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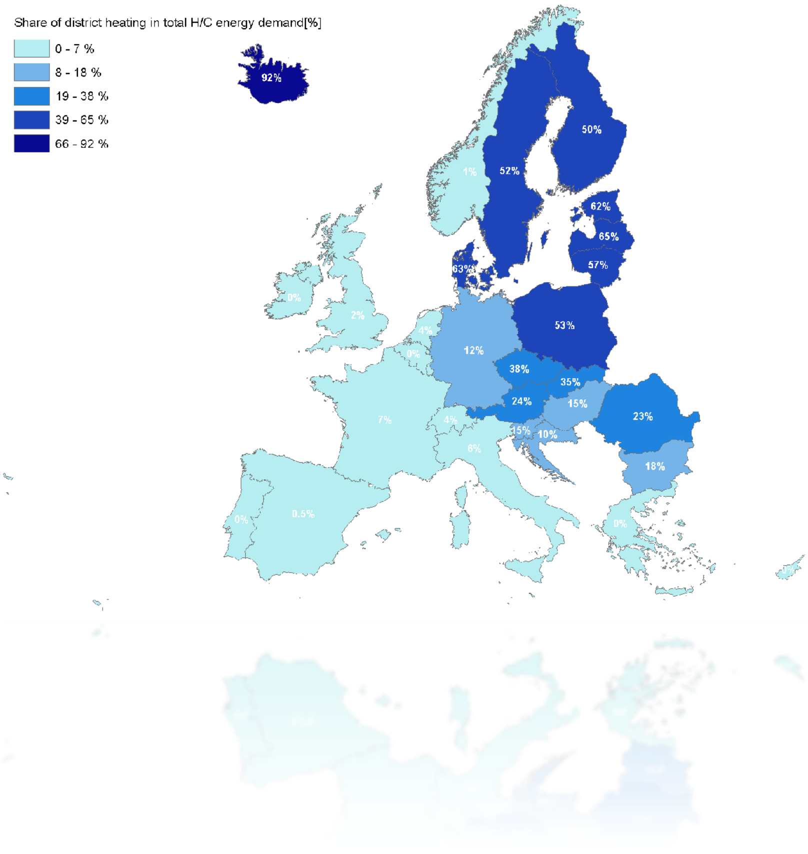
Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables)



Executive summary

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Table of contents

1 Overview

The heating and cooling (H/C) sector has become much more important over the last years and now represents a major field of European energy policy. The H/C sector accounts for about half of Europe's final energy demand and a high share of its CO_2 emissions. While the use of renewable energy sources (RES) for H/C has increased over the last decade and was almost 18% in 2014[1], H/C is still dominated by fossil fuels in most European countries and in the EU as a whole. There is still a large untapped potential in this sector to replace imported fossil fuels by mostly domestic RES. Despite the high importance of H/C as a field of energy policy, the relevant data are often scattered and based on different definitions and methods in the individual countries.

Our project aims to provide a comprehensive assessment of the entire H/C sector in the EU including Switzerland, Norway and Iceland. We analyse the current state of the sector as well as its evolution up to the year 2030. The assessments include detailed analyses of residential and non-residential buildings, industrial processes and district heating.

In particular, the project covers the following topics, each represented by an individual work package.

1. **End-use energy balances for H/C for 2012:** A consistent end-use energy balance is compiled for Europe's H/C sector. The results are disaggregated by country, sector, sub-sector, building type, energy carrier end-use and temperature level.
2. **Current state of H/C technologies:** This work package gathers information on the current stock of H/C technologies in European countries. It distinguishes technologies in buildings, industry and district heating and assesses the current performance of H/C technologies.
3. **Scenarios up until 2030:** Using the bottom-up models FORECAST, Invert/EE-Lab and Green-X, this work package develops scenarios for the evolution of the H/C sector up until 2030. The results are analysed with regard to final, useful and primary energy, CO2 emissions, import shares, induced investments and RES-H/C shares.
4. **Analysis of economic impacts up until 2030:** The macro-economic model ASTRA is then used to assess the economic impacts of the different scenario results in terms of induced employment and economic growth.
5. **Analysis of barriers, best practices and policies:** Based on the existing literature and expert interviews, we analyse and discuss the barriers, best practices and policies for the increased use of RES in the individual market segments of the H/C sector.

