
Cyprus	1.2	31.3%	0.0
Czech Republic	32.8	22.1%	0.0
Denmark	37.8	49.4%	>9.7
Estonia	8.3	44.7%	0.9
Finland	97.4	71.1%	9.0
France	197.8	30.4%	3.5
Germany	214.3	19.5%	9.0
Greece	20.3	39.0%	0.0
Hungary	19.4	21.0%	0.0
Ireland	9.8	20.9%	8.0
Italy	222.2	31.4%	>9.7
Latvia	16.1	60.0%	>9.0
Lithuania	10.5	41.4%	>6.0
Luxembourg	2.0	17.2%	>9.0
Malta	0.4	37.3%	>18.5
Netherlands	30.7	11.8%	0.0
Poland	103.1	24.4%	9.0
Portugal	26.4	41.1%	>15.1
Romania	50.1	30.9%	0.0
Slovakia	13.1	18.5%	0.0
Slovenia	7.7	39.4%	0.0
Spain	79.3	26.4%	0.0
Sweden	118.8	80.3%	>10.2
UK	59.9	10.9%	0.0
EU28	1489.1	27.0%	-

5.4 Comparison of scenarios

The comparison will focus on the two obligation scenarios – *Annual Quota MS (Q055)* and *2030 Quota EU 27 (Q27)* – calculated within this study. The following table illustrates the main indicators which will be discussed in detail in the next paragraphs.

Table 38: Comparison of main indicators

	MAPPING-HC quota with annual increase [Q55]	MAPPING HC quota 2030 on EU level with trade [Q27]
FED HC without electricity 2030 [TWh]	5 269	5 280
RES-H/C 2030 EU28 [TWh]	1 454	1 437
RES-H/C share 2030 EU28	27.6 %	27.2%
Certificate price 2030 EU average [EUR/ MWh]	7.4	3.5
Max certificate price 2030 [EUR/ MWh]	9.7	3.5
Cost past on consumer 2030 EU ave [% of gas price]	0.35 %	0.27%
Max cost past on consumer 2030 [% of gas price]	1.2%	1.2 %

5.4.1 RES-H/C share

The main target indicator of the obligation scenarios is the RES-H/C share achieved by 2030. Table 39 shows the resulting RES-H/C shares in the two obligation scenarios *Quota MS 0.55 (Q055)* and *Quota EU 27 (Q27)* compared to the *current policy scenario* (CP).

For the EU28 as a whole, the RES-H/C share achieved is 1.7 *(Q055)* and 1.4 *(Q27)* percentage points higher than in the *current policy scenario*. Although, in total, the level of ambition in the two obligation scenarios is only little higher than in the *current policy scenario*, this picture is different across the individual member states. For example Latvia, Malta, Netherlands and UK show a substantial increase in their RES-H/C share compared to the current policy scenario in the obligation scenarios.

Table 39: Comparison of RES-H/C share in 2030 across scenarios

	RES-H/C share 2030			Difference to Current Policy	
	CP	Q0.55	Q27	CP - Q0.55	CP - Q27
Austria	36,3%	38,2%	37,4%	1,9%	1,1%
Belgium	18,9%	21,0%	21,7%	2,1%	2,9%
Bulgaria	43,4%	44,8%	44,9%	1,3%	1,5%
Cyprus	40,3%	34,0%	33,6%	-6,4%	-6,7%
Czech Republic	31,2%	30,8%	34,3%	-0,4%	3,1%
Germany	17,8%	21,0%	18,4%	3,2%	0,7%
Denmark	45,0%	48,7%	42,8%	3,7%	-2,2%
Estonia	56,0%	58,3%	58,3%	2,3%	2,3%
Greece	34,5%	36,8%	37,6%	2,3%	3,1%
Spain	27,5%	27,9%	28,5%	0,4%	0,9%
Finland	63,4%	60,4%	60,8%	-3,0%	-2,6%
France	30,3%	30,0%	32,0%	-0,4%	1,7%
Croatia	41,5%	43,3%	45,1%	1,8%	3,6%
Hungary	30,2%	29,8%	33,3%	-0,4%	3,1%
Ireland	17,0%	19,3%	19,8%	2,4%	2,9%
Italy	22,0%	25,0%	22,8%	3,0%	0,8%
Lithuania	44,9%	45,9%	45,5%	1,0%	0,6%
Luxembourg	13,4%	14,7%	13,8%	1,3%	0,4%
Latvia	54,4%	61,1%	56,3%	6,7%	1,9%
Malta	32,8%	38,6%	41,5%	5,8%	8,6%
Netherlands	12,8%	17,0%	17,8%	4,3%	5,0%
Poland	23,7%	24,0%	23,3%	0,4%	-0,4%
Portugal	40,2%	41,7%	40,3%	1,5%	0,0%
Romania	36,5%	39,5%	37,2%	2,9%	0,7%
Sweden	66,3%	65,7%	67,2%	-0,5%	0,9%
Slovenia	42,0%	43,5%	44,7%	1,5%	2,7%
Slovakia	19,3%	21,3%	24,4%	1,9%	5,1%
United Kingdom	9,6%	12,0%	12,3%	2,4%	2,7%
EU28	25,9%	27,6%	27,2%	1,7%	1,3%

5.4.2 Final energy demand and energy carrier mix

As a result of the varying ambition levels across scenarios, but also across member states, the mix of energy carriers in the total final energy demand also varies substantially.

Table 40 shows changes in the energy carrier mix for the *Quota EU 27* and *Quota MS 0.55* scenarios in comparison with the *current policy scenario*. Accordingly, the highest absolute increase is in biomass, with 42 additional TWh in the *Q27* and 81 TWh in the *Q055* scenario. This also reflects the attractiveness of biomass use in all sectors compared to other forms of RES. In the medium term biomass is the main relevant substitute for fossil fuels in the steam generation industry, and in the residential and tertiary sector biomass is a cost efficient option in countries with sufficient biomass potentials.

Ambient heat increases substantially in the *Q055* scenario compared to the other scenarios. Heat pumps are a sensible option for countries with limited biomass resources and relatively cheap electricity supply. The use of solar thermal energy also increases substantially (+22%) compared to the CP scenario. However, demand for the two secondary energy carriers, district heating and electricity, is less affected (-1% in the *Q055* and -2% in the *Q27* scenario). District heating decreases by 3% in the *Q27* scenario and by 5% in the *Q055* scenario compared to the CP scenario. The effect on district heating will, in reality, depend on the final implementation of a quota design and specific treatment of district heating. In any case it is important to consider the share of RES in the supply mix in such a policy design to exploit cost effective potentials for renewable integration (like waste heat or geothermal heat) in heating networks. Total electricity demand for heating and cooling varies by +/- 1% between the scenarios. Note that by definition, in the current Eurostat approach, RES shares in the electricity sector do not affect RES shares of heat supply.

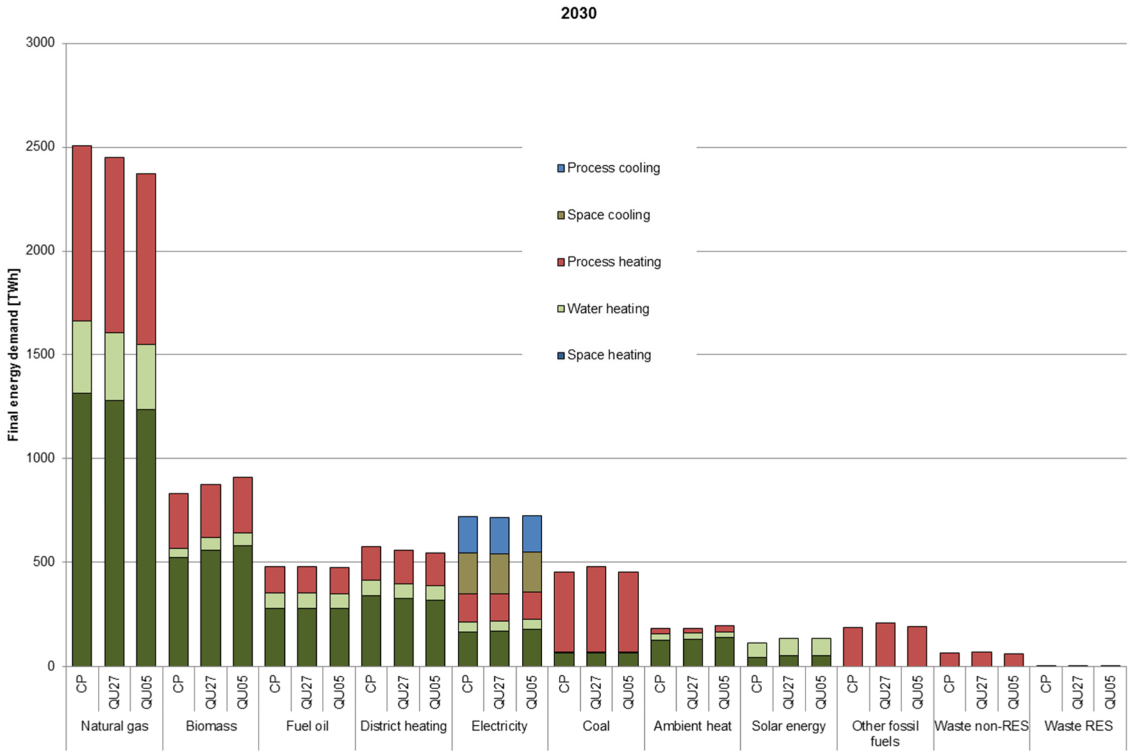
Table 40: Scenario comparison of total final energy demand in 2030 for EU28 [TWh]

	2012 [TWh]			2030 [TWh]	Change compared to current policy scenario [TWh 2030]		Change compared to current policy scenario [% in 2030]	
	all	CP	Q27	Q055	Q27	Q055	Q27	Q055
Ambient heat	79.9	168.3	169.8	181.0	1	13	1%	8%
Biomass	691.9	813.5	855.3	894.8	42	81	5%	10%
Coal	537.7	448.1	471.7	453.7	24	6	5%	1%
District heating	577.5	559.1	542.8	533.3	-16	-26	-3%	-5%
Electricity	719.9	675.4	667.8	684.6	-8	9	-1%	1%
Fuel oil	781.9	448.2	446.4	448.0	-2	0	0%	0%
Natural gas	2656.7	2460.2	2404.7	2348.2	-55	-112	-2%	-5%
Other fossil	237.0	185.2	206.0	193.9	21	9	11%	5%
Solar energy	19.5	108.1	132.4	131.5	24	23	22%	22%
Waste non-RES	37.2	61.3	65.9	61.8	5	1	8%	1%
Waste RES	2.5	3.4	3.5	3.6	0	0	2%	3%
Total	6342	5931	5966	5934	36	4	1%	0%
Total RES	794	1093	1161	1211	68	117	6%	11%
Total non-RES	4251	3603	3595	3506	-8	-97	0%	-3%
Total secondary energy	1297	1234	1211	1218	-24	-17	-2%	-1%

Comparing the use of fossil fuels in total it can be seen it is hardly affected in the *Q27* scenario and declines by only 3% in the *Q055* scenario compared to the CP scenario where fossil fuel use reduces by more than 15% compared to the base year 2012. It can also be seen that natural gas use decreases compared to the current policy scenario while other fossil fuels, such as coal, even increase. This is due to the fact that in some countries, efficient gas boilers are subsidised, which is not the case in the obligation scenarios where we assume that all subsidies for RES and fossil fuel technologies are phased out by 2020.

Figure 69 shows the development of energy carrier by end-use category in different scenarios. Biomass use increases significantly for space heating and hot water supply. Solar thermal energy is increasingly used for hot water supply in the quota scenarios compared to the current policy scenario. Reductions of natural gas use are mainly driven by reductions in space heating which is a direct effect of phased out subsidies for condensing boilers which are currently subsidised in some countries.

Figure 69: Comparison of final energy carriers by end-use category in three scenarios



5.4.3 Cost effectiveness

An indicator of the efficiency of the obligation systems is the resulting marginal RES deployment cost, which equates to the certificate price. The system design with the lowest price tends to be the most efficient. This is at least valid if the target level of the system, for example the RES-H/C share, is similar across the options compared. Due to the varying design, both obligation scenarios result in a different total RES-H/C share in 2030 and thus, a simple comparison of certificate prices does not allow us to draw conclusions on the comparable efficiency of the systems.

In order to cope with this situation, the scenarios *Quota EU 27* and *Quota MS 0.55* are redefined to reach the same RES-H/C share. Due to the step-wise character of the RES cost deployment curve, the RES-H/C share for each obligation design cannot be matched. Therefore, three alternative scenario variations with increasing level of ambition are calculated: 28.0%, 29.0% and 29.8% RES-H/C share for the EU28. These 2030 targets are translated into minimum annual increase figures for the scenarios with national trade only (see Table 41 for an overview).

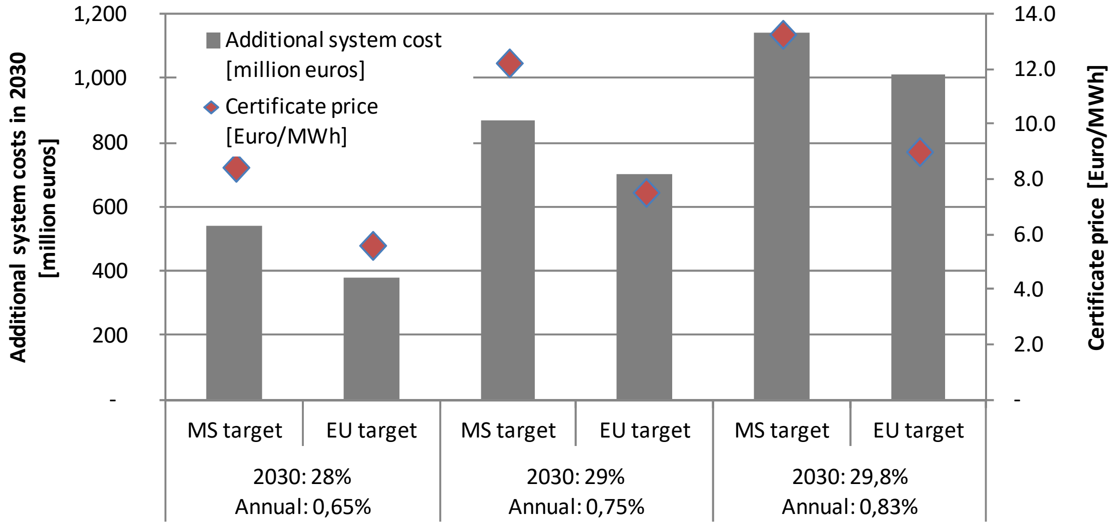
Table 41: Overview of scenario variations used for cost-effectiveness comparison (Each variation reaches the same RES-H/C share in 2030)

	EU target Trade between countries	MS target No trade between countries
Variation 1	28.0% in 2030	0.65%/a from 2020 to 2030
Variation 2	29.0% in 2030	0.75%/a from 2020 to 2030
Variation 3	29.8% in 2030	0.83%/a from 2020 to 2030

Figure 70 and Table 42 show the resulting certificate prices, as well as total annual RES deployment cost in 2030, for all three variations. We distinguish between the two scenario designs: EU-wide target with trade between countries and a specific member state target for the average annual increase in the RES-H/C share without trade between countries. It becomes obvious that, for all three target levels, the system design incorporating the EU-wide trade has a lower certificate price as well as a lower total system cost. The certificate price (and the additional consumer expenditure) is 32% to 38% lower in the case of EU-wide trade, and the RES system cost decreases by 11% to 29%.

Both results clearly indicate the better cost-effectiveness of a system that allows EU-wide trade rather than trade only within member states. However, the technical and administrative feasibility of an EU wide trade system in highly fragmented market makes such a system rather a theoretical policy case. We did not analyse the details of the technical implementation of the trading system. The EU trade could for example either be implemented on the Member State level using cooperation mechanisms or as trading platform between market participants.