An overview of the work packages and the role of the bottom-up modelling system are shown in Figure 1. The bottom-up sector models are used to ensure a consistent methodology across countries in WP1, to fill data gaps in WP2 and to calculate the scenarios up to 2030 in WP3. The bottom-up models are also used in conjunc-

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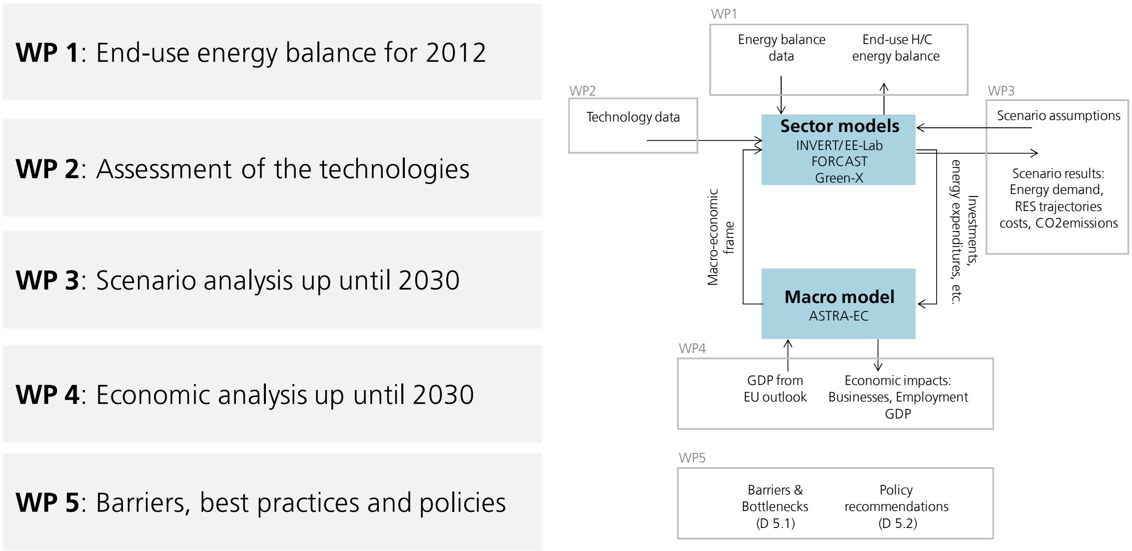
1 See Eurostat SHARES project (http://ec.europa.eu/eurostat/de/web/energy/data/shares)

tion with the macro-economic model and feed investments in H/C technologies into the macro-economic model.

Figure 1: Overview of the project structure



The following report provides a brief summary of the individual work packages including the main results. Given the scope of the analysis and its multiple aspects, this summary is only able to show selected aspects and results. The individual work packages contain a rich pool of results for the individual sectors and technologies. Furthermore, the reports of WP1, WP2 and WP3 are accompanied by an **annex of extensive data sheets**. These include the full end-use energy balance for the individual European countries for 2012 (WP1) and 2030 (WP3), for example, as well as technology stock and performance data for the most relevant RES and fossil H/C technologies in buildings, industry and district heating (WP2).

2 Work package 1: Energy balances for 2012

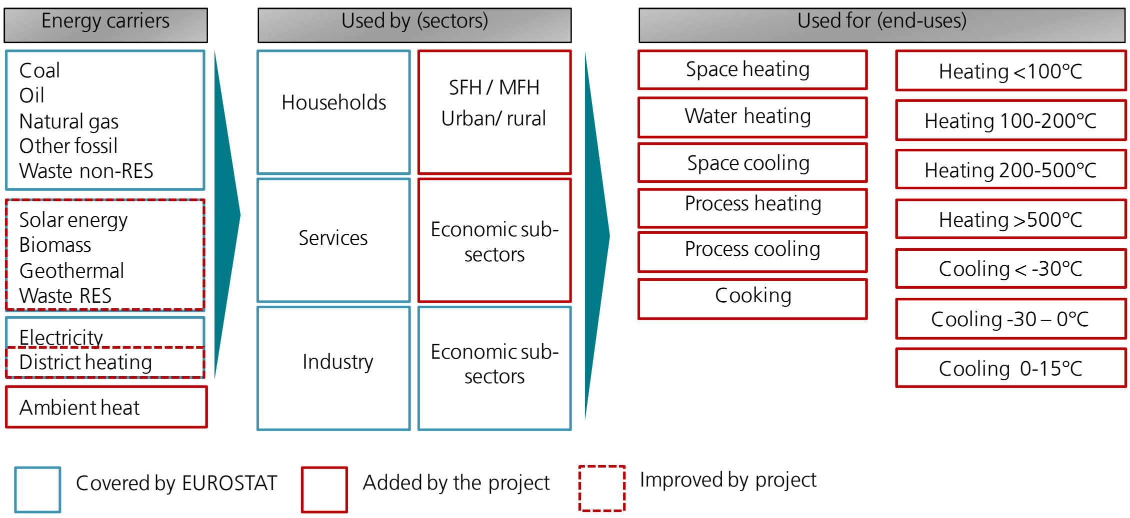
2.1 Objective and approach

Work package (WP) one assesses the status-quo of energy demand for heating and cooling in the European countries in the year 2012. The main goal of the WP is the calculation of a consistent European end-use energy balance for heating and cooling. In contrast to classical energy balances that show sectors and energy carriers, end-use energy balances also include information on the purposes energy is used for. Examples are space heating or water heating. Consequently, end-use balances provide valuable information to understand the structure of energy demand and provide a basis for demand-oriented energy policies.

Following on an assessment of available energy balances in member states, a consistent end-use balance for the EU28 countries plus Norway, Switzerland and Iceland is calculated. The approach used combines empirical data with a bottom-up modelling approach to assure a consistent and complete set of results. The final energy demand balance is calibrated to the energy balances as provided by Eurostat.

The end-use balance differentiates three main demand sectors and five end-use categories as shown in Figure 2. Data delivery and disaggregation in particular includes the split of energy carriers, end-uses and sectors by country. Process heating and cooling is further disaggregated into individual temperature levels. For the industrial and the tertiary sector energy balances by country are further broken down into sub-sectors, whereas the residential sectors are differentiated by building type and into urban and rural regions. The quantification of end-use balances is provided for final, useful and primary energy.

Figure 2: Structure of end-use balances calculated in comparison to Eurostat final energy balances



The methodology to calculate end-use balances by country consists of the following main elements.

- Data of final energy demand by energy carrier and demand sector (industry, tertiary, household) are taken from **Eurostat** and were used to "anchor" heating and cooling energy balance.
- **Surveys** were carried out to close data gaps with regard to renewable energy use and district heating. The surveys collected data from national statistical offices, energy agencies and industry associations.
- If no information could be gathered, a coherent approach was developed to **impute missing data** or to resolve inconsistencies in case of data availability from different sources. Either model results were used to impute missing values or model results were calibrated with data gathered.
- Sector-specific **bottom-up models** are used to close data gaps and provide a consistent data set. The models are fed with data from studies, norms and standards, literature and engineering-estimates.
- **Useful energy demand** is derived from final energy demand by applying specific end-use conversion factors (e.g. technical efficiency scores of heating and cooling systems and appliances). To this end data from WP 2 is used to complement current model database content.
- **Primary energy demand** is calculated from final energy consumption by applying primary energy factors based on the countries' input mix to the conversion sector.

2.2 Data used

The main input data for the calibration of the end-use balances are the Eurostat final energy balances. The end-use balances calculated are calibrated to Eurostat on the level of sub-sectors, countries and energy carriers. Additional input data and assumptions are sector-specific. A brief overview is presented in the following.

Industry sector

The end-use balances for the industrial sector are calculated using the bottom-up model FORECAST-Industry by combining activity parameters and energy-related indicators.

Main activity parameters are industrial production by process for process heat and cooling and floor area in buildings for space heating and cooling. Industrial production is collected from various sources including Prodcom, UNFCCC, industrial organisations (cement, paper, steel) and US geological survey. The coverage and robustness of the most important processes is relatively good. For the floor area in industrial buildings, no official statistic is available (only scattered data for individual countries). Consequently, floor area is calculated based on the number of employees (source Eurostat) and the specific area per employee (source individual studies). Given the uncertainty in the input data, also the results for space heating and cooling in industry are more uncertain than e.g. for process heating.

Main energy-related parameters are among others the specific energy consumption of processes (e.g. kWh per tonne of clinker produced), shares of temperature levels for individual processes (e.g. heat above 500°C as share of total heat in clinker furnace) and specific energy consumption per floor area for heating and cooling (kWh/m²). These values are based on numerous studies. Still, especially for the energy-intensive processes assumptions are relatively robust, because differences between countries are small and technical change rather slow.

Tertiary Sector

The end-use balances for the tertiary sector are calculated using the bottom-up model FORECAST Tertiary by combining activity parameters and energy-related indicators.

Main activity parameters for the services sector are the specific demand driver employment and floor space. Demand data is collected from Eurostat (employees) and individual studies (building related information on floor area, insulation standards, etc.).

Main energy-related parameters are among others the specific energy consumption of end use appliances (e.g. heat pumps, direct electric heating, boilers, refrigeration, etc.), installed capacities of appliances, utilisation rates of appliances and/or specific data on energy consumption per floor area for heating and cooling (kWh/m²). These values are based on numerous studies. For the heating related data (space heating, warm water and process heat), assumptions are relatively robust, because of higher data availability and fewer uncertainties. Data assumptions on space cooling and process cooling are less robust since in most of the member states, less information is available on the use and distribution of cooling.

Residential sector

The end-use balances for the residential sector is based on existing national energy balances, empirical data provided by national statistical experts to the ODYSEE database as well as model results using the building stock model INVERT/EE-Lab. Own in-depth analysis are conducted for renewable energy sources and district heating based on national data sources such as end-use balances where available.