Figure 70: Comparison of additional system costs[32] and certificate prices for alternative EU and member state targets



Note that due to the limited potentials available on the calculated RES deployment cost curves, many countries reach the maximum RES deployment at 29.8%. This

32 Cost to induce the required RES deployment compared to the case with a certificate price of zero euros (equal to the area below the cost curve and left of the resulting target RES share)

requires other countries with lower cost potentials to fill the remaining gap and, as a consequence, the difference between the additional annual system cost between the two system designs decreases as both move towards the maximum RES deployment. When reaching the maximum, there will be no difference in the impact and costs of both designs.

Table 42: Comparison of additional system cost and certificate prices for alternative EU and member state targets

Target	MS or EU wide trade?	Certificate price [euro/MWh]	Additional system cost [million euros]
Variation 1 (28.0%)	MS target	8.4	542
	EU target	5.6	382
Variation 2 (29.0%)	MS target	12.2	868
	EU target	7.5	705
Variation 3 (29.8%)	MS target	13.3	1,142
	EU target	9.0	1,014
Variation 1 (28.0%)	Change	-34%	-29%
Variation 2 (29.0%)	Change	-38%	-19%
Variation 3 (29.8%)	Change	-32%	-11%

5.4.4 Primary energy demand, CO_2 emissions and energy imports

In this section the scenarios are compared in terms of primary energy demand, CO_2 emissions and energy imports for the year 2030.

Table 43 and

Figure 71 illustrate differences in **primary energy demand** per energy carrier. Only small changes in total primary energy demand between the scenarios can be observed. In the *Quota EU 27 scenario* primary energy demand is 0.3% higher than in the current policy scenario while the *Quota MS 0.55 scenario* leads to reduction of 0.1%. The increasing use of RES which reduces primary energy demand is partly offset by a shift from natural gas to other fossil energy carriers which typically have lower conversion efficiencies. Both scenarios however lead to a significant increase in RES from a primary energy demand perspective. In relative terms solar energy increases significantly in both scenarios while biomass contributes most in absolute terms. Note that also heat production from biomass results in lower conversion efficiencies compared to natural gas which increases primary energy demand. The reduction of natural gas compared to the *current policy scenario* is a result of both, substitutions by RES due to quota requirements and because it was assumed that subsidies phase out in 2020 if RES obligations are introduced.

Table 43: Primary energy demand and changes compared to the *current policy scenario* for the year 2030, EU28

Energy carrier	Primary energy [TWh]			Change compared to CP in %	
	CP	QU27	QU055	QU27	QU055
Coal	791	807	779	2.0%	-1.5%
Fuel oil	466	464	464	-0.5%	-0.3%
Natural gas	2924	2860	2785	-2.2%	-4.8%
Other fossil fuels	222	242	229	9.0%	3.1%
Waste non-RES	129	131	126	2.1%	-2.0%
Biomass	1161	1194	1236	2.8%	6.4%
Geothermal	36	36	50	-2.1%	38.5%
Solar energy	108	133	132	22.4%	21.6%
Waste RES	73	71	70	-2.7%	-4.3%
Ambient heat total	171	172	183	0.8%	7.3%
Other RES	104	103	104	-1.6%	-0.5%
RES-E (Wind, PV, Hydro)	257	254	273	-1.2%	6.3%
Nuclear	381	380	386	-0.4%	1.1%
Total	6823	6845	6816	0.3%	-0.1%

Figure 71: Primary energy demand in all three scenarios for the year 2030, EU28

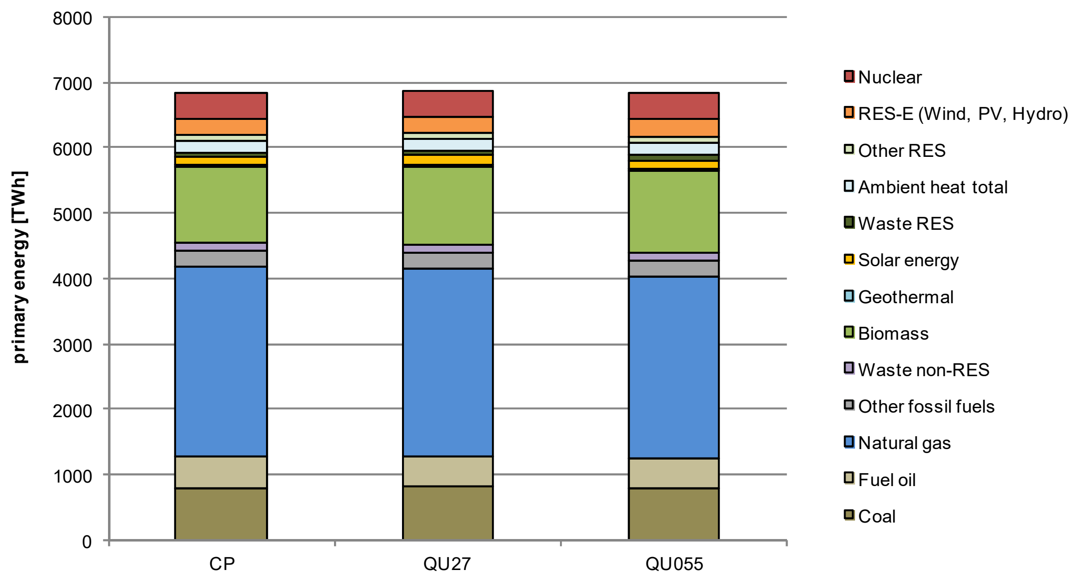
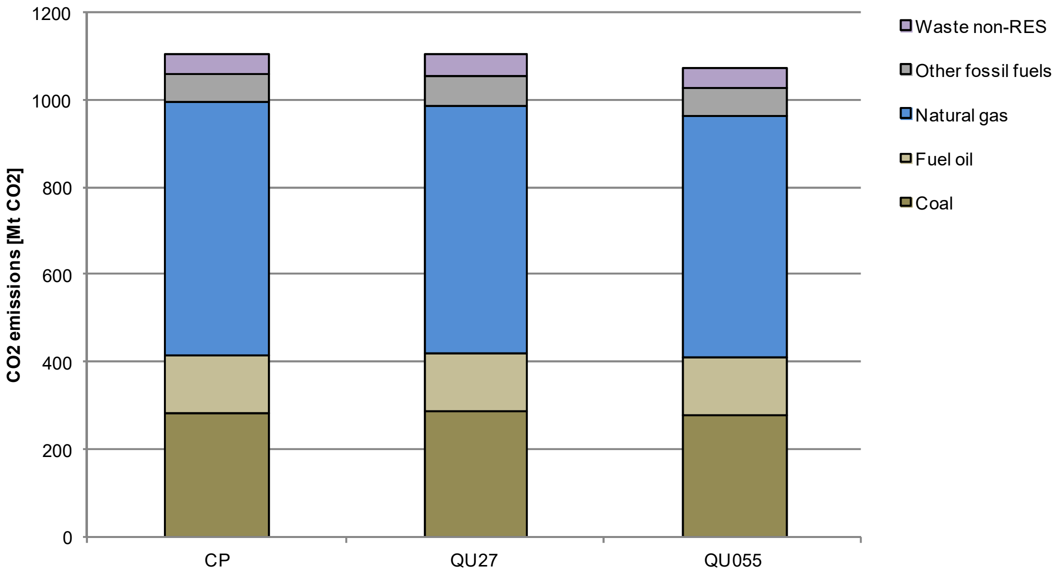


Table 44 and Figure 72 compare **CO_2 emissions** in the year 2030 across the scenarios. The *Quota EU 27 scenario* leads to only -0.1% emission reduction while the *Quota MS 0.55 scenario* results in a reduction of -2.8% compared to the *current policy scenario*. Similar to the development of primary energy demand, emission reductions due to increased use of RES are partly offset by shifts towards other fossil fuels with lower conversion efficiencies and higher CO_2 emission factors offsetting some of the emission reductions achieved through the increase of RES. More specifically, the main reason behind this is the switch from natural gas to other fossil fuels induced by the phase out of natural gas condensing boiler subsidies in 2020 in the quota scenarios. In all scenarios however natural gas combustions accounts for more than 50% of total emissions resulting from H/C demand.

Table 44: CO_2 emissions by energy carrier and scenario for the year 2030, EU28

Energy carrier		Emissions [$MtCO_2$]		Change compared to CP in %	
	CP	QU27	QU055	QU27	QU055
Coal	282	288	278	2.0%	-1.5%
Fuel oil	134	134	134	-0.5%	-0.3%
Natural gas	579	566	551	-2.2%	-4.8%
Other fossil fuels	64	70	66	9.0%	3.1%
Waste non-RES	46	47	45	2.1%	-2.0%
Total	1106	1105	1074	-0.1%	-2.8%

Figure 72: CO_2 emissions by energy carrier and scenario for the year 2030, EU28



Finally Table 45 illustrates **imports and domestic production** of energy carriers for H/C in EU28 for the year 2030. The figures shown in Table 45 are based on the assumption that import shares of each energy carrier do not change from 2012 to 2030. Both scenarios lead to a decrease in imports. In the *Quota EU 27 scenario* imports decrease by -20 TWh (-0.7%) and in the *Quota MS 0.55 scenario* by -90 TWh (-3.1%) compared to the current policy scenario. Most reductions are achieved by substituting natural gas.

Table 45: Comparison of energy carrier imports for H/C between scenarios in the year 2030, EU28

Energy carrier	Domestic [TWh]			Imports [TWh]			Import change to CP in %	
	CP	QU27	QU055	CP	QU27	QU055	QU27	QU055
Coal	459	468	452	332	339	327	2.0%	-1.5%
Fuel oil	56	56	56	410	408	409	-0.5%	-0.3%
Natural gas	1000	978	952	1924	1882	1832	-2.2%	-4.8%
Other fossils	33	36	34	189	205	194	9.0%	3.1%
Waste non-RES	127	130	125	2	2	2	2.1%	-2.0%
Biomass	1130	1162	1202	31	32	33	2.8%	6.4%
Other energy carriers	1131	1147	1197	0	0	0	0.0%	0.0%
Total	3935	3977	4018	2888	2868	2798	-0.7%	-3.1%

As discussed in section 4.1.8 the development of domestic production of fossil fuels and the resulting import share is uncertain. If we assume constant import shares for each energy carrier (case 1) total energy import shares to cover demand for H/C would be 42.3% in the *CP scenario*, 41.9% in the *Q27 scenario* and 41% in the *Q055 scenario* as shown in Table 46. Assuming that all demand reductions of fossil fuels would directly reduce imports (case 2) the import shares would be reduced to 36.6%, 36% and 34.6% respectively. Assuming that only domestic production is affected by demand reductions (case 3) import shares are above 49% in all scenarios although total imports would be reduced. As already discussed the actual reduction will be determined by global market prices, marginal production costs in EU28 and political decisions concerning the use and exploration of lignite and shale gas, all of which were not in the focus of this study.

Table 46: Total energy import shares for H/C by scenario and in the year 2030, EU28

Domestic production case			Import share
	CP	QU27	QU05
Case 1	42.3%	41.9%	41.0%
Case 2	36.6%	36.0%	34.6%
Case 3	49.3%	49.4%	49.4%

6 Conclusions and recommendations

The ***current policy scenario*** shows a decrease in **final energy demand** for H/C of around 7% from 6,350 TWh in 2012 to 5,930 TWh in 2030. This decrease is mainly driven by thermal efficiency measures in buildings. The use of RES increases by 38% up to 2030, from 2012, and reaches a total of 1,093 TWh. At the same time, the direct use of fossil fuels is reduced by 15%. Electricity and district heating also experience a slight decrease of about 7% and 3%, respectively.

Although **space cooling** demands will rise substantially and **space heating** energy use falls in the period up to 2030, space cooling will still be much less important, in terms of energy demand, than space heating.

Consequently, the **RES-H/C share** increases, from 16.7% in 2012 to 25.9% in 2030, mostly driven by increased deployment of RES, but also as a result of falling final energy demand.

Primary energy use for H/C also decreases substantially, from 7,495 TWh in 2012 to 6,823 TWh in 2030. Previous trends in energy mix continue and shift towards higher shares of RES. For example, biomass provides about 17% of all primary energy for H/C in 2030, up from 12% in 2012. Ambient heat and solar energy increase to shares of 3% and 2%, respectively, while the use of fossil fuel continuously declines. For example the share of coal drops from 15% in 2012 to 12% in 2030.

In 2012 EU28 **import dependency** for primary energy used for H/C was about 49.2%. In the *current policy scenario*, the import share is ranging from 36.6% to 49% in 2030 depending on the domestic production[33]. Thus, it is very likely that – assuming an ambitious implementation of current policies in the H/C sector - EU28 import dependency will decrease up until 2030. This is driven by both energy efficiency improvements and a shift towards (domestic) RES.

Total **CO_2 emissions** related to H/C fall by 22.5% from 1,427 million tonnes in 2012 to 1,106 million tonnes in 2030. The residential sector contributes most to this reduction, with a drop of about 41%, while the industrial sector emissions only fall by about 5%. CO_2 emissions are calculated based on the primary energy demand of the industry, tertiary and residential sectors and thus also include CO_2 emissions from the production of electricity and district heating. Lifecycle emissions, for example from biomass use, are not considered.

With the changing technology structure in the H/C sector, the structure of the system **cost** changes, as investment costs become more important than fuel costs.

In summary, the *current policy scenario* reflects a substantial change in the entire H/C sector towards greater use of RES, driven by existing policy initiatives mostly at the EU level. As might be expected however, the model assumptions and results contain a certain degree of uncertainty. For example, if fuel prices develop differently, or policies are not enforced, the development of RES deployment could be less dynamic.

The **results** of the supplier obligation scenario with a **annual increase of the quota**

[33] The overall import reduction will mainly depend on the global market price and European production costs. For high prices above marginal production costs in Europe the assumption that reductions in demand for fossil fuels mainly affect imports (case 2) is more justified than in a scenario with low fossil fuel prices in which also domestic producers would be affected by reductions in domestic demand (case 3).

on member state level (Gradual Quota MS) show that the targeted annual average RES-H/C share increase, of at least 0.55%/a, is reached in all countries except Cyprus (0.1%/a) and Italy (0.54%). The majority of countries achieve an average annual increase between 0.55% and 0.6%. The required certificate price to induce this RES increase varies substantially by country, from zero to nearly 10 euros/MWh. The average EU28 price is 7.7 euros/MWh and in total a RES-H/C share of 27.6% is achieved.

The supplier obligation scenario **with EU wide quota for 2030 (2030 Quota EU)** achieves a RES share of 27.2% and a related certificate price of 3.5 euros/MWh in all member states (reflecting EU wide trade between countries or companies).

Comparing the scenarios shows that for the EU28 as a whole, the RES-H/C share achieved is 1.7 (*Gradual Quota MS*) and 1.4 (*2030 Quota EU)* percentage points higher than in the *current policy scenario*. This additional level of ambition is comparably low, simply because the *current policy scenario* already achieves a high RES-H/C share of 25.9% by 2030. However, the cost curve indicates that, up to 2030, the contribution of an obligation scheme could be substantially higher, achieving, for example, a 30% RES H/C share with a certificate price of about 10 euros/MWh.

Biomass contributes most to this RES increase with 41 TWh (*2030 Quota EU*) and 81 TWh (*Gradual Quota MS*) more than in the *current policy scenario* in 2030. However, solar energy also increases substantially in both scenarios (+22%). Among the fossil fuel technologies, the largest decrease is in natural gas, while other fossil fuels, such as coal, even increase slightly. This shift is mainly driven by the phase out of subsidies for highly efficient natural gas boilers, as well as by the fact that the RES Obligation system does not discriminate between fossil technologies.

In order to compare the **cost-effectiveness** of the individual systems, the policy targets (RES-H/C share) have to be levelled. We have calculated three variations with varying RES-H/C shares for the two obligation system designs.. Results show that for all three target levels the system design with the EU-wide quota and trade between suppliers and different member states achieves the same results as the MS target (with no trade) using a lower certificate price and lower additional system cost. The certificate price (and thus also the consumer expenditure) is 32% to 38% lower in the case of EU-wide trade, and the additional system cost decreases by 11% to 29%.