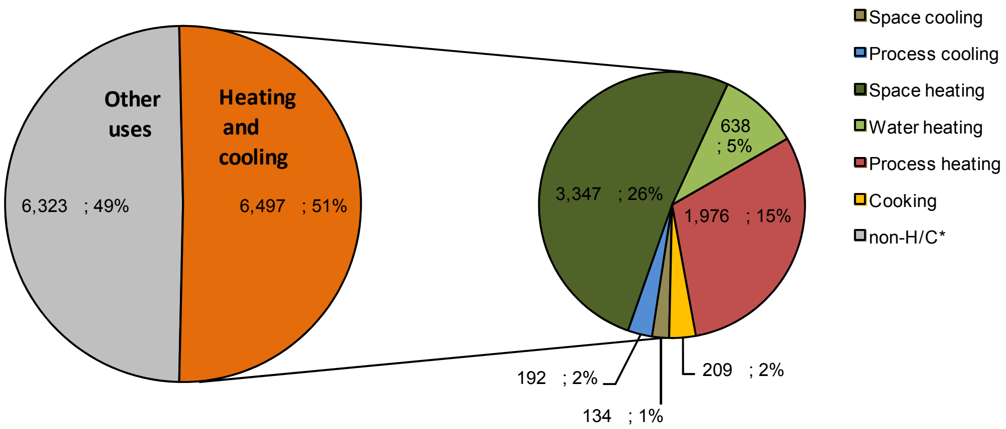
The Invert/EE-Lab model is mainly applied to fill data gaps on the disaggregation of end-uses to building categories. The model follows a building physics approach to calculate the energy demand for space heating, water heating and space cooling. The main input data are geometry data and u-values of building components as well as installed heating systems and heat distribution systems. Detailed input data for the model has been collected within the EU project ENTRANZE.

2.3 Results

It becomes apparent that the **final energy for heating and cooling** is responsible for about 51% of the total final energy consumption that was roughly 12,800 TWh in 2012. Space heating is the most relevant end-use with a share of 52% of the total final energy demand for H/C (~3350 TWh), followed by process heating which makes up 30% (~2000 TWh). Water heating (sanitary hot water) accounts for about 10% (~640 TWh), cooking in the residential sector for about 3% (~200 TWh) and cooling uses 5% with about 130 TWh for space cooling and about 190 for process cooling (see Figure 3).

Within the three demand sectors, industry, residential and tertiary, H/C demand breaks down quite differently into the individual end-uses: The **residential sector** is dominated by space heating and water heating (share of 76% and 16% respectively) whereas the remaining end-uses such as cooking and space cooling account for only 7% and 1% of H/C, respectively. In the **industry sector**, process heating makes up for the major share with about 81%, space heating accounts for 15% and cooling 3%. Also in the **tertiary sector**, space heating has the major share (61%), but as a whole, other end-uses such as water heating, (14%), process cooling (10%) and space cooling (9%) also show relevant shares.

Figure 3: Final energy demand for EU28 by end-use for H/C in all sectors in 2012 [TWh]



In total, 66% of **final energy for H/C** is supplied by fossil fuels and 14% by renewable energy sources. The remaining 20% are based on the secondary energy carriers – electricity and district heating. However, the proportions of each energy carrier are varying across different end-use categories: while heating is characterized by a diverse mix of energy carriers, cooling is almost predominantly generated by electricity.

In 2012, about 8000 TWh **primary energy** were used in the EU28 for H/C purposes. 45% of this was natural gas which is the individual most relevant energy carrier for the supply of heating and cooling. It is followed by coal with about 15%. Biomass and fuel oil both account for about 11%. Nuclear energy for 7% and other RES (wind, PV and hydro) for 5%; both is used for electricity generation which in turn is used for heating and cooling. Other RES like solar thermal energy, ambient heat and geothermal energy in sum account for 1.5%. Across all energy carriers, RES account for 18% of primary energy supply for H/C, whereas fossil fuels account for the major share of 75% in the EU28. This calculation is different to the methodology applied in the SHARES tool used by EUROSTAT which calculates RES-H&C share on the level of final energy. Thereby derived heat from renewables (district heating) is considered but RES used to generate electricity is not taken into account.

Useful energy is calculated to complete the equation of the different energy balances. This is insofar important to derive valuable insights into transformation efficiencies. From the 6500 TWh final energy demand in 2012 only about 5100 TWh are effectively used and roughly 21% of final energy is dissipated during conversion to useful energy. The transformation losses are not evenly distributed among the different end uses. The useful energy demand has been defined as the heat/cold used by the end-user (e.g. at the radiator), which implies that the useful energy demand can be further reduced by energy-efficiency measures e.g. via insulation of a building.

2.4 Quality of results

The calculated end-use energy balances for final energy are based on numerous sources from national and EU studies and statistics. By including the data sources in bottom-up models to provide a consistent set of results, the uncertainties could be reduced considerably in the scope of the project. Albeit that, some uncertainties are remaining. **Across the three sectors** the following observations were made with regard to the robustness of the results:

- **Uncertainty** occurs at different levels (total consumption, share H/C, end-uses etc.) and increases with differentiation (e.g. total space heating well defined, but allocation to individual energy carriers less certain).
- **Share of H/C** is well defined for most energy carriers (exception: electricity, which is used for many other non-H/C purposes).
- **H/C in absolute terms** is well defined for fossils, but less accurate for RES. Main reason is the better quality of energy balances for fossil sources, because RES are often not even commercially traded (non-commercial biomass, solar energy).
- **Space cooling:** empirical data is scarce and energy estimates are uncertain, because they are mainly based on assumptions for user behavior and (average) performance of appliances.
- **Space heating in industry** is uncertain, because virtually no empirical / statistical information is available and all energy carriers are mainly used for process heating.
- The split of residential demand in **urban/rural** is substantially less robust than the total for each end-use.
- For **RES** and **district heating**, the breakdown to the three demand sectors is relatively uncertain, because most statistics only provide totals.
- Among the **RES**, results are relatively robust for solar thermal, geothermal and renewable waste, while they are more uncertain for biomass (especially small-scale non-commercial biomass) and ambient heat tapped by heat pumps.
- While the total amount of **district heating** consumed is relatively well known from Eurostat, the allocation to sectors is less certain as well as its supply composition.
- Parameters to estimate **useful energy estimates** have low empirical basis (specific studies for selected countries and years, but not consistently longitudinal and cross-sectoral). Consequently, useful energy balances are less robust than final energy balances.

2.5 Conclusions and recommendations

The analysis of national end-use energy balances shows that consistent data regarding heating and cooling energy consumption only exist in a minority of countries, mostly focusing on the household sector. Particularly original (i.e. empirical) information on heating and cooling use in the different economic sub-sectors is scarce.

A methodological framework combining bottom-up models with survey methods and empirical data was used to calculate energy demand of various heating and cooling end-uses. The approach allowed establishing a full end-use energy balance for H/C in Europe by member state. The following conclusions can be drawn with regard to the quality of the results:

- Coverage: Data gaps with regard to end-uses could be closed and a complete European end-use energy balance was established.
- Coherence and comparability: The use of models increases the coherence and comparability of results.
- Robustness: With the combined approach, the quality of the data is improved and the robustness of the results increased since better conditions for calibration are achieved.
- Generally: Energy balances that consider end-uses always have a higher uncertainty than traditional energy balances considering sectors and energy carriers, even when being based on surveys.

It is **recommended** to establish a methodological framework that allows for a coherent monitoring and ex-post analysis of policy measures targeting heating and cooling services. Ideally such a framework combines empirical and modelling approaches to overcome weaknesses and emphasize strengths. Empirics is important for models and models are able to separate stochastic effects (e.g. from weather influence) from deterministic effects as a result of technological development or policy instruments.

For many countries and end-uses the empirical data foundation is weak. More empirical assessments via broad surveys could substantially increase the robustness of the end-use balances. Even when balances are calculated by the use of models, more robust empirical input data will improve the results. Across Europe, the main data gaps currently exist with regard to space cooling across all sectors; space heating in the industrial sector; the current use of RES in industry and tertiary (besides biomass); the use of non-commercial biomass in the residential sector; derived heating regarding the split between district heating and industrial auto-generation and regarding the break down into the main demand sectors; the split between urban and rural and the use of ambient heat. Additional surveys are needed to fill these data gaps.

Comparing results on a country level reveals huge differences across the individual countries as well as in comparison to the EU average values. Policies addressing H/C will therefore need to take country-specific situation and the heterogeneity across Europe into account.

3 Work package 2: Current state of technologies

The objective of work package 2 was to acquire detailed information about the stock of heating and cooling technologies in the European Union member states, Norway, Switzerland and Iceland. The data collected is be distinguished between the building sector (chapter 2), industry sector (chapter 3) and in the district heating and cooling systems (chapter 4). The main challenge in all sectors is data availability. Almost no data source combines detailed information on installed units and capacities for the different countries. Therefore, many different data sources had to be used and integrated into a consistent set of data. In some cases data were not publicly available at all. Furthermore, the data were not usually available at the desired level of detail. Therefore, modelling results had to be used to fill remaining data gaps. The approach, the main findings and the concluding recommendations are summarised in the following sections.

3.1 Space heating and cooling in buildings

Space heating in European buildings is dominated by fossil fuel burning technologies (Figure 4). Natural gas, oil and coal boilers account for 61% of the total installed thermal capacity and 50% of the installed units (small scale has a negligible share).