In summary, the following conclusions can be drawn from the obligation scenarios.

- Supplier obligation schemes for RES-H/C can act as new policy instrument to reach a 27% RES-H/C target on the EU level in 2030.
- Additional potentials to reach higher RES-H/C shares are available and can theoretically be exploited using an obligation scheme: a support level of 10 euros/MWh would generate a RES-H/C share of about 30% – given the assumptions of the current policy scenario.
- The starting point and remaining RES-H/C potential vary substantially between countries. Depending on the design, a supplier obligation scheme can be a significant burden for some countries while hardly affecting others.
- If markets work efficiently, an EU wide obligation scheme with trade between countries can generate efficiency gains than pure national targets that do not allow flexibility between countries.
- An obligation scheme can follow a least cost RES deployment in the short term. However it is not clear that this would be sustainable in the long term or whether it would result in lock-in effects. An example is the projected use of available biomass in the space heating sector which might in the long term be more efficiently used in other sectors.
- If the introduction of a RES obligation scheme also involves the phase out of

existing subsidies for H/C technologies, such as efficient natural gas boilers, a substantially reduction of natural gas can be achieved..

When interpreting the scenario results it is also essential to bear in mind the **assumptions** and **system boundaries** of this analysis. Scenarios for the long-term future evolution of the economy always involve a certain degree of uncertainty. The RES-H/C deployment is particularly driven by the relative level of fuel prices. For example, lower fossil fuel prices could substantially affect shares of RES-H/C. Furthermore, the models assume compliance with the policies considered, as well as the efficient working of markets.

Finally, our analysis also revealed the **need for additional research**. This includes the following aspects.

The RES deployment cost curve approach used, enabled certificate prices in the range between zero and 10 euros/MWh to be analysed. Prices above this range have not been systematically assessed. While in many countries RES deployment increased linearly with certificate price increases, it is very likely that this pattern will change with higher price / support levels that are not included in our analysis. At a certain point, early replacement of capital stock might cause an exponential increase in cost. Future research could explore the impact and costs of very ambitious RES deployment paths.

While our analysis examined the period to 2030 it is important to bear in mind long-term development and targets. Even if obligation schemes might be an efficient instrument for short-term least-cost RES deployment, they might not be in line with long-term optimal paths. All scenarios result in a strong deployment of biomass in all scenarios. While this is a competitive and effective energy supply for heating and cooling in the short term, in the long term it might be more efficiently used in other sectors where fewer alternative mitigation options are available. Future research could particularly look at the role of the H/C sector in long-term mitigation scenarios that take all sectors into account.

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8 Annex Workpackage 3

8.1 Annex to chapter 4.1: Current policy results – All sectors

Primary energy demand for H/C in the EU28 in all sectors by energy carrier, *current policy scenario* [TWh/a]

	2012 Total	2012 Share	2020 Total	2020 Share	2030 Total	2030 Share	2030 / 2012 Change
Ambient heat	82	1%	128	2%	171	3%	107%
Biomass	878	12%	1049	14%	1161	17%	32%
Coal	1149	15%	1040	14%	791	12%	-31%
District heating	0	0%	0	0%	0	0%	0%
Electricity	0	0%	0	0%	0	0%	0%
Fuel oil	878	12%	645	9%	466	7%	-47%
Geothermal	23	0%	28	0%	36	1%	55%
Natural gas	3286	44%	3072	42%	2924	43%	-11%
Other fossil fuels	292	4%	255	4%	222	3%	-24%
Other RES	71	1%	101	1%	104	2%	47%
Solar energy	20	0%	60	1%	108	2%	452%
Waste non-RES	83	1%	119	2%	129	2%	55%
Waste RES	47	1%	69	1%	73	1%	55%
RES-E (Wind, PV, Hydro)	144	2%	214	3%	257	4%	78%
Nuclear	542	7%	452	6%	381	6%	-30%
Total	7495	100%	7233	100%	6823	100%	-9%
Total RES	1265	17%	1649	23%	1910	28%	51%
Total non-RES	6230	83%	5583	77%	4913	72%	-21%

Primary energy demand by end-use category, EU 28, current policy scenario [TWh/a and %]

	Total [TWh/a]			Share [%]			Change
	2012	2020	2030	2012	2020	2030	2030/2012
Space cooling	291	324	347	4%	4%	5%	19%
Space heating	3848	3487	3056	51%	48%	45%	-21%
Water heating	738	746	744	10%	10%	11%	1%
Process heating	2188	2335	2360	29%	32%	35%	8%
Process cooling	430	341	316	6%	5%	5%	-26%
Total	7495	7233	6823	100%	100%	100%	-9%

Useful energy demand by country and by end-use in 2030, *current policy scenario* [TWh]

	2030					Change 2030/2012				
	Space heating	Process heating	Space cooling	Process cooling	Water heating	Space heating	Process heating	Space cooling	Process cooling	Water heating
Austria	58.4	53.2	3.3	8.0	8.8	-11%	16%	41%	-20%	27%
Belgium	65.9	58.5	3.9	15.9	9.2	-20%	13%	71%	15%	22%
Bulgaria	17.4	16.5	10.5	1.9	2.5	-4%	27%	51%	-55%	-3%
Croatia	11.8	7.5	4.5	1.7	1.7	-2%	21%	39%	-32%	-1%
Cyprus	0.7	1.1	2.6	0.6	0.6	-36%	8%	29%	-31%	28%
Czech Republic	59.6	46.5	5.8	5.5	7.0	-8%	24%	64%	-19%	17%
Denmark	33.1	14.5	0.9	9.0	5.7	-17%	27%	129%	25%	9%
Estonia	7.6	3.5	0.6	0.6	0.6	-26%	35%	98%	-30%	-6%
Finland	71.1	59.2	1.7	8.5	3.8	-8%	15%	28%	15%	4%
France	341.8	127.6	68.9	68.2	45.7	-11%	3%	62%	7%	26%
Germany	398.8	308.3	27.2	83.5	74.0	-28%	-1%	76%	-2%	0%
Greece	30.2	13.7	22.7	5.1	4.7	-61%	-4%	35%	-35%	-8%
Hungary	43.8	16.3	4.0	3.4	4.7	-17%	30%	93%	-33%	9%
Ireland	19.7	9.9	1.0	6.1	2.7	-21%	26%	77%	13%	7%
Italy	286.5	151.2	118.7	51.5	59.2	-10%	9%	40%	1%	47%
Latvia	9.8	6.7	0.8	0.6	1.3	-25%	38%	81%	-57%	-2%
Lithuania	9.4	6.3	1.1	1.2	1.3	-24%	18%	138%	-46%	-4%
Luxembourg	5.0	3.2	0.4	1.7	0.6	-23%	-4%	2%	114%	13%
Malta	0.2	0.1	1.2	0.2	0.1	-30%	16%	59%	-15%	19%
Netherlands	88.0	91.0	7.0	25.7	12.5	-29%	13%	45%	20%	-4%
Poland	148.9	115.3	11.3	16.7	17.0	-15%	36%	100%	-25%	12%
Portugal	15.8	29.4	20.3	4.6	5.5	-15%	13%	106%	-40%	19%
Romania	48.5	53.0	3.3	4.3	6.0	-4%	55%	64%	-43%	-5%
Slovakia	25.3	23.8	3.9	1.7	2.5	-31%	11%	46%	-38%	-17%
Slovenia	7.7	7.1	1.6	1.1	0.9	-17%	33%	44%	-16%	1%
Spain	88.9	122.5	82.9	30.5	33.0	3%	12%	13%	-25%	-5%
Sweden	64.6	57.5	1.7	14.1	8.1	-20%	3%	30%	29%	4%
United Kingdom	224.9	129.6	6.8	30.0	64.2	-32%	15%	177%	-40%	23%
Iceland	7.9	0.5	0.2	1.2	0.6	9%	15%	24%	41%	58%
Norway	34.2	18.0	0.9	11.0	3.0	-12%	8%	90%	43%	4%
Switzerland	54.6	17.0	4.0	10.7	9.0	0%	13%	39%	37%	28%
EU28	2183	1533	419	402	384	-20%	12%	44%	-9%	14%
EU28+NO+CH+IS	2280	1568	424	425	396	-19%	12%	44%	-7%	14%

RES-H/C shares reported by the Eurostat SHARES project from 2004 to 2014 [%]

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
EU28	10.2	10.8	11.4	12.8	13.1	14.7	14.8	15.4	16.2	16.6	17.7
Belgium	2.9	3.4	3.7	4.5	5.0	5.9	5.8	6.7	7.3	7.5	7.8
Bulgaria	14.1	14.3	14.8	13.9	17.3	21.7	24.4	24.9	27.5	29.2	28.3
Czech Republic	8.4	9.1	9.7	11.4	11.2	11.8	12.6	13.2	14.1	15.4	16.7
Denmark	20.7	22.8	23.8	26.9	28.1	29.5	30.9	32.3	33.6	34.9	37.8
Germany	6.3	6.8	7.0	8.4	7.4	9.2	9.8	10.5	10.4	10.6	12.2
Estonia	33.2	32.2	30.7	32.7	35.5	41.8	43.3	44.1	43.1	43.2	45.2
Ireland	2.9	3.5	3.6	3.9	3.6	4.3	4.5	4.9	5.1	5.4	6.6
Greece	12.8	12.8	12.5	14.4	14.3	16.4	17.8	19.4	23.3	26.5	26.9
Spain	9.5	9.4	11.4	11.3	11.7	13.3	12.6	13.6	14.1	14.1	15.8
France	12.3	12.3	11.6	12.6	13.1	14.9	15.9	15.9	16.9	17.8	17.8
Croatia	29.4	30.0	29.1	29.2	28.7	31.2	32.8	33.7	36.5	37.2	36.2
Italy	5.7	8.2	10.1	13.3	15.3	16.4	15.6	13.8	17.0	18.1	18.9
Cyprus	9.3	10.0	10.4	13.1	14.5	16.3	18.2	19.2	20.8	21.7	21.8
Latvia	42.5	42.7	42.6	42.4	42.9	47.9	40.7	44.7	47.3	49.7	52.2
Lithuania	30.4	30.1	29.7	29.8	32.8	34.4	33.2	33.7	35.5	37.7	41.6
Luxembourg	1.8	3.6	3.6	4.4	4.6	4.7	4.8	4.8	5.0	5.8	7.4
Hungary	6.5	6.0	7.5	8.9	8.3	10.5	11.0	12.3	13.5	12.6	12.4
Malta	1.1	2.2	2.6	3.2	3.6	1.8	7.4	10.7	13.1	14.6	14.6
Netherlands	2.2	2.4	2.8	3.0	3.1	3.4	3.1	3.7	3.9	4.1	5.2
Austria	21.4	22.1	22.9	25.7	26.1	28.1	29.8	30.2	31.2	32.7	32.6
Poland	10.3	10.2	10.2	10.4	10.9	11.6	11.7	13.1	13.4	14.1	13.9
Portugal	32.5	32.1	34.2	35.0	37.5	38.0	33.9	35.2	34.0	34.5	34.0
Romania	17.6	18.0	17.6	19.4	23.2	26.4	27.2	24.3	25.8	26.2	26.8
Slovenia	18.4	18.9	18.6	20.4	19.2	27.3	28.3	30.2	31.7	33.7	33.3
Slovak Republic	5.1	5.0	4.5	6.2	6.1	8.2	7.9	9.3	8.8	7.9	8.7
Finland	39.5	39.1	41.4	41.5	43.4	43.4	44.3	46.0	48.5	50.8	51.9
Sweden	46.7	51.9	56.4	58.7	61.1	63.6	60.9	62.5	65.8	67.1	68.1
United Kingdom	0.8	0.8	0.9	1.1	2.0	2.5	2.8	3.1	3.3	3.8	4.5
Iceland	52.3	53.4	56.9	58.6	62.0	62.1	63.9	65.2	67.2	62.1	76.7
Norway	25.6	28.9	28.6	29.6	31.2	32.3	32.9	34.6	34.2	33.4	32.5

Average annual cost for heating and cooling in industry including building insulation [million euro / a]

		Fuel costs		Investments
Country	**2012-2020**	**2021-2030**	**2012-2020**	**2021-2030**
Austria	1,889	2,317	673	589
Belgium	1,887	2,258	654	537
Bulgaria	578	672	90	81
Croatia	342	383	61	54
Cyprus	57	86	6	5
Czech Rep.	1,424	1,712	272	252
Denmark	771	999	174	160
Estonia	166	208	20	20
Finland	3,820	4,101	814	751
France	4,591	5,331	1,380	1,297
Germany	12,776	13,218	3,073	2,708
Greece	846	890	161	153
Hungary	456	507	76	72
Ireland	606	751	158	134
Italy	6,866	7,289	1,448	1,339
Latvia	201	270	33	31
Lithuania	337	375	33	30
Luxembourg	108	116	42	43
Malta	14	14	5	5
Netherlands	3,096	3,716	684	648
Poland	2,133	2,845	456	389
Portugal	1,232	1,443	227	200
Romania	1,195	1,553	184	186
Slovakia	949	925	265	257
Slovenia	246	285	41	41
Spain	4,265	5,037	1,289	1,087
United Kingdom	5,743	6,683	1,591	1,440
Sweden	2,603	3,177	487	465
Iceland	372	315	256	298
Norway	673	770	197	252
Switzerland	625	750	177	151
EU 28	59,196	67,161	14,396	12,973

Average annual costs for heating and cooling in the tertiary sector including building insulation [million euro / a]

	Fuel costs		Investments		O&M	
Country	2012-2020	2021-2030	2012-2020	2021-2030	2012-2020	2021-2030
Austria	1,519	1,248	361	282	91	101
Belgium	2,237	1,582	482	424	134	152
Bulgaria	602	611	624	476	74	94
Croatia	362	302	110	90	41	48
Cyprus	660	872	36	37	9	8
Czech Republic	979	818	356	342	93	110
Denmark	1,735	1,450	132	116	52	58
Estonia	267	218	35	33	13	15
Finland	2,030	1,576	195	168	63	72
France	11,477	11,296	3,353	2,638	808	943
Germany	15,815	10,387	5,301	4,080	1434	1630
Greece	1,997	1,955	333	361	128	143
Hungary	483	508	307	285	92	109
Ireland	769	556	475	383	65	79
Italy	6,927	6,619	1,391	1,386	431	555
Latvia	353	290	65	65	21	23
Lithuania	360	296	81	85	18	22
Luxembourg	225	152	27	20	6	8
Malta	122	90	18	16	4	4
Netherlands	2,835	2,728	636	633	230	267
Poland	3,371	2,467	1,436	1,215	346	404
Portugal	1,313	1,434	459	405	93	109
Romania	606	552	362	394	122	141
Slovakia	452	391	202	169	58	65
Slovenia	317	248	64	51	24	28
Spain	10,018	9,480	1,569	1,457	359	414
Sweden	3,008	2,436	454	384	101	116
UK	2,960	2,300	2,276	2,211	762	908
Switzerland	80	70	390	289	118	131
Norway	1,568	1,309	537	384	69	84
Iceland	2,648	1,937	46	37	5	6
EU28	73,796	62,862	21,139	18,206	5,673	6,626
EU28+3	78,091	66,179	22,112	18,914	5,865	6,847

Average annual cost for heating and cooling in the residential sector including investments in building insulation [million euro / a]