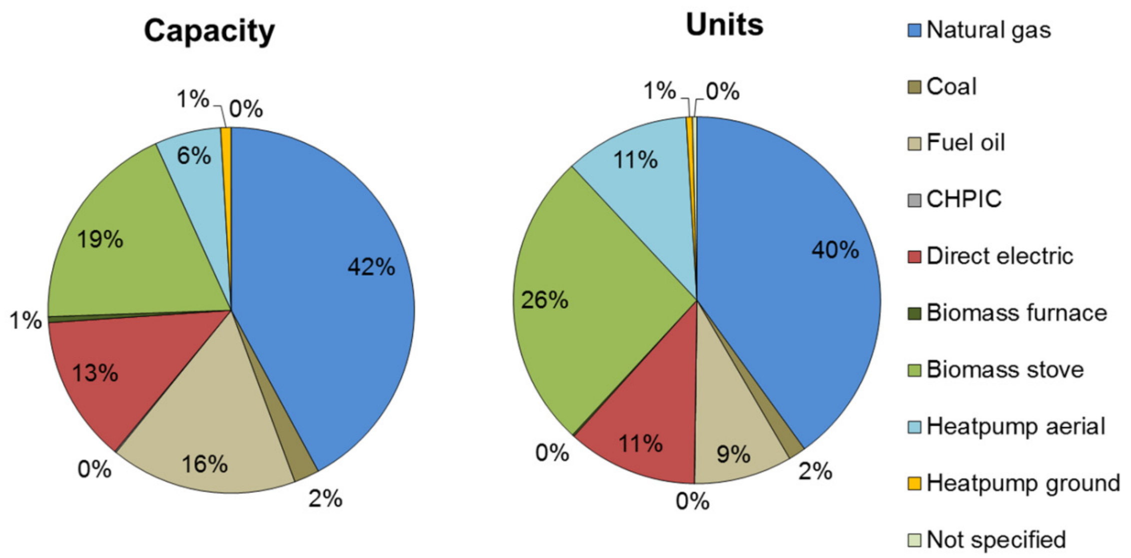
In recent years coal-fired boilers have largely been replaced in most European countries. An exception is Poland where coal technologies still represent 36% of the total installed heating capacity. In contrast with the countries which have majority shares of fossil fuel-fired technologies (natural gas, fuel oil and coal) there are countries which use very low proportions of fossil fuel-fired technologies including Sweden, Estonia and Finland.

Biomass based heating technologies also play an important role in terms of installed capacity (~20%), and installed units (~26%). As biomass stoves and furnaces are usually secondary heating systems the share of biomass in the heat generation in buildings is below the proportion of installed capacity. Countries with a very high share of biomass burning technologies in the installed capacity are Estonia with 73%, Latvia with 65%, Slovenia with 63% and Romania with 57%.

Heat pump technologies are a relatively new technology compared with fossil fuel, biomass burning technologies, and direct electric heating systems. Nevertheless, heat pumps represent 7% of installed capacity and 12% of installed units.[2]

2 Note that the aerial heat pump figures also include reversible split air-conditioning, for which particularly in Italy and France very high numbers of about 16 million and 5 million units are reported by the national ministries, respectively. In contrast, European Heat pumps association (EHPA) reports only about 10% of the national figures for aerial heat pumps. Using the figures from EHPA for aerial heat pumps would result in lower figures of about 1-2% of installed capacity and units for the EU28 in Figure 4.

Figure 4: Installed individual heating systems in buildings in EU-28

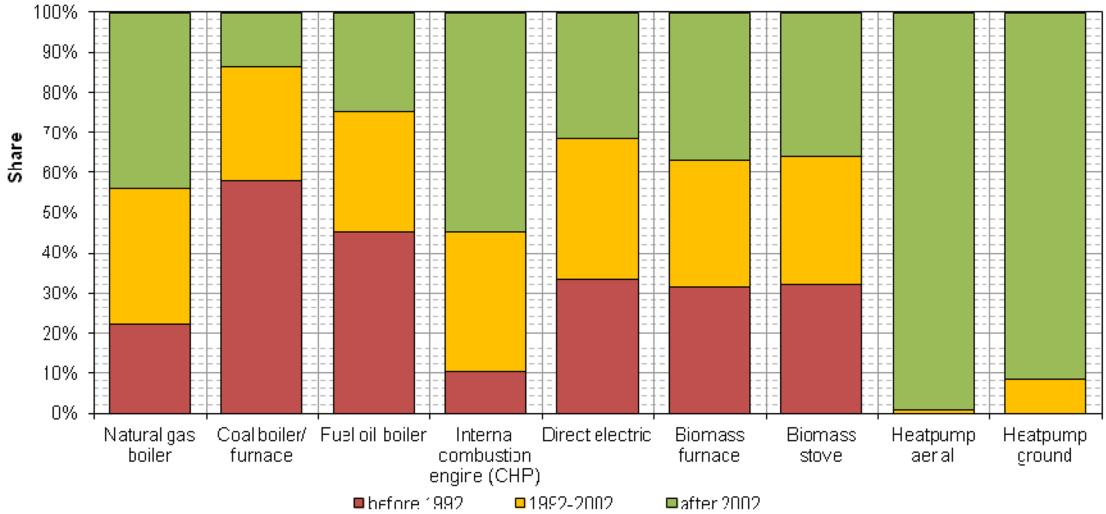


Note: CHPIC: Combined heat and power internal combustion engine

Most heating technologies in buildings were installed after 1992. The age distribution in the EU-28 differs between renewable energy technologies and conventional heating technologies (fossil fuel boilers, direct electric). The oldest heating technologies are those based on coal with about 58% installed before 1992 and only 14% installed after 2002. The newest are aerial heat pumps; 99% of the installed units were installed after 2002. The relative age distribution in the EU-28 by technology is illustrated in Figure 5.

The countries with the oldest heating stock in terms of installed units are Cyprus, Poland and Greece where 45%, 36% and 36% respectively were installed before 1992. The newest heating stock can be found in Estonia (61% installed after 2002), Italy (60% after 2002; mainly due to a high share of aerial heat pumps) and Sweden (54% installed after 2002).

Figure 5: Age of the heating technology stock (in terms of installed capacity) by technology in the EU-28



Source: own illustration based on the sources given in chapter 3.[3]

3.2 Process heating and cooling

Process heat demand can be differentiated by direct use of heat (e.g. in furnaces) and indirect use of heat (via steam and hot water). The analysis considers technologies from both types of heat use including furnaces in the iron and steel industry, cement and glass production as well as CHP and steam boilers for steam and hot water supply across all industrial sub-sectors.

The analysed technologies cover 85% of the total process heat demand of around 2000 TWh in the EU28 in 2012.

Regarding the **completeness and quality of data** on the stock of technologies, the picture is very diverse. Information consists of the number and capacity of units installed, and the construction year. For some technologies, for example iron and steel, data from commercial sources are complete and even include the construction year of most plants. The database for CHP also provides very detailed analyses; however, the distinction between autoproduction (mainly industrial CHP) and central CHP for district heating is not robust and substantially underestimates the share of CHP in industrial autoproduction. For glass furnaces some information on the age of plants is available, while for clinker kilns there is no such information. The worst data situation is for steam boilers. For these, even the capacities by country had to be estimated. This is particularly astonishing given the significance of steam boilers which account for about one third of process heat demand.

Thermal efficiency has been assessed for both the average technology in the stock and for new technology on the market. The difference between these, however, is relatively low for most technologies. Replacing the entire technology stock for process heating with current technology would only improve energy efficiency

3 The age distribution of CHP internal combustion engines only refers to Germany as the information is not available for the other Member States.

by a few percentage points.

The **use and potential of RES** is very much process-specific. In the blast furnaces of the steel industry coal is still the dominant energy carrier. The co-firing potential of solid biomass is limited and is still an issue for R&D. In the cement industry, however, co-firing of waste (renewable and fossil) as well as biomass in the clinker kiln is common practice and depends on energy prices. However, due to the low calorific value of biomass compared to coal for example, there are technical limits to co-firing in the clinker kiln. In glass melting furnaces, natural gas is the dominant fuel due to reasons of process control and purity. While renewable sources are currently not used, the use of biogas in glass melting furnaces is subject to R&D projects. In CHP as well as steam boilers, RES have been used in the past, although only in selected countries and to a relatively low extent compared to fossil fuels. For example in Sweden many biomass fired CHP units date back to the decades from 1950 to 1980 and in Finland large biomass CHP capacities were constructed between 1993 and 2002. Multi-fuel burners could be an attractive option for biomass co-firing, particularly for steam boilers.

Regarding the **age distribution** of the capital stock the picture provided by the available data is incomplete. Only for furnaces in the iron and steel industry, CHP plants and some glass melting furnaces information about the construction year of individual plants was available.

However, for large industrial facilities, the construction year is not the only determinant of their efficiency. In practice, industrial plants are typically retrofitted and modernized without being completely replaced. Modernization for example allows using more efficient burners (e.g. replacing recuperative by regenerative burners) or using multi-fuel burners that provide more flexibility with regard to the heat used.

3.3 District heating and cooling

District heating systems for the heat supply in buildings and industry is very heterogeneous in Europe. The largest proportion of citizens served by district heating system can be found in Northern and Eastern European countries (see work package 1) with the highest share in Iceland (>90%), Latvia (~65%), Denmark (~63%) and Estonia (~62%). There is, however, no district heating in Cyprus, Ireland and Malta.

The countries with the highest installed thermal capacities are Poland (58 GW), Germany (49 GW) and the Czech Republic (24 GW), Denmark (23 GW). In Iceland, Latvia and Estonia the share of district heating in the heat supply is high and has comparably small installed capacities, due to the small population size of the countries.