		Fuel costs		Investments		O&M
Country	**2012-2020**	**2021-2030**	**2012-2020**	**2021-2030**	**2012-2020**	**2021-2030**
Austria	2,263	1,836	2,759	3,887	251	233
Belgium	4,404	4,101	2,357	3,562	204	244
Bulgaria	1,013	853	269	423	84	77
Croatia	751	811	335	417	67	60
Cyprus	151	131	121	180	27	25
Czech Republic	3,166	2,806	542	788	152	150
Denmark	2,942	2,598	1,321	1,742	153	159
Estonia	376	330	118	176	15	14
Finland	3,355	3,128	1,663	1,933	246	265
France	21,066	18,344	7,858	14,464	1,237	1,208
Germany	20,717	17,997	20,666	17,918	2,031	1,649
Greece	2,878	2,400	974	1,236	262	210
Hungary	1,637	1,289	786	1,120	74	80
Ireland	2,144	1,803	719	878	56	70
Italy	22,166	18,951	12,727	15,267	1,112	1,033
Latvia	456	391	223	387	24	22
Lithuania	642	432	199	215	27	23
Luxembourg	209	189	93	140	19	20
Malta	54	53	13	18	2	2
Netherlands	5,126	4,307	2,485	3,257	276	250
Poland	20,101	16,881	1,168	1,604	437	422
Portugal	705	542	1,058	1,501	108	114
Romania	1,607	1,460	770	1,160	354	319
Slovakia	913	746	407	581	34	38
Slovenia	520	453	95	116	27	23
Spain	7,399	5,932	4,800	6,811	669	690
Sweden	4,069	3,647	2,620	3,165	285	263
United Kingdom	16,484	12,736	7,200	9,432	630	549
Switzerland	2,865	3,010	1,214	1,784	223	208
Norway	2,663	2,132	905	1,123	139	124
Iceland	68	71	30	36	10	10
EU28	147,313	125,144	74,345	92,379	8,860	8,211
EU28+3	152,910	130,357	76,493	95,322	9,232	8,553

8.2 Annex Chapter 4.2: Current policy scenario - Industry

Current policy scenario final energy demand for H/C in industry by country [TWh]

Country	2012	2020	2030	Change 2020/2012	Change 2030/2012
Austria	83.0	86.6	87.7	4%	6%
Belgium	90.0	96.2	95.3	7%	6%
Bulgaria	23.9	25.6	27.3	7%	14%
Croatia	11.2	11.8	12.5	6%	12%
Cyprus	1.5	1.6	1.6	7%	7%
Czech Republic	69.2	75.2	77.6	9%	12%
Denmark	19.8	21.3	23.3	8%	18%
Estonia	4.7	5.3	5.6	13%	20%
Finland	97.2	99.1	101.4	2%	4%
France	219.9	231.3	215.7	5%	-2%
Germany	522.6	515.2	493.6	-1%	-6%
Greece	25.7	23.8	24.1	-8%	-6%
Hungary	22.3	25.8	26.4	16%	19%
Ireland	18.0	19.2	20.2	6%	12%
Italy	252.3	258.3	258.2	2%	2%
Latvia	8.4	9.9	10.7	18%	27%
Lithuania	9.3	10.1	10.0	9%	8%
Luxembourg	6.2	6.4	6.1	3%	-2%
Malta	0.1	0.1	0.1	-3%	-9%
Netherlands	135.1	141.0	143.1	4%	6%
Poland	132.7	156.5	171.8	18%	29%
Portugal	43.4	44.7	46.0	3%	6%
Romania	61.8	78.6	85.5	27%	38%
Slovakia	46.0	47.8	49.2	4%	7%
Slovenia	8.9	9.8	10.9	11%	23%
Spain	190.3	192.0	202.5	1%	6%
Sweden	88.2	89.5	87.2	1%	-1%
United Kingdom	198.4	215.0	209.2	8%	5%
Iceland	3.2	3.3	3.4	2%	4%
Norway	28.8	30.0	30.0	4%	4%
Switzerland	23.6	24.4	25.2	3%	7%
EU28	2390	2498	2503	5%	5%
EU28+NO+CH+IS	2446	2556	2561	4%	5%

8.3 Annex Chapter 4.2: Current policy scenario - Tertiary

Current policy scenario, final energy demand for H/C in the tertiary sector by energy carrier and by country for 2012 and 2030 [TWh]

		Natural Gas	Fuel oil	Electricity	District heat	Biomass	Other RES	Other Fossil
AT	2012	6.1	0.7	1.5	9.8	0.8	0.6	0.0
	2030	7.3	1.0	1.5	11.9	1.8	1.1	0.0
BE	2012	19.7	9.6	2.6	1.1	0.4	0.0	0.0
	2030	18.9	5.1	2.6	0.8	0.6	1.8	0.0
BG	2012	1.0	0.3	0.8	1.3	0.5	0.1	0.0
	2030	2.5	0.2	1.2	0.7	0.4	3.2	0.0
CY	2012	0.0	0.2	0.1	0.0	0.0	0.1	0.0
	2030	0.0	0.1	0.1	0.2	0.1	0.0	0.0
CZ	2012	15.0	0.1	1.6	6.0	0.4	0.1	0.3
	2030	13.7	0.2	1.5	3.8	1.9	1.1	0.1
DE	2012	106.2	81.2	17.2	21.0	14.5	1.2	1.2
	2030	92.5	34.5	17.0	23.0	19.8	14.1	0.3
DK	2012	2.3	0.7	1.4	8.9	0.4	0.2	0.0
	2030	1.4	0.5	1.1	8.4	0.3	0.3	0.0
EE	2012	0.4	0.5	0.2	1.9	0.1	0.0	0.0
	2030	0.3	0.4	0.3	1.2	0.1	0.1	0.0
EL	2012	1.6	0.7	1.2	0.0	0.3	0.2	0.0
	2030	1.7	1.5	1.4	0.0	0.8	1.6	0.0
ES	2012	18.8	14.4	7.7	0.3	0.8	0.5	0.0
	2030	24.5	12.1	10.7	0.2	2.4	6.4	0.0
FI	2012	0.4	3.3	3.4	11.9	1.0	0.4	0.0
	2030	0.7	2.0	2.5	10.6	0.7	0.8	0.0
FR	2012	77.9	26.8	13.5	9.9	2.4	1.8	0.0
	2030	89.2	15.3	12.5	9.7	7.5	7.2	0.0
HR	2012	1.5	0.7	0.3	0.5	0.0	0.0	0.0
	2030	1.0	1.0	0.5	0.3	0.2	1.1	0.0
HU	2012	16.1	0.1	1.1	1.3	1.5	0.0	0.0
	2030	15.7	0.4	1.2	1.4	2.4	1.0	0.0
IE	2012	4.7	4.2	0.8	0.0	0.3	0.0	0.0
	2030	4.1	2.9	1.0	0.2	0.7	1.4	0.0
IT	2012	84.6	2.2	6.3	2.6	0.5	3.2	0.0
	2030	143.7	4.9	5.8	2.1	3.4	8.2	0.0
LT	2012	0.7	0.0	0.3	1.8	0.4	0.0	0.5
	2030	1.1	0.0	0.4	2.1	0.3	0.2	0.1
LU	2012	1.8	0.7	0.2	0.7	0.0	0.0	0.0
	2030	1.5	0.2	0.1	0.4	0.0	0.1	0.0
LV	2012	1.1	0.5	0.2	1.6	1.1	0.0	0.1
	2030	1.1	0.4	0.3	1.8	0.4	0.2	0.0
MT	2012	0.0	0.0	0.1	0.0	0.0	0.0	0.0

		Natural Gas	Fuel oil	Electricity	District heat	Biomass	Other RES	Other Fossil
	2030	0.0	0.1	0.1	0.0	0.0	0.0	0.0
NL	2012	56.3	1.3	3.6	3.6	0.6	0.2	0.1
	2030	36.7	1.1	3.5	1.8	1.6	2.7	0.0
PL	2012	22.5	5.1	3.1	16.4	2.5	0.1	9.5
	2030	28.0	4.3	3.8	9.9	2.6	4.2	2.0
PT	2012	2.5	1.1	1.5	0.2	0.2	0.3	0.0
	2030	3.1	1.0	1.6	0.4	1.9	0.7	0.0
RO	2012	8.9	0.7	0.9	2.7	0.0	0.0	0.0
	2030	10.1	0.7	1.2	2.7	0.1	1.9	0.0
SE	2012	1.4	4.0	6.5	16.6	0.6	1.2	0.0
	2030	1.5	1.6	2.7	18.1	0.3	0.5	0.0
SI	2012	0.2	1.2	0.5	0.5	0.0	0.0	0.0
	2030	0.2	0.9	0.5	0.4	0.3	0.7	0.0
SK	2012	7.5	0.0	0.7	9.8	0.2	0.0	1.1
	2030	7.1	0.3	0.8	1.1	0.3	0.5	0.2
UK	2012	90.6	7.8	12.4	4.7	0.7	0.1	0.1
	2030	89.9	8.7	11.7	5.9	1.0	7.5	0.0

8.4 Annex Chapter 4.2: Current policy scenario - Residential

Final energy demand by country and end-use in residential buildings for 2012, 2020 and 2030, current policy scenario [TWh]

	2012	2020	2030	Change 2020/2012	Change 2030/2012
Austria	63.2	59.8	48.5	-5%	-23%
Belgium	79.1	75.9	64.9	-4%	-18%
Bulgaria	22.0	21.3	19.3	-3%	-12%
Croatia	14.9	14.3	13.9	-4%	-6%
Cyprus	2.1	1.9	1.8	-8%	-17%
Czech Republic	60.8	62.0	59.5	2%	-2%
Denmark	43.0	41.4	37.8	-4%	-12%
Estonia	10.1	9.3	7.8	-8%	-23%
Finland	58.5	58.9	58.1	1%	-1%
France	373.1	358.7	339.4	-4%	-9%
Germany	558.3	470.9	391.8	-16%	-30%
Greece	51.2	40.6	31.9	-21%	-38%
Hungary	51.8	48.0	39.4	-7%	-24%
Ireland	25.1	22.7	19.0	-10%	-25%
Italy	365.2	333.1	288.4	-9%	-21%
Latvia	13.6	12.3	9.5	-10%	-30%
Lithuania	13.8	11.9	9.0	-14%	-35%
Luxembourg	4.8	4.6	4.2	-5%	-12%
Malta	0.5	0.5	0.4	-6%	-25%
Netherlands	97.0	85.6	72.5	-12%	-25%
Poland	198.9	185.3	165.9	-7%	-17%
Portugal	12.2	11.1	9.1	-9%	-26%
Romania	61.8	59.5	54.3	-4%	-12%
Slovakia	20.2	18.1	15.0	-10%	-26%
Slovenia	11.5	10.1	9.4	-12%	-18%
Spain	107.8	107.2	101.9	-1%	-5%
Sweden	70.4	66.1	61.0	-6%	-13%
United Kingdom	360.3	288.4	236.3	-20%	-34%
Iceland	5.2	4.9	4.5	-6%	-12%
Norway	32.3	31.1	28.2	-4%	-13%
Switzerland	56.8	57.1	55.8	0%	-2%
EU28	2751	2480	2170	-10%	-21%
EU28+NO+CH+IS	2846	2573	2259	-10%	-21%

Final energy demand by end-use in residential buildings by country, current policy scenario, 2030 [TWh]

	2030			Change 2030/2012		
	Water heating	Space heating	Space cool-ing	Water heating	Space heating	Space cool-ing
Austria	39.2	0.16	9.20	-28%	136%	4%
Belgium	53.5	0.23	11.18	-23%	185%	15%
Bulgaria	14.6	1.57	3.16	-13%	13%	-15%
Croatia	11.0	0.84	2.14	-7%	18%	-9%
Cyprus	0.7	0.28	0.79	-38%	25%	2%
Czech Republic	48.1	0.23	11.19	-5%	82%	11%
Denmark	29.4	0.08	8.30	-16%	789%	3%
Estonia	6.9	0.01	0.90	-25%	32%	-10%
Finland	53.8	0.06	4.23	-1%	84%	-4%
France	300.2	1.89	37.33	-12%	213%	16%
Germany	295.7	1.70	94.44	-35%	112%	-10%
Greece	23.4	1.11	7.46	-42%	23%	-24%
Hungary	35.3	0.09	4.07	-24%	142%	-22%
Ireland	14.9	0.01	4.03	-29%	68%	-2%
Italy	232.9	11.59	43.89	-25%	21%	-7%
Latvia	7.9	0.02	1.54	-33%	81%	-16%
Lithuania	7.3	0.07	1.59	-38%	445%	-22%
Luxembourg	3.6	0.01	0.63	-17%	296%	43%
Malta	0.2	0.14	0.07	-29%	-11%	-33%
Netherlands	59.9	0.14	12.44	-29%	74%	-2%
Poland	145.2	0.23	20.47	-18%	18%	-4%
Portugal	5.0	0.33	3.80	-20%	57%	-34%
Romania	46.7	0.60	7.00	-10%	19%	-25%
Slovakia	12.0	0.05	2.94	-30%	229%	-4%
Slovenia	7.5	0.14	1.76	-21%	60%	-6%
Spain	60.4	3.70	37.76	3%	96%	-20%
Sweden	49.2	0.07	11.66	-17%	442%	5%
United Kingdom	154.2	0.52	81.59	-46%	943%	9%
Iceland	4.1	0.00	0.42	-13%	76%	-2%
Norway	25.1	0.02	3.08	-14%	205%	-7%
Switzerland	45.5	0.08	10.22	-6%	77%	18%
EU28	1719	26	426	-25%	45%	-4%
EU28+NO+CH+IS	1793	26	439	-24%	45%	-4%

Estimated development of electricity needs for cooling, supplied cooling needs and installed capacity and modelled theoretical cooling needs of the total building residential building stock

Country	Year	Electricity demand [GWh]	Supplied cooling [GWh]	Installed capacity [MW]
AT	2012	69.3	189.7	38.1
AT	2030	163.7	518.6	89.9
BE	2012	81.0	221.6	1156.5
BE	2030	230.5	730.6	3293.4
BG	2012	1395.8	3819.9	5510.8
BG	2030	1574.7	4989.9	6217.1
CH	2012	45.0	123.2	539.0
CH	2030	79.8	252.9	956.1
CY	2012	220.7	604.0	331.4
CY	2030	275.8	874.0	414.2
CZ	2012	128.8	352.6	1337.2
CZ	2030	234.1	741.9	2430.2
DE	2012	804.0	2200.3	6977.2
DE	2030	1703.6	5398.6	14785.0
DK	2012	9.1	24.8	129.3
DK	2030	80.5	255.1	1150.0
ES	2012	1886.4	5162.6	2454.9
ES	2030	3696.1	11712.0	4810.1
EE	2012	6.6	18.1	94.3
EE	2030	8.7	27.6	124.3
FI	2012	33.9	92.9	484.8
FI	2030	62.4	197.9	892.1
FR	2012	603.4	1651.3	5052.3
FR	2030	1889.5	5987.6	15821.0
UK	2012	50.0	136.8	714.3
UK	2030	521.6	1652.7	3725.3
EL	2012	900.0	2463.1	1125.0
EL	2030	1108.0	3511.2	1385.0
HR	2012	713.2	1951.8	1899.2
HR	2030	845.0	2677.6	2250.1
HU	2012	38.6	105.6	118.5
HU	2030	93.2	295.5	286.5
IE	2012	5.7	15.6	81.3
IE	2030	9.5	30.2	136.2
IS	2012	0.0	0.1	0.4
IS	2030	0.1	0.2	0.8
IT	2012	9602.0	26278.0	20627.0
IT	2030	11585.0	36710.0	24886.0
LT	2012	13.0	35.6	155.7
LT	2030	70.9	224.7	849.1
LU	2012	3.2	8.8	44.2
LU	2030	12.7	40.2	175.1
LV	2012	10.7	29.2	152.4
LV	2030	19.3	61.2	275.8
MT	2012	156.1	427.1	234.4

Country	Year	Electricity demand [GWh]	Supplied cooling [GWh]	Installed capacity [MW]
MT	2030	138.6	439.3	208.2
NL	2012	80.6	220.5	1150.8
NL	2030	140.2	444.2	2002.7
NO	2012	6.6	18.1	94.3
NO	2030	20.1	63.7	287.2
PL	2012	196.0	536.3	1640.9
PL	2030	231.4	733.4	1937.8
PT	2012	210.2	575.4	1275.5
PT	2030	329.7	1044.9	2000.4
RO	2012	508.5	1391.7	946.7
RO	2030	602.6	1909.7	1121.9
SK	2012	15.3	41.9	58.4
SK	2030	50.3	159.6	191.8
SI	2012	85.4	233.6	227.3
SI	2030	136.6	433.0	363.9
SE	2012	12.9	35.4	184.6
SE	2030	70.1	222.1	1001.2
Total	2012	17891.8	48965.1	54836.6
Total	2030	25984.5	82339.8	94068.4

II. Workpackage 4 – Economic Analysis

9 Objectives and approach

9.1 Objective

The main objective of WP4 is to assess major macro-economic impacts induced by integrating increasing shares of RES-H/C on EU member state level. In order to enable this assessment the System Dynamics model ASTRA-EC is applied. Inputs for the three scenarios calculated were provided in the context of the first three WPs by all technology-specific bottom-up models.

Further key objectives of WP4 are:

- Estimating the impacts of the scenarios developed in WP3 on GDP and full-time equivalent employment.
- Assessing the investment costs of replacing the fossil fuel H/C by RES-H/C on member state level by the applied technology-specific bottom-up models.
- Comparing costs and benefits of replacing currently used heating and cooling technologies with state-of-the-art technologies available in the time horizon 2020 and 2030.
- Analysing the economic impacts of the two policy scenarios on different economic sectors.

The results of WP4 build on results from WP1, WP2 and especially from the scenario analysis carried out in WP3. Thus, the macro-economic impacts strongly depend on the assumptions set out in WP3.

9.2 Economic Analysis

The quantitative assessment of economic impacts of RES-H/C until 2030 mainly builds on the preparation and application of the ASTRA-EC model. ASTRA-EC is an integrated assessment model which has been developed continuously in numerous national and European research projects since FP4. It consists of several modules, one of which is the Macroeconomic module, applied in this case. Apart from the transport system it does not simulate micro-economic investment decisions based on changing policy environments in the energy system in detail as required for the economic analysis of RES-H/C policies. ASTRA-EC requires the resulting inputs of the simulated investment decisions from sophisticated bottom-up energy models: INVERT/ EE-Lab, FORECAST and Green-X. Therefore it was planned to link the macroeconomic module of the ASTRA-EC model with the bottom-up models of the residential, the industry and the service sector as well as from district heating.

The following sub-chapters will start with an overview of the approach of ASTRA-EC for assessing economic impacts. Further, it will present the major inputs provided by the bottom-up models which provide the impulses that change the national economies due the designed scenarios. And finally, it will describe the macro-economic consequences of the established RES-H/C strategies on the member state level and on the level of economic sectors.

9.3 Approach of the ASTRA-EC model

The methodology to assess the impacts of RES-H/C strategy until 2030 is determined by the ASTRA-EC model, developed during the FP7 project ASSIST and provided as a tool to the European Commission DG MOVE for the assessment of social, economic and environmental impacts of sustainable transport policies. ASTRA-EC is the most recent version of the ASTRA model, continuously developed since 1997 (see www.astra-model.eu). ASTRA and ASTRA-EC were applied in the EmployRES I and II research projects to assess macroeconomic impacts of renewable energy strategies and policies. The most detailed descriptions of ASTRA are provided by Schade (2005), Krail (2009) and Fermi et al. (2014).

The System Dynamics model ASTRA-EC (Assessment of Transport Strategies) is a tool enabling Integrated Assessment of transport policy strategies. It links the systems of transport, society, economy and environment. Furthermore, the ASTRA model has been successfully linked to energy system models such as the POLES world energy model. ASTRA has been developed and applied in a sequence of German, European and global research projects by two institutions since 1998: Fraunhofer Institute for Systems and Innovation Research (ISI) and Trasporti e Territorio (TRT).

The ASTRA-EC model is based on System Dynamics methodology. System Dynamics as a methodology does not focus on the analysis of specific fields or systems like economy or transport, but is a general methodology that can be applied to any kind of system that meets a number of basic conditions. In brief, a System Dynamics model consists of a set of hypotheses on the relationship between causes and resulting effects. Hypotheses may be based on theory or may only be informed by theory, but empirical inputs from statistics, surveys or other observations may also be used.

Relationships are represented by equations that are written and solved by mathematical simulation. In other words, a System Dynamic model does not have a specific set of unknown parameters or variables whose value is estimated as a solution of the model. Instead, most of the model variables change dynamically over time as an effect of the interaction of positive or negative feedback loops. This can be considered as the most important characteristics of any complex system. System Dynamics models consist of three main types of variables: level, flow and auxiliary variables. The state of a variable is mainly calculated within level variables changed over time by inflows and outflows that are driven by auxiliary variables. Mathematically, level variables are solved with differential equations. Since the solution of a system with a set of level variables is too complex, an approximation is applied by solving only the related difference equations. Nevertheless, the mathematical calculations in a large scale System Dynamics model like ASTRA-EC are challenging and demanding on the computational equipment. As opposed to computed general equilibrium models, reaching a steady state or equilibrium at each stage of the simulation is not foreseen in System Dynamics models. Dedicated software allows the development of System Dynamics models to concentrate on the causal relationships by means of intuitive graphical interfaces.

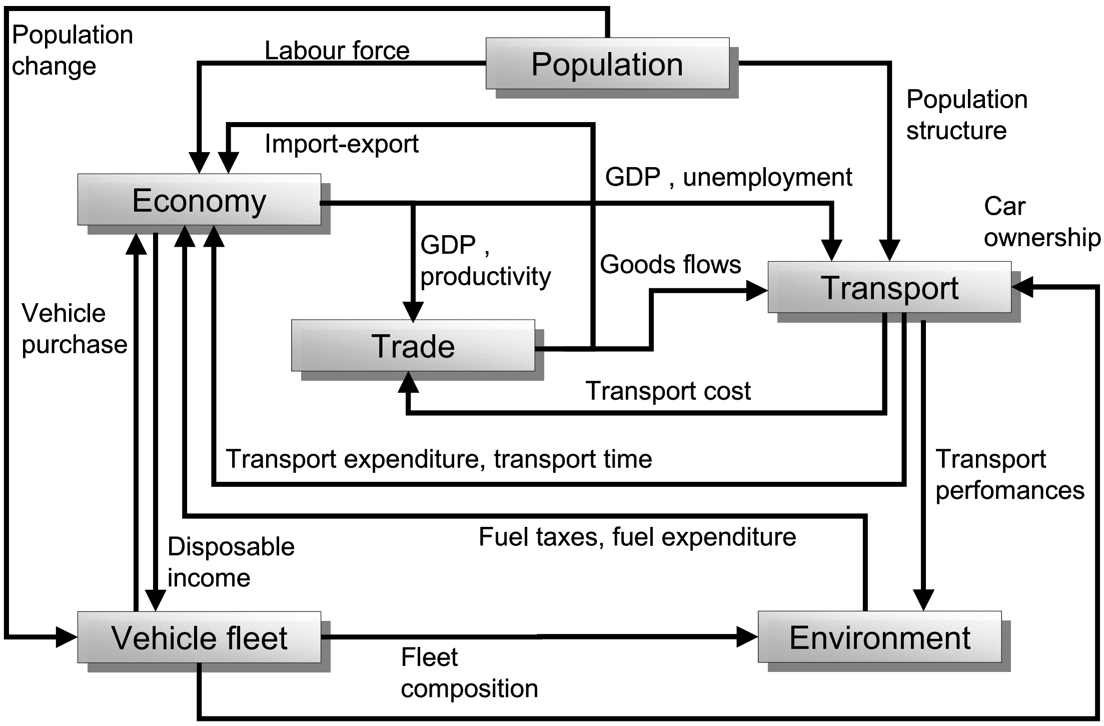
The ASTRA-EC model is therefore focused on investigating functional cause and-effect relationships between the systems represented (transport, economy, and environment) and connected through several feedback loops. The model is developed using Vensim® software. It covers the time period from 1995 until 2050 but for the economic analysis of RES-H/C strategies the time horizon was set by 2030. Results in terms of main indicators are available on a yearly basis via a user interface. Geographically, ASTRA-EC covers all EU member states besides Croatia plus Norway and Switzerland. Croatia which acceded to the EU in July 2013 is not yet covered by the ASTRA-EC model. Therefore, impacts for Croatia were assessed separately via a simplified approach which will be described at the end of this chapter.

ASTRA-EC consists of different modules, each related to one specific aspect, such as the economy, the transport demand, the vehicle fleet. The main modules cover the following aspects:

- Population and social structure (household types and income groups),
- Economy (including input-output tables, government, employment and investment),
- Foreign trade (inside EU and to partners from outside the EU),
- Transport (including demand estimation, modal split, transport cost and infrastructure networks).
- Vehicle fleet (passenger and freight road vehicles),
- Environment (including pollutant emissions, CO2 emissions, fuel consumption).

A key feature of ASTRA-EC as an integrated assessment model is that the modules are linked together. Changes in one system are thus transmitted to other systems and can feedback to the original source of variation. Since all modules are part of the same dynamic structure, the whole model is simulated simultaneously. The most appealing consequence is that there is no need for iterations to align the results of the various modules. All parts of the model are always consistent to each other throughout the whole simulation. An overview of the modules and their main linkages is presented in the following figure. As for the purpose of this study, only the population, the macroeconomic and the foreign trade modules are required, only these three will be described in the following.

Figure 73: Overview of the interaction of modules in ASTRA-EC



Source: Fraunhofer-ISI

The Population Module (POP) in ASTRA-EC provides the demographic developmentfor each of the 29 European countries (EU27 plus Norway and Switzerland) as well as for all NUTS II zones in EU27. It differs between groups of society, the population is differentiated by one-year age cohorts. The model depends on fertility rates, death rates and immigration to the EU countries. Furthermore, there is an income distribution model which dynamically allocates the population into five income groups based on a number of socio-economic drivers. The development of these income groups steer the consumption of private households as the level of income strongly determines the level and the share of consumption for products and services provided by different economic sectors.

The Economic Module (MAC) simulates the national economic framework, which imbeds the other modules. The MAC incorporates elements of different economic theories. The model uses production functions of the Cobb-Douglas type derived from neoclassical theory. Keynesian elements are also considered, like the dependency of investments on the consumption of private households, which are extended by some further influences on investments like exports or government debt. Further elements of endogenous growth theory are incorporated, for example the implementation of endogenous technical progress (e.g. depending on sectoral investment) as one important driver for the overall economic development.

Six major elements constitute the functionality of the macroeconomics module. The first is the sectoral interchange model (Input-Output module) that reflects the economic interactions between 25 economic sectors of the national economies. ASTRA-EC applies a classification of economic sectors derived from the NACE-CLIO classification formerly used for European input-output tables. It can easily by converted into the NACE Rev. 2 classification (Fermi et al. 2014). Structural changes in the economy allow an interpretation of RES-H/C strategies; policies on businesses as well as impacts of changing energy prices on the 25 different economic sectors can be simulated via this module. Demand-supply interactions are considered by the second and third element. The second element, the demand side model, depicts the four major components of final demand: consumption of private households, investments, exports-imports and the government consumption. The supply side model reflects influences of three production factors: capital stock, labour and natural resources as well as the influence of technological progress that is modelled as total factor productivity. Endogenised total factor productivity depends on investments, freight transport times and labour productivity changes. The fourth element of MAC is constituted by the employment model that is based on value-added as output from input-output table calculations and labour productivity. The development of full-time equivalent per economic sector depends on the development of sectoral gross value-added and sectoral labour productivity development. Due to this relationship, investments in goods and services of economic sectors with low labour productivity (as for example the Agriculture, the Catering or Construction sector) have stronger impacts on the development of the labour market than investments in sectors with high labour productivity (like the Energy or the Banking sector). Employment is differentiated between full-time equivalent employment and total employment in order to be able to reflect the growing importance of part-time employment.

ASTRA-EC considers direct, indirect and second-round effects on employment. Direct impacts are those that stem directly from changing investments in goods and services. Indirect impacts are those induced by changing structures and levels of intermediate goods and services described in the input-output tables. For example increasing investments in the sector Industrial Machines will also impact on the Transport sector as higher outputs of the sector Industrial Machines requires increasing intermediate services from the Transport sector. And finally, second-round impacts are often neglected but can play important roles in the change of the economy. ASTRA-EC does take them into account by increasing the GDP which leads to a causal chain via increasing disposable income, increasing consumption, increasing investments and increasing employment.

The fifth element of MAC describes governmental behaviour. As far as possible government revenues and expenditures are differentiated into categories that can be modelled endogenously by ASTRA and one category covering other revenues or other expenditures. The sixth and final of the elements constituting the MAC are the micro-macro bridges. These link micro and meso-level models, for instance the transport module or the vehicle fleet module to components of the macroeconomic module. The macroeconomic module provides several important outputs to other modules like the Gross Domestic Product (GDP). This is for instance required to calculate sectoral trade flows between European countries.

The Foreign Trade Module (FOT) is divided into two parts: trade between the EU European countries (INTRA-EU model) and trade between the EU European countries and the rest-of-the world (RoW) that is allocated to nine regions. Both models are differentiated into bilateral relationships by country pair by sector. Trade between EU member states is driven by world GDP growth, by GDP growth of the importing country of each country pair relation, by relative change of sectoral labor productivity between the countries and by averaged generalized cost of passenger and freight transport between the countries. The latter is chosen to represent an accessibility indicator for transport between the countries. The EU-RoW trade model is mainly driven by relative productivity between the European countries and the rest-of-the-world regions. Productivity changes together with GDP growth of the importing RoW-country and world GDP growth drive the export-import relationships between the countries. The resulting sectoral export-import flows of the two trade models are fed back into the macroeconomics module as part of final demand and national final use respectively.

Assessing the macroeconomic impacts of RES-H/C strategies with ASTRA-EC requires a number of exogenous inputs from the bottom-up energy models. As for all inputs, they are required in time series from the starting year to the final year of simulation. Furthermore, the allocation of inputs to economic sectors classified in the ASTRA economic sector structure is required. And finally, the inputs need to be provided on member state level. The major inputs for ASTRA-EC are described in the following (and by figure 2).

Investments

ASTRA-EC requires as input the delta between additional net investments induced by the simulated RES-H/C strategy and the avoided net investments in fossil fuel technologies. In specific cases or scenarios, this can lead to a reduction of investments when the level of avoided investments is higher than the additional investments. According to the economic theory applied in ASTRA-EC, the delta investments need to be further distinguished between investments made by companies and those made by private households (which is relevant for the residential sector). The latter are assigned to the consumption of private households, such that a further assumption on the share of investments made by private households needs to be made. In this case, the share between ownership and rent from Eurostat are applied to this differentiation. In the case of consumption, the additional consumption induced by the RES-H/C investment activities will endogenously lead to lower consumption in other economic sectors than those affected by the investment. As in the case of investments by companies, the delta investments will not lead to a further reduction of other investment activities. Delta investments and consumption both need to be differentiated by economic sectors.

Energy costs

The resuming change of energy costs due to the increased share of RES-H/C technologies is required as the second important input into the macroeconomic module in ASTRA-EC. Energy cost changes in the case of private households lead to reduced consumption of products and services in the energy sector. This allows for higher consumption of products and services in other economic sectors which induces a structural change. Reduced energy consumption of companies can be observed directly in the input-output tables. The share of input from the energy sector of total intermediates decreases such that gross value-added of these sectors increases while the gross value-added of the energy sector decreases. Energy intensive sectors benefit more than less energy intensive sectors.

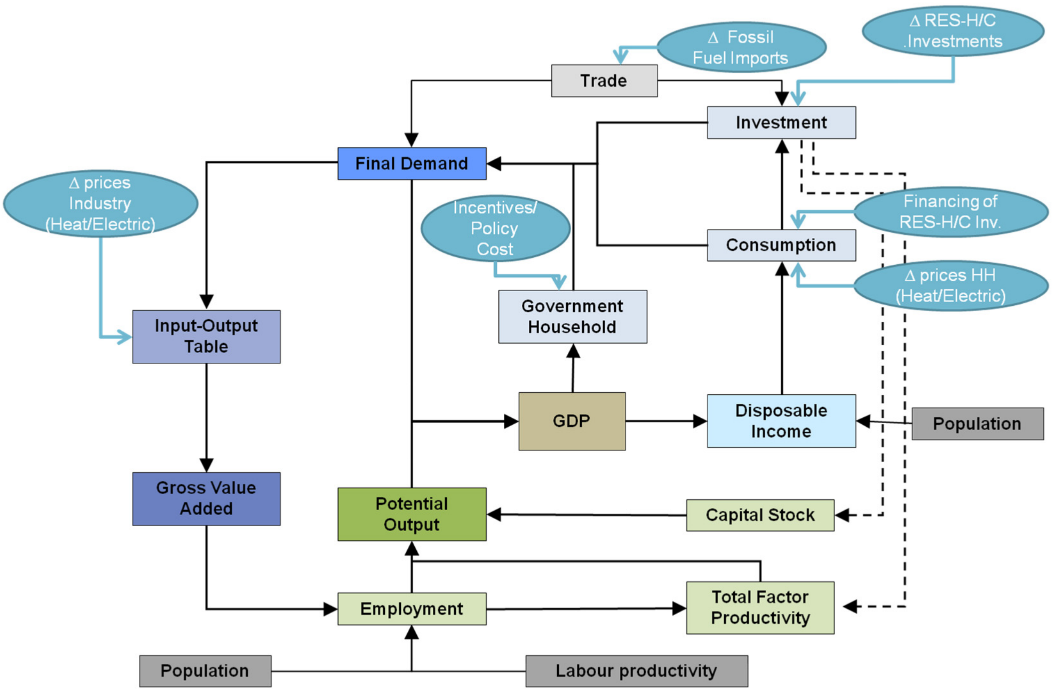
Fossil fuel imports

ASTRA-EC considers endogenous changes of exports and imports within the Foreign Trade module (FOT). Decreasing imports of fossil fuels due to increasing shares of RES for heating and cooling leads to higher trade balances and therefore to higher final demand. Increasing final demand directly affects GDP such that there is an impact on the overall economy. Within this project the bottom-up energy models provided the annual amount of change of fossil fuel imports per member state to ASTRA-EC derived from the change of energy consumption per energy carrier.

Subsidies and financial incentives

Each policy or strategy leading to changes in public subsidies or financial incentives needs to be considered in ASTRA-EC by changing these indicators. As for all exogenous indicators, ASTRA-EC requires the delta between additional subsidies and avoided subsidies in order to avoid an exaggeration of impacts. As for the delta investments, this can lead to lower public subsidies than in the *Current Policy scenario (CP)*. In the ASTRA-EC model structure, subsidies increase the national income compensating potentially higher investments of companies and private households. In the case of private households, they directly increase disposable income. In the case of companies, they increase the gross value-added. On the other hand, public subsidies lead to higher government expenditures burdening the government balance. This can lead to an overall reduction of investments due to increasing interest rates. Financial incentives induced for example by trading schemes are considered as well. They have similar effects as public subsidies without affecting the government expenditures and with less strong impact on gross value-added.

Figure 74: Economic impulses induced by RES-H/C strategies



Source: Fraunhofer-ISI

A crucial assumption to be considered in an economic analysis is that each investment as well as consumption needs to be financed or at least compensated by lower investments and consumption in other goods and services. In the case of consumption, ASTRA-EC considers this requirement by decreasing consumption in other sectors endogenously. For companies, ASTRA-EC assumes financing by reducing company gains which form a part of gross value-added. Taking these assumptions into account prevents overestimating economic impacts of investments in new technologies. Effects on technical progress are represented endogenously in ASTRA-EC. Investments in new technologies lead to increasing total factor productivity. ASTRA-EC considers varying impact levels for different economic sectors. For example an increase of investments in high-tech sectors like Electronics, Computers or Industrial Machines has stronger impacts on overall total factor productivity than investments in Agriculture.

Potential lead market effects due to strong investments in RES-H/C technologies are not considered in the economic analysis as such a quantification would require a comprehensive micro-economic analysis of the competitiveness of European industries producing RES-H/C technologies in comparison with industries abroad.

Preparation of ASTRA-EC for the economic analysis of RES-H/C strategies

The first stage of preparing ASTRA-EC for the assessment of RES-H/C strategies and policies consisted in the modelling of interfaces for the bottom-up model inputs described above. This was done partially in spreadsheets collecting and transforming the bottom-up model input into ASTRA-EC classification and partially within the ASTRA-EC model. ASTRA-EC does not simulate inflation of prices such that all monetary indicators are calculated in real terms in constant euro 2005. Hence, all inputs needed to be converted applying Eurostat GDP deflators from 2016.

The second stage of preparing the ASTRA-EC model consisted of matching major population and economic developments with the latest EC Reference Scenario projections from the EC from 2016 (European Commission 2016) agreed on with the EC during the project. Before, ASTRA-EC was made in line in 2013 with the EC Reference Scenario from 2013. For this purpose, the population development in the ASTRA-EC POP module was adapted to the changing population projections according to the latest EC Reference Scenario 2016. This was mainly managed by assuming changing migration, less by changing birth or death rates. Running ASTRA-EC with the changing population projections already led to changing economic developments. GDP was the second indicator to be made in line with the new projections. Due to its dynamic model structure, the simple way of using exogenous GDP projections was not applied to adapting the model. Most second-round impacts of the RES-H/C strategy and policy would have been lost by fixing the GDP development. Hence, the GDP was kept endogenously. Via the trial- and error approach, the GDP development was adapted to the latest *Reference Scenario* projections by changing major exogenous economic assumptions like the change of saving ratios of private households, the change of activity levels of the population and changing productivity projections.

The third stage of analysing economic impacts of the two RES-H/C strategies developed in WP3 was the development of a simplified approach allowing for a quantification of impacts for Croatia as ASTRA-EC does not yet cover the 28th member state. For this purpose, investment multipliers on GDP growth were calculated for each member state and each of the two scenarios. Then, those multipliers were chosen from the countries with comparable GDP level and RES-H/C investment levels like those of Croatia. Finally, GDP and employment impacts could be approximated.

Scenarios simulated with ASTRA-EC

In total ASTRA-EC calculated macroeconomic impacts for the three scenarios agreed on in WP3. For this purpose, the model was adapted to estimate economic impacts of the two scenarios *Gradual Quota MS (Q0.55)* and *2030 Quota EU (Q27)* defined in WP3 against the *Current Policy scenario (CP)* (see Table 2).

Table 47: Overview and definition of scenarios

Name	Definition
Current Policy scenario (CP)	Includes all policies and measures implemented at the end of 2015 All policies are assumed to continue until 2030 with their current design

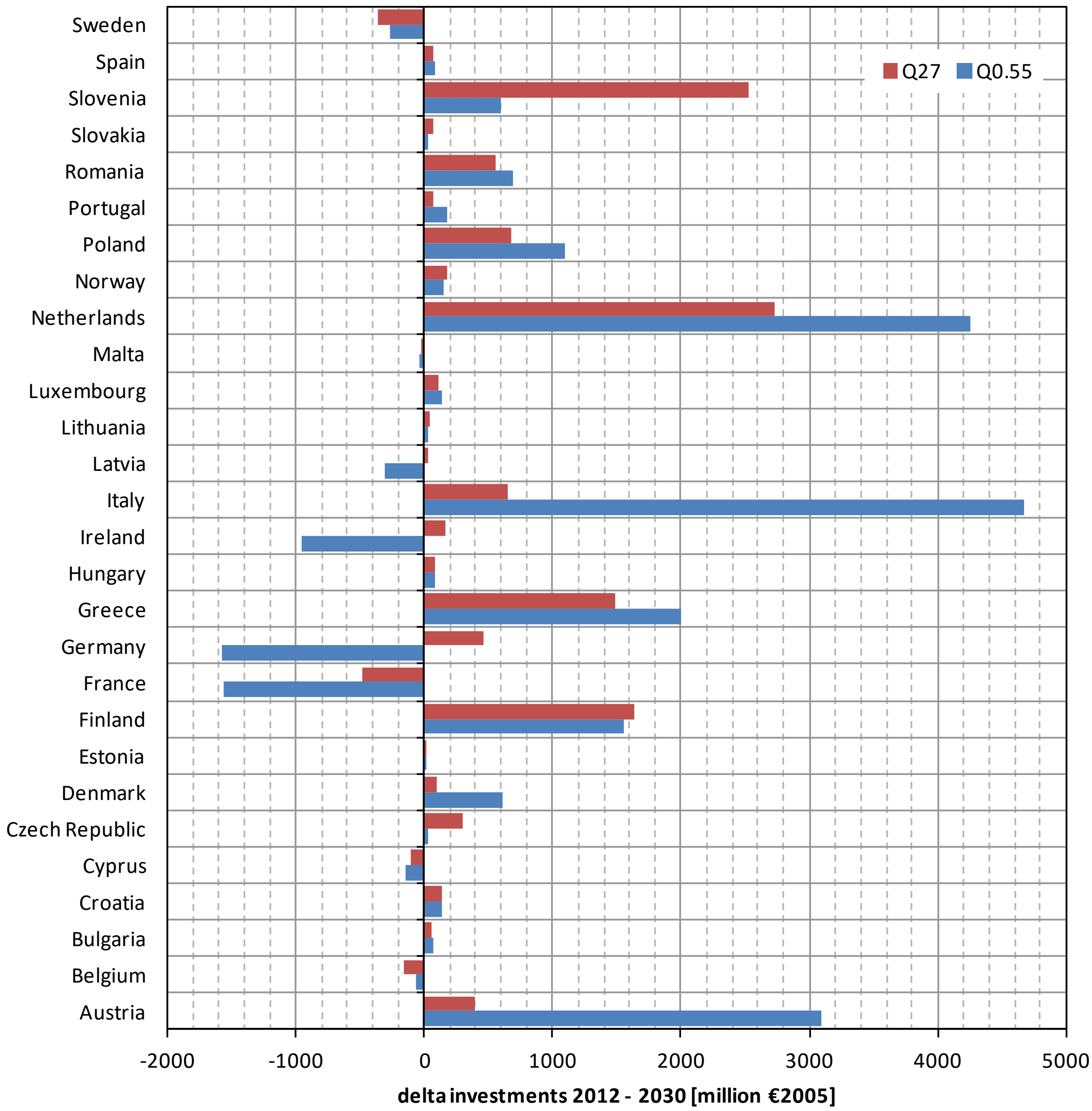
Gradual Quota MS (Q0.55)	Annual increase in RES-H/C share of at least 0.55% Certificate trade: member state wide No other RES-H/C subsidies Other policies from the *Current Policy scenario* continue until 2030
2030 Quota EU (Q27)	Total EU RES-H/C share of 27% in 2030 No particular member state restrictions Certificate trade: EU wide, no other RES-H/C subsidies Other policies from the *Current Policy scenario* continue until 2030

9.4 Micro-economic input from bottom-up models

The three bottom-up models (INVERT/ EELab, FORECAST and Green-X) provide micro-economic inputs for the simulation of wider economic impacts on ASTRA-EC. According to the approach developed for exchanging economic results on the micro-economic level up to the macro-economic level represented within the ASTRA-EC model, the following inputs are applied to the simulation of the two policy scenarios *Q0.55* and *Q27* and the *CP scenario*. All sector models provide changes in investments, energy costs and subsidies. Changes in the import of fossil fuels are derived from the energy balances in WP3 across all sectors for each country assuming that the share of domestic production and imports for each energy carrier stay at 2012 levels. The inputs are further differentiated by economic sector and are provided in time series from 2013 to 2030. All figures must be interpreted as delta between CP *scenario* and the respective alternative scenario.

Changes in investments between the *current policy scenario* and the two quota scenarios mainly stem from differences in investments in heating systems (Figure 75). Higher investments are required for RES-HC technologies compared to gas or oil fired boilers which result in different investment levels in each scenario. The replacement of existing support policies by the introduction of an obligation scheme does not necessarily lead to higher investments in all countries. Especially countries which have already ambitious support policies in place (e.g. subsidies for renewable heating systems) exhibit lower levels if the quota target is below the RES share reached in the *current policy scenario*. It is important to mention that the RES-H/C obligation is modeled as the only support scheme for RES-H/C in the quota scenarios, assuming that all other subsidies for heating systems are phased out. Total investments of EU28 member states increase by €14.6 billion in the *Q0.55 scenario* and by €11.4 billion in the *Q27 scenario*. In relative numbers, these changes account for less than 1 % of the investments of the *CP scenario* due to the similar ambitious levels of all scenarios.

Figure 75: Sum of delta investments from bottom-up models for *Q0.55* and *Q27* [million €2005]



Public subsidies for heating and cooling systems are phased out in 2020 (Table 48). This leads to a reduction of public spending of about €38 billion in the two quota scenarios. On the other hand, subsidies provided within the obligation scheme account for €145 billon in the *Q0.55 scenario* and €59 billion in the *Q27 scenario*. This is a substantial higher level of support, which is however not financed by a state budget. It can be expected that these additional costs to reach the quotas are passed on to consumers by obliged suppliers.

Table 48: Sum of delta subsidies and financial incentives from bottom-up models for *Q0.55* and *Q27* [million €2005]

Country	Sum of delta subsidies [million €$_{2005}$]		Sum of delta other financial incentives [million €$_{2005}$]	
	Q0.55	Q27	Q0.55	Q27
EU28	-38,676	-37,560	150,086	61,738
Austria	-2,150	-2,136	10,609	2,651
Belgium	-627	-627	1,357	2,191
Bulgaria	-16	-16	776	776
Croatia	-10	-10	0	60
Cyprus	-7	-7	253	42
Czech Republic	-239	-239	0	1,583
Denmark	-168	-175	4,895	410
Estonia	-12	-12	815	368
Finland	-2,531	-2,531	3,342	2,877
France	-10,746	-10,733	8,378	11,873
Germany	-1,127	-1,114	51,235	8,888
Greece	-218	-218	0	139
Hungary	-44	-44	1,257	1,309
Ireland	-91	-91	329	376
Italy	-1,503	-1,500	39,327	5,504
Latvia	-18	-17	2,199	450
Lithuania	-198	-198	825	341
Luxembourg	-35	-35	245	100
Malta	0	0	0	1
Netherlands	-34	-34	1,718	2,853
Poland	-910	-910	7,120	2,724
Portugal	-182	-182	1,972	832
Romania	-985	-949	5,075	2,099
Slovakia	-75	-75	0	642
Slovenia	-4	-4	384	534
Spain	-11,216	-11,216	2,013	2,541
Sweden	-307	-307	504	3,930
United Kingdom	-4,029	-4,029	515	3,311

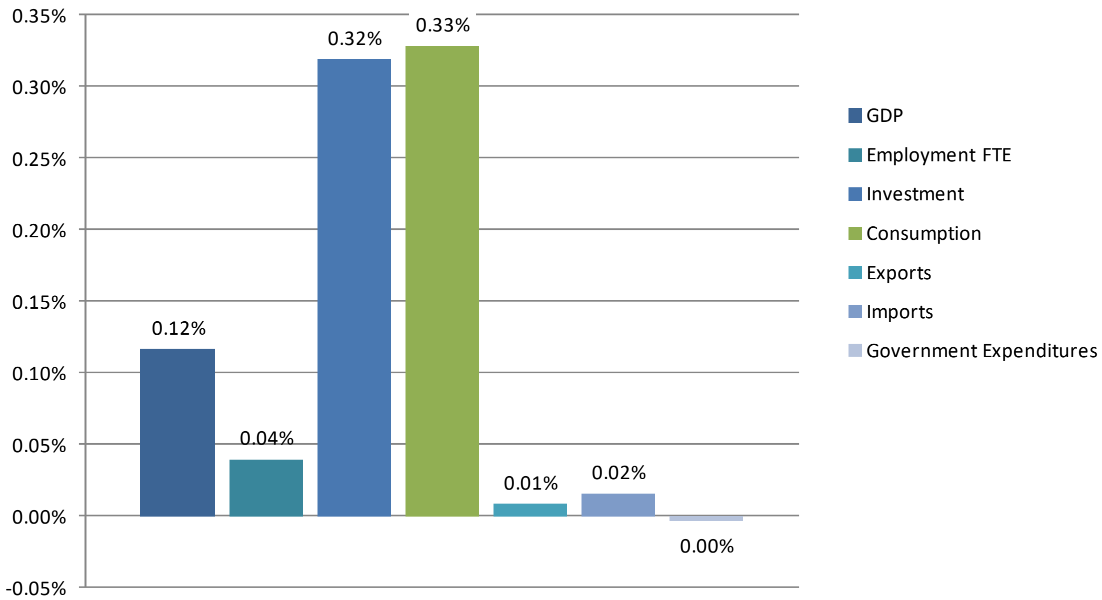
10 Economic analysis with ASTRA-EC

Based on the approach of ASTRA-EC described in the previous chapters, so-called wider economic impacts were assessed in WP4 using ASTRA-EC. Besides the *CP scenario*, the two quota scenarios *Q0.55* and *Q27* were quantitatively assessed using ASTRA-EC. All results of the ASTRA-EC simulations presented in this chapter are described in comparison to the development of the macro-economic indicators in the *CP*. As described in the chapters above, ASTRA-EC calculates each macroeconomic indicator annually between 1995 and 2030. On the aggregate EU28 level, the development of major economic indicators like GDP and employment (expressed in full-time equivalent employment) is presented for the whole period from 2013 to 2030. On member state level and on sectoral level, the focus was on the two reference years 2020 and 2030. Hence, a decline of an indicator does not per definition mean a decline of the indicator in absolute terms. It simply shows that the growth is lower than in the *CP*. All impacts on monetary indicators like GDP or investment are presented in real terms in constant euro 2005 (using a EU28 GDP deflator from Eurostat).

As opposed to many other studies conducted with macro-economic modules comparable to ASTRA-EC, the definition of the policy framework does not induce large amounts of delta investments as the level of avoided investments is at least in a number of countries or for some years in-between 2013 and 2030 even higher than the additional investments in RES-H/C technologies. This is the result of the comprehensive micro-economic simulation of investment decisions in the bottom-up models INVERT/ EELab, FORECAST and Green-X. Typically, high delta investments steer economic growth and employment strongest. In the case of the scenarios Q0.55 and Q27 the level of delta net investments are moderate or even only marginal compared to *CP* such that the overall economic impact is very low.

Figure 76 presents the impacts of the bottom-up model inputs for *Q0.55* on major macroeconomic indicators for EU28 in comparison with the development in *CP* (expressed in relative terms). ASTRA-EC calculates a +0.12% higher GDP for EU28 in 2030 in *Q0.55* compared with *CP*. Full-time equivalent (FTE) employment in EU28 is expected to increase marginally by +0.04% in 2030 compared with *CP*. The sum of direct, indirect and second-round impacts on investments sums up to an increase of +0.32% compared with *CP*. Consumption of private households follows this trend and ends up in *Q0.55* at a +0.33% higher level than in the *CP* for EU28. GDP in ASTRA-EC is driven both by the demand side as well as the supply side. Hence, the low impact on labour supply together with low impacts on exports lead to less strong impacts on GDP compared with consumption or investments. Impacts stemming from reduced imports of fossil fuels cannot be observed on this aggregate EU28 level. It could be expected that imports decrease compared with *CP* but overall increasing GDP compared with *CP* also leads to higher trade levels including imports. Therefore, the higher demand for imported goods and services outbalances the reduced imports of fossil fuels due to higher shares of RES-H/C. The policy framework defined in *Q0.55* leads to marginally lower government expenditures until 2030.

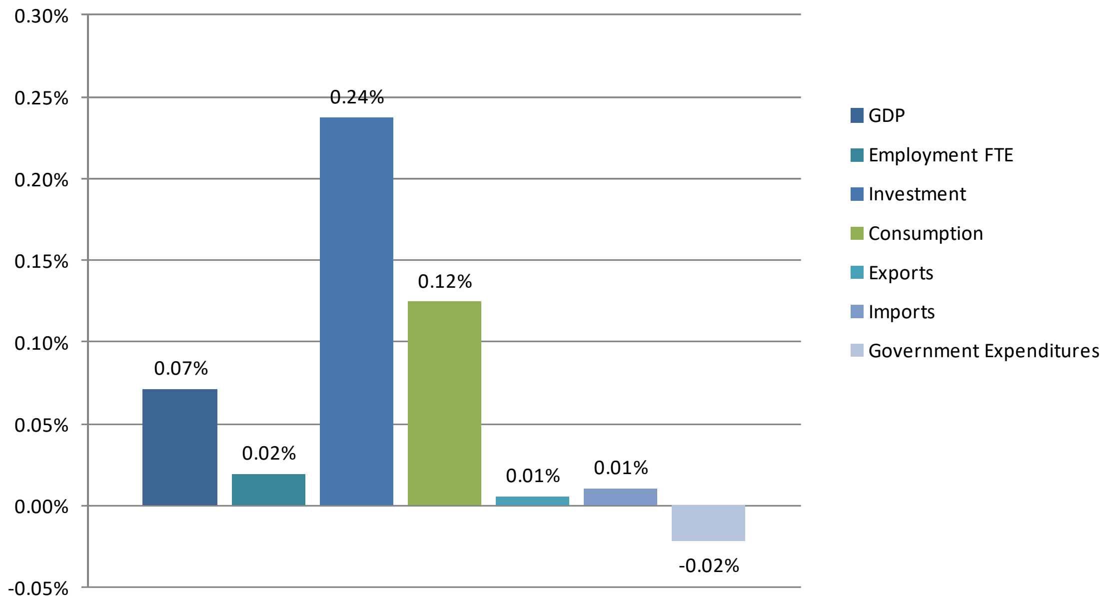
Figure 76: Relative change of major macro-economic indicators in EU28 for Q0.55 compared with CP in 2030



Source: Fraunhofer-ISI, ASTRA-EC

On aggregate EU28 level, a similar but even lower positive economic outcome could be detected by ASTRA-EC for the *Q27 scenario* (Figure 77). According to the simulation results for the *Q27 scenario* with ASTRA-EC, GDP is only by +0.07% higher in the year 2030 compared with the *CP scenario*. FTE employment in EU28 is expected to be by +0.02% higher than in *CP*. The scenario impulses lead to increasing investments up to +0.25% higher than in the *CP scenario*. Consumption of private households in the *Q27 scenario* increases as well but not as strong in relation to investments as in *Q0.55* (+0.12% in 2030 compared with *CP*). Trade in terms of exports and imports show a similar effect in *Q27* as in *Q0.55*. This holds as well for government expenditures which are marginally lower in *Q27* than in the *CP scenario*.

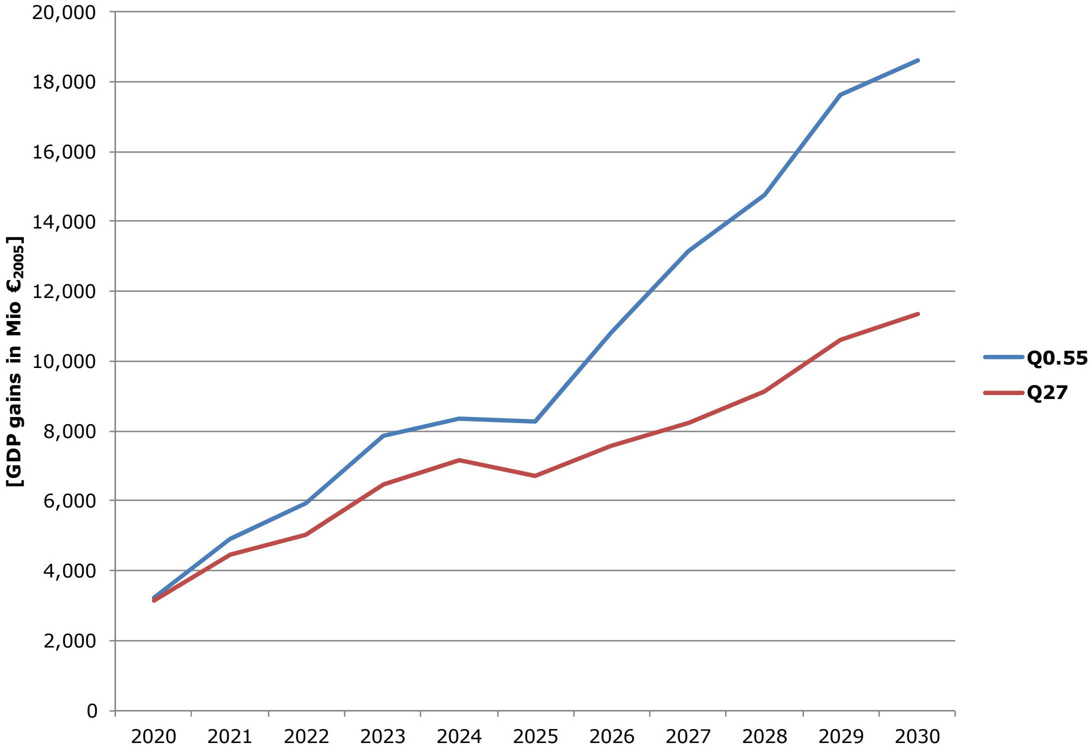
Figure 77: Relative change of major macro-economic indicators in EU28 for Q27 compared with CP in 2030



Source: Fraunhofer-ISI, ASTRA-EC

In absolute terms EU28 GDP increases in both scenarios compared with the *CP scenario* until 2030 (see Figure 78). The development of GDP compared with *CP* is similar in both scenarios. In total EU28 GDP in 2030 is in *Q27* by +€11.4 billion 2005 and in Q0.55 by +€18.6 billion 2005 higher than in *CP.* Accumulating GDP gains and losses of each year between 2020 and 2030 would lead to GDP gains of about €80 billion 2005 in *Q27* and even 114 billion Euro 2005 in *Q0.55* compared with the *CP scenario*.

Figure 78: GDP gains/loss in EU28 for Q0.55 and Q27 compared with CP

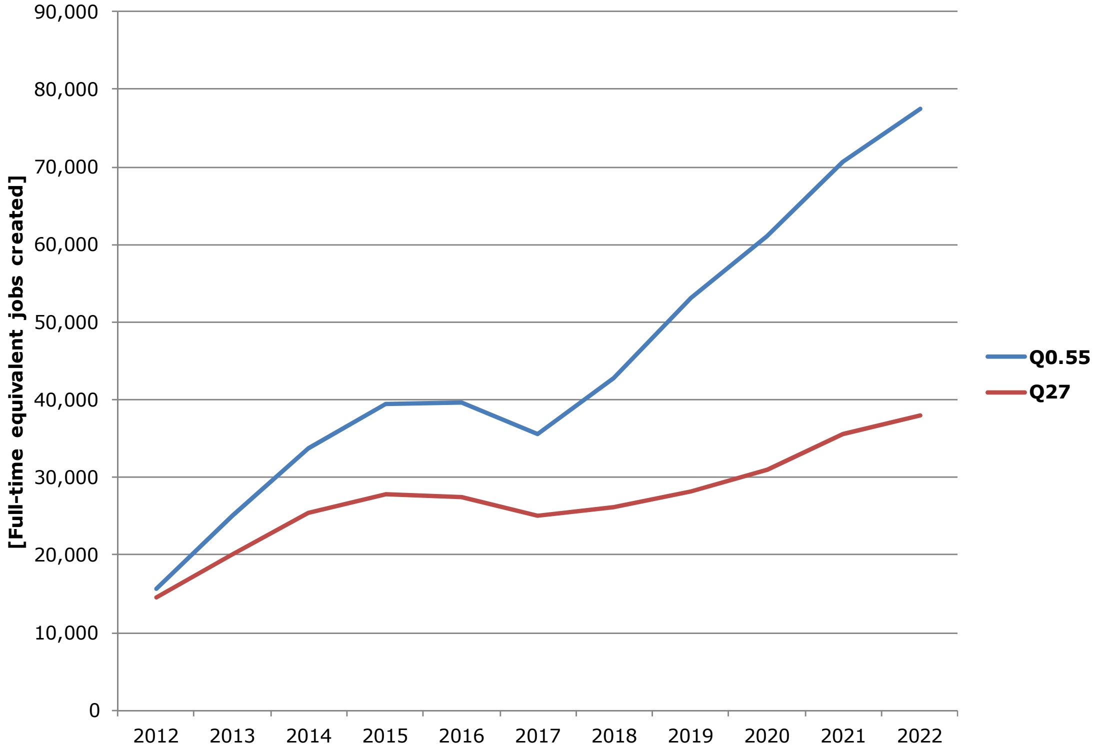


Source: Fraunhofer-ISI, ASTRA-EC

The development of FTE employment in absolute terms follows the scheme of GDP. Until 2030, ASTRA-EC simulates about 38,000 FTE jobs created in *Q27* and even 71,000 jobs created in the *Q0.55 scenario* compared with the *CP scenario*.

Accumulating the FTE job-years created leads to about 299,000 job-years created for the period between 2020 and 2030 in Q27 and about 494,000 job-years created in *Q0.55* in comparison with *CP* for EU28.

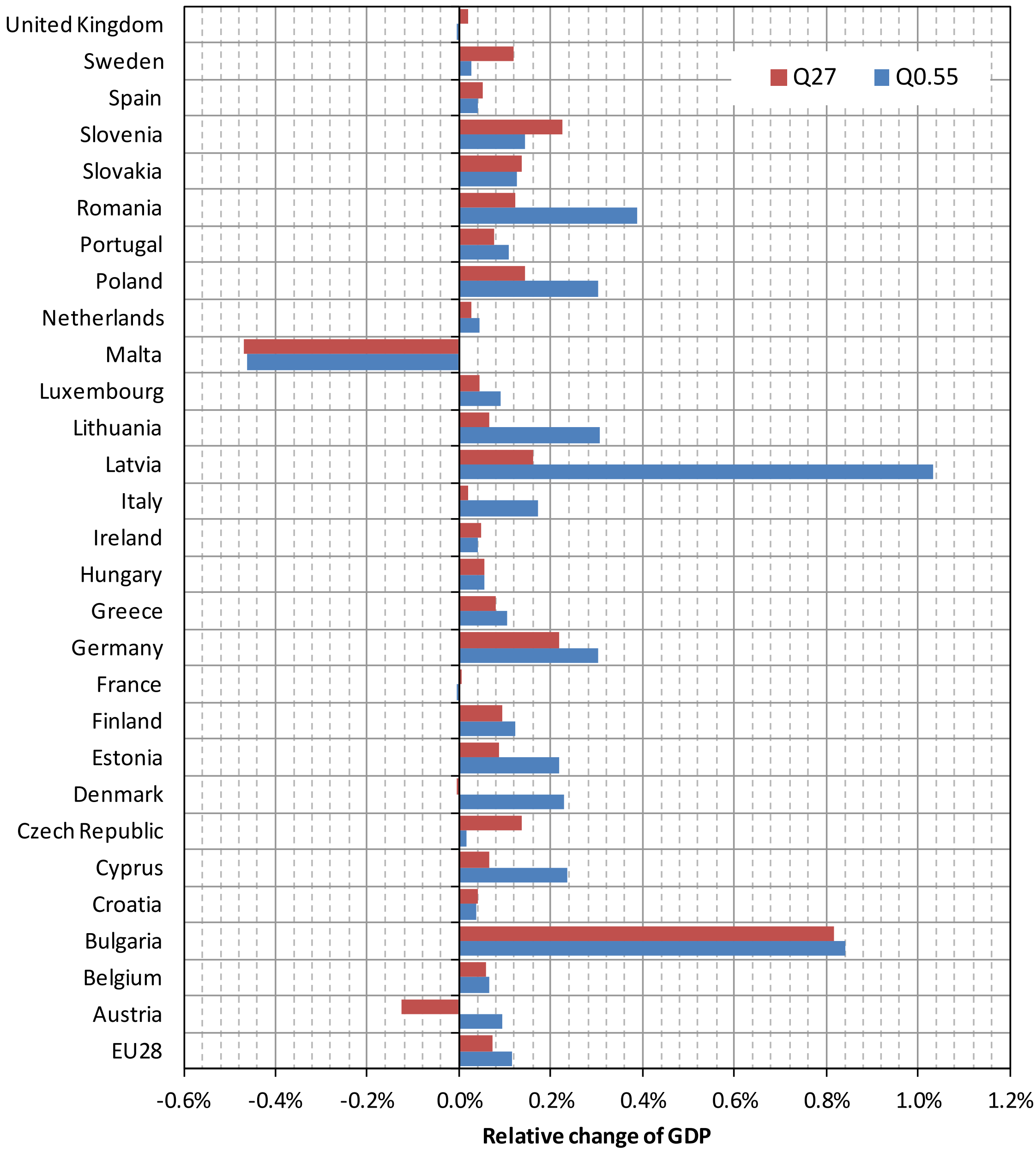
Figure 79: Full-time equivalent jobs created/destroyed in EU28 for Q0.55 and Q27 compared with CP



Source: Fraunhofer-ISI, ASTRA-EC

The policy framework designed for both scenarios tackles the member states in very different ways which is reflected by varying deltas between additional investments in RES-H/C technologies and avoided investments in fossil fuel heating and cooling technologies. And due to the resulting country-specific investment patterns induced by the policies and strategies defined in both scenarios the resulting energy costs differ as well between the member states. The microscopic inputs from the bottom-up models applied in this study did not only come up with different magnitudes of delta investments between the policy scenario and the *CP* but resulted even in different directions of inputs. The macro-economic results estimated with the ASTRA-EC model reflect these differences. Figure 80 provides an overview of the relative GDP changes in both scenarios, *Q0.55* and *Q27*, compared with the *CP* for the year 2030. While most member states at least on the final time horizon 2030 benefit in terms of growing GDP compared with the *CP*, the overall macroeconomic effect of *Q0.55* and *Q27* is negative for Malta. The *Q27 scenario* result in lower investment activities in Austria leading to less GDP growth than in the *CP scenario.*

Figure 80: Relative change of GDP in Q0.55 and Q27 in 2030 compared with CP on Member State level



Source: Fraunhofer-ISI, ASTRA-EC

In relative terms, the ASTRA-EC results of the economic assessment reveal that Latvia and Bulgaria benefit most from the policy frameworks decided upon in *Q0.55* with changes in GDP between +0.8% and +1% in 2030 compared with the *CP*. The positive investment impulses in combination with energy cost reductions and reduced fossil fuel imports induce in a number of countries like Romania, Germany, Cyprus, Poland, Denmark, Estonia, Lithuania and Italy changes of GDP between +0.2% and +0.4 compared with the *CP*. The effect of the policy framework on GDP in *Q0.55* for all remaining EU member states is only marginal.

The impacts on GDP in *Q27* differ in some countries from those in *Q0.55*. According to the ASTRA-EC results, Bulgaria benefits most with a GDP increase of 0.8% in *Q27* compared with the *CP*. A few member states (e.g. Germany, Slovenia and Sweden) react on *Q27* with an increase of GDP between +0.1% and +0.2%.

Table 49: Absolute change of GDP in *Q0.55* and *Q27* in 2020 and 2030 compared with the *CP* on Member State level [in million Euro 2005]

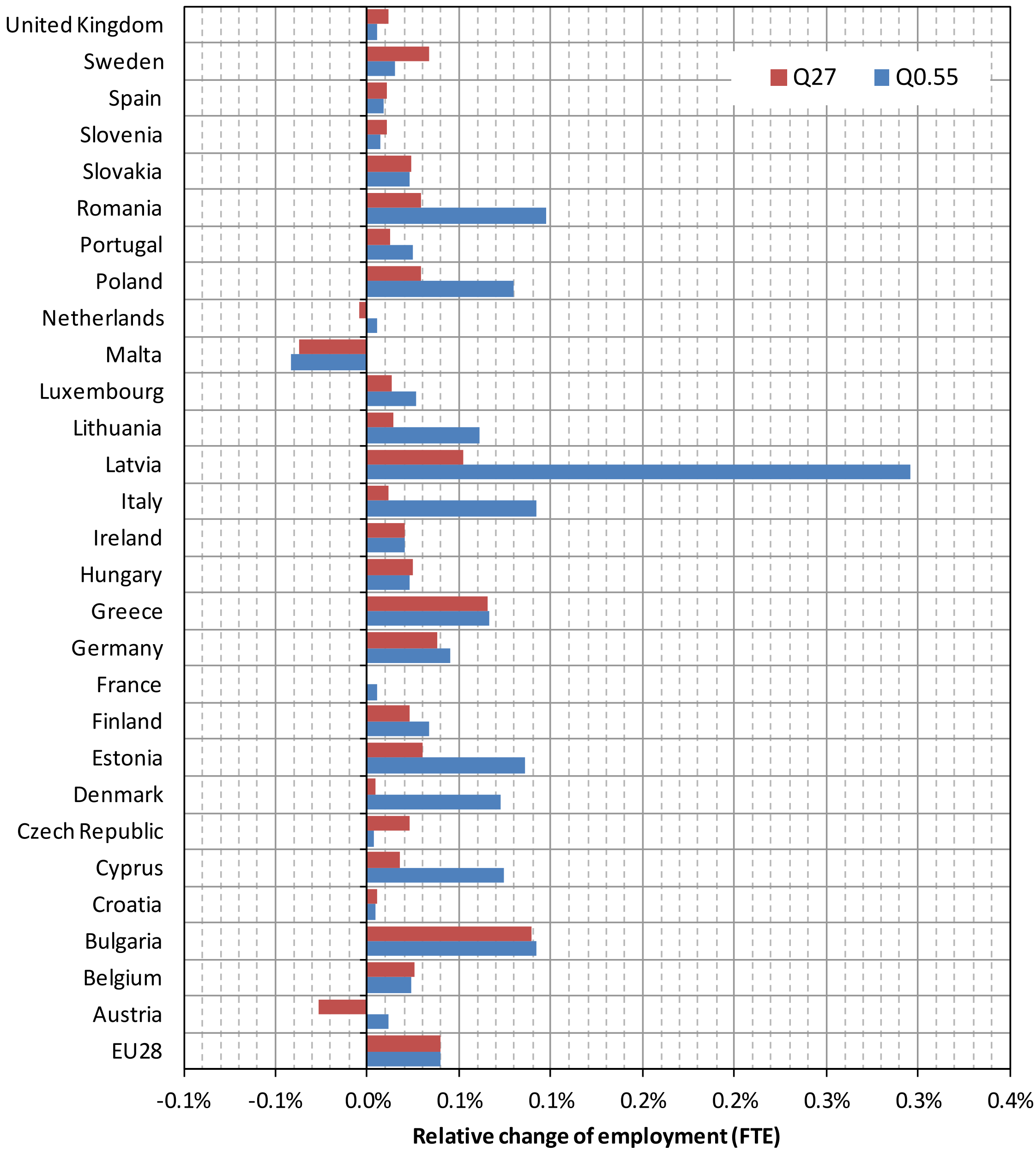
Country	Q0.55	Q27
EU28	18,598	11,664
Austria	357	-131
Belgium	273	336
Bulgaria	343	339
Croatia	19	19
Cyprus	65	10
Czech Republic	29	251
Denmark	726	21
Estonia	45	14
Finland	297	229
France	-26	94
Germany	8,911	6,468
Greece	265	256
Hungary	73	64
Ireland	103	123
Italy	3,331	351
Latvia	217	31
Lithuania	109	56
Luxembourg	55	42
Malta	-32	-37
Netherlands	299	301
Poland	1,503	628
Portugal	221	133
Romania	663	193
Slovakia	102	65
Slovenia	68	99
Spain	541	629
Sweden	120	583
United Kingdom	-78	500

Source: Fraunhofer-ISI, ASTRA-EC

Table 49 shows the absolute changes of GDP in both scenarios *Q0.55* and *Q27* for 2020 and 2030 against the *CP scenario* on member state level. All results are expressed in real terms in constant Euro 2005. The highest effect on GDP in absolute terms could be observed in both scenarios for Germany. In *Q0.55* ASTRA-EC calculates an increase of GDP in Germany of about 8.7 billion euro 2005, in *Q27* about 6.5 billion euro 2005 in 2030.

Further countries with comparably high absolute growth of GDP in *Q0.55* are Italy, Poland, Romania and Spain. In *Q27* Germany, Spain, Poland, Sweden and United Kingdom benefit most in absolute terms on GDP compared with the *CP scenario* in 2030.

Figure 81: Relative change of employment (FTE) in Q0.55 and Q27 in 2020 and 2030 compared with the *CP* on Member State level



Source: Fraunhofer-ISI, ASTRA-EC

Figure 81 and Table 50 provide an overview of the ASTRA-EC results for *Q0.55* and *Q27* on full-time equivalent (FTE) employment. While Figure 81 shows labour market impacts in relative terms against the *CP scenario*, Table 50 presents the results in terms of absolute changes of FTE employment in a number of FTE jobs created compared with the *CP scenario*. The reactions on labour markets on member state level differ partially from the relations observed for the GDP. GDP gains cannot be converted in a linear way into jobs created as the change of employment depends on the sectoral allocation of investment and consumption changes and the country-specific indirect effects via input-output tables. Furthermore, labour productivity per sector deviates between member states in some cases significantly. Hence, the highest absolute impact on labour markets in the *Q0.55* was not assessed for Germany, but for Italy, followed by Germany and Poland. According to the quantitative assessment with ASTRA-EC, *Q0.55* induces about 19,900 additional jobs created in Italy compared with the *CP* in 2030. In Germany about 15,450 and in Poland about 11,900 additional FTE jobs can be expected until 2030.

The impact of *Q27* on the EU labour market is only half as high as in Q0.55. In total only about 38,000 FTE jobs created in 2030 are the outcome of the ASTRA-EC simulations. In Q27 about one third of all EU28 FTE jobs created in 2030 compared with the *CP* are expected to be on the German labour market. Poland, Bulgaria, Greece, Italy, Romania, Spain and United Kingdom are expected to gain additional 1,800 up to 4,300 FTE jobs more in Q27 than in *CP* in the year 2030.

Table 50: Jobs (FTE) created/destroyed in *Q0.55* and *Q27* in 2020 and 2030 compared with *CP* on Member State level [in FTE jobs]

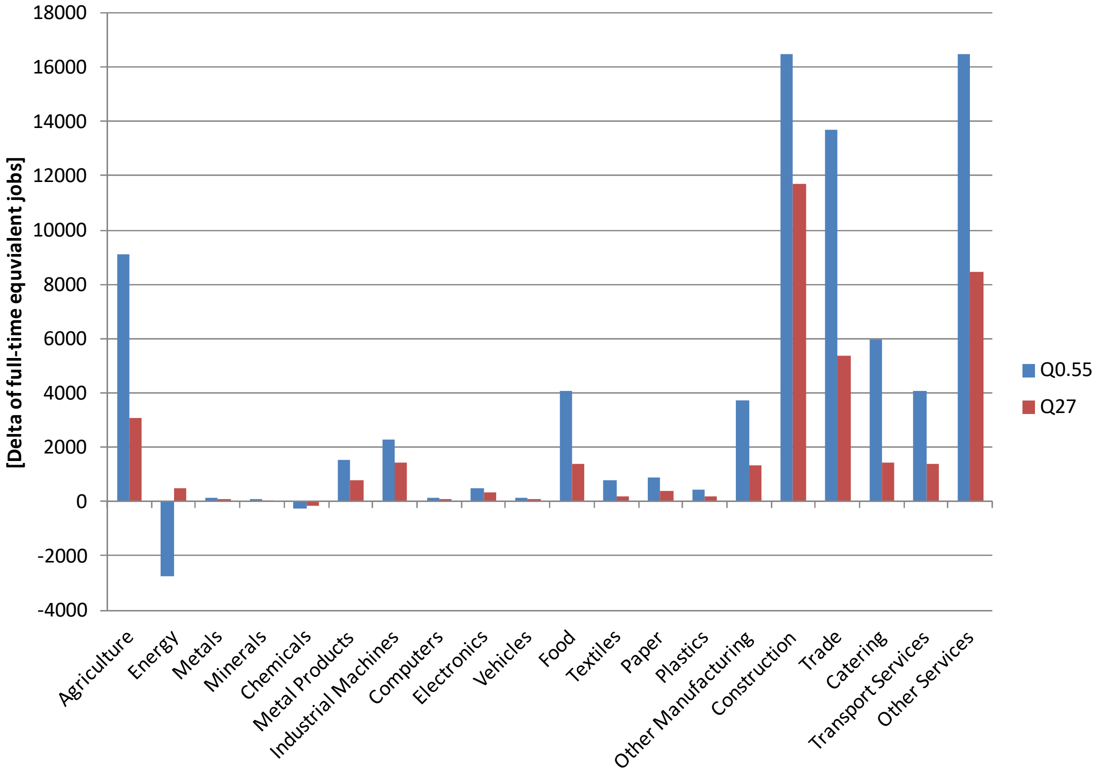
	Q0.55	**Q27**
EU28	77,534	38,033
Austria	400	-943
Belgium	921	977
Bulgaria	2,824	2,751
Croatia	78	81
Cyprus	266	63
Czech Republic	170	1,071
Denmark	1,773	110
Estonia	527	184
Finland	759	515
France	1,284	-170
Germany	15,448	12,956
Greece	2,622	2,597
Hungary	832	899
Ireland	322	321
Italy	19,876	2,442
Latvia	3,027	534
Lithuania	883	209
Luxembourg	48	24
Malta	-58	-52
Netherlands	334	-263
Poland	11,925	4,327
Portugal	1,126	554

	Q0.55	Q27
Romania	8,284	2,444
Slovakia	498	532
Slovenia	68	97
Spain	1,474	1,838
Sweden	612	1,335
United Kingdom	1,210	2,668

Source: Fraunhofer-ISI, ASTRA-EC

Figure 82 illustrates the impact of both RES-H/C strategies in *Q0.55* and *Q27* on the sectoral structure of labour market effects induced by the policies in EU28 compared with the *CP* for 2020 and 2030. Both figures demonstrate that indirect and second-round impacts have a strong impact on the economic development. Even if there are no direct investments or even private household consumption expected in sectors like Agriculture, Food, Catering or Other Services the ASTRA-EC simulations show up positive labour market impacts on these sectors on top of those economic sectors directly affected by investments in RES-H/C technologies like Construction, Trade, Industrial Machines, Metal Products and Other Manufacturing. The moderate economic growth of GDP in almost all EU member states besides Austria and Malta leads to increasing disposable income of private households and additional gains for companies allowing for further investments. This leads to increasing numbers of FTE jobs especially in sectors with low labour productivity. The opposite effect can be observed for sectors with high labour productivity (e.g. Industrial Machines or Computers) where changes in final demand will not end up in strong changes of FTE employment.

Figure 82: Change of FTE-Employment in Q0.55 and Q27 compared with CP [in Number of FTE Jobs]



Source: Fraunhofer-ISI, ASTRA-EC

Another plausible and observable model reaction is the marginal decline of jobs in the energy sector induced by energy cost reductions in most EU member states from the shift towards higher shares of RES-H/C. In macro-economic terms, this leads to lower levels of gross value-added in this sector which leads at least in *Q0.55* to a decrease of jobs in the energy sector in EU28 of about -2,700 FTE jobs in 2030 compared with the *CP scenario*.

According to the ASTRA-EC simulation results for **Q0.55**, between 13,700 and 16,500 FTE jobs created can be expected in the Other Services, in the Construction and the Trade sector. Further sectors benefiting from the RES-H/C strategies determined in *Q0.55* are the Catering, the Food, the Transport Service, the Industrial Machines and the Metal Products sector.

The picture provided by the ASTRA-EC results in *Q27* is somewhat different. The labour market changes are dominated by the increase of FTE jobs in the Construction, the Other Services and Trade sectors with about 5,400 (Trade) up to 11,700 (Construction) FTE jobs created in 2030.

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