The supply source of district heat (fossil/ renewable energy sources) is highly variable between the analysed countries. In Iceland for example the district heat capacity is 100% renewable (geothermal), while the share of renewable capacity in Estonia, Germany and Romania is very low. The use of solar thermal collectors and heat pumps is not yet widespread in Europe; it is only used in Denmark, Finland, Germany, Italy and Spain, and provides a small proportion of the installed thermal capacity. Nevertheless, the integration of heat pumps and solar thermal energy has increased in recent years and there are currently several efforts to increase the share of renewables and CHP in district heating systems.

3.4 Recommendations

The investigation and data acquisition in WP 2 revealed the poor empirical basis for installed units and capacities of heating and cooling technologies in buildings in Europe. The empirical data on renewable heating technologies like heat pumps and biomass burning units are much more detailed than the data for fossil fuel technologies in all European countries. Data with the aspired level of detail were only available in a few countries. Most of the data gaps could be filled by using bottom-up models to estimate the technology stock. The main gaps in the empirical data on heating and cooling technologies are:

- The sectoral split into households, industry and tertiary sectors for technologies used for space heating and hot water.
- Similarly for large CHP, the split between industry and district heating is not known by technology type (only on a highly aggregated level from Eurostat).
- In most countries, there are only statistics on installed units, but not on the installed capacities of heating and cooling technologies.
- Virtually no empirical information is available for (industrial) steam boilers.
- The split into different capacities and age categories is usually not available.
- Hardly any country has empirical data on cooling technologies, especially in buildings.

In some countries (e.g. Germany) there are schemes which allow constant monitoring of installed heating technologies in terms of age, installed capacity and units. Expanding such schemes to cover all Member States and heating (and cooling) technologies could improve the empirical data basis tremendously. Another possible approach, which in case it should be developed, is the systematic use of sales statistics.

As described in the recommendations of WP 1, district heating statistics could be substantially improved by harmonizing the statistics on installed units supplying heat and their capacity. A critical point is that peak boilers installed together with a CHP plant are usually accounted for as CHP plants and are not listed separately. Statistics based on units rather than plants would improve data quality.

Despite the empirical data gaps and difficulties with the available statistics, most of the identified and described gaps can be closed by combining the available empirical data with the results from established and validated models.

4 Work package 3: Scenarios up until 2030

4.1 Scenario definition

The main objective of WP3 is to calculate and analyse scenarios energy demand for heating and cooling and its evolution until 2020 and 2030. Technology-specific bottom-up models are used to simulate technology changes in the sectors industry, tertiary, residential and district heating.

Three individual scenarios are defined. A current Policy scenario describes the current implementation of policies while the three remaining scenarios focus on supplier obligations for RES heating and cooling deployment, each with alternative design options. All scenarios use the same framing macro-economic development to allow for a maximum comparability among scenarios. The economic framework assumptions are aligned with assumptions for the EU reference scenario 2016.

The Current Policy scenario includes the EU policy legislation related to heating and cooling (among others the Energy Performance of Buildings Directive, the Emissions Trading Directive and the Renewable Energy Directive) as well as major national initiatives. All policies have been defined as they were implemented at the end of 2015. No future changes or tightening of existing policies was assumed.

Two additional scenarios analyse the implementation of new RES-H/C policies, namely RES obligations for H/C supply companies. In such obligation schemes the suppliers and distributors of H/C energy are required to reach a certain RES-H/C or quota or render the equivalent amount of RES-H/C certificates. A variety of alternative design options is thinkable. The variations analysed in the form of individual scenarios as shown in Table 1. A key performance indicator for all scenarios is the share of RES-H/C in the total final energy demand (FED) excluding electricity.

The scenario *Gradual Quota MS* assumes gradual quota requiring that all H/C suppliers to achieve an annual average increase in RES-H/C share of at least 0.55% between 2020 and 2030. The quota is defined on member state level; that is trade among obliged suppliers in different member states is not allowed. The scenario *2030 Quota EU* allows for trade among suppliers in different member states in order to reach a uniform quota of 27 % on EU level.

The obligation scenarios assume that current subsidies for H/C are phased out after 2020 including subsidies for installing technologies as well as feed-in-tariffs e.g. for biomass CHP. The defined obligation schemes enter into force in 2020.

Table 1: Overview of scenario design

Scenario 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% by member state 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

4.2 Results and conclusions

The **Current Policy** scenario shows a decreasing **final energy demand** by around 7% from 6,350 TWh in 2012 to 5,930 TWh in 2030. The decrease is mainly driven by thermal efficiency measures in buildings. The use of RES increases by 38% until 2030 compared to 2012 and reaches a total of 1,093 TWh. At the same time, the direct use of fossil fuels is reduced by 15%. Also electricity and district heating experience a slight decrease of about 7% and 3%, respectively (see also Figure 6).

Although **space cooling** demands will rise substantially and **space heating** energy use will be falling until 2030, space cooling will still be of minor importance in terms of energy demand compared to space heating.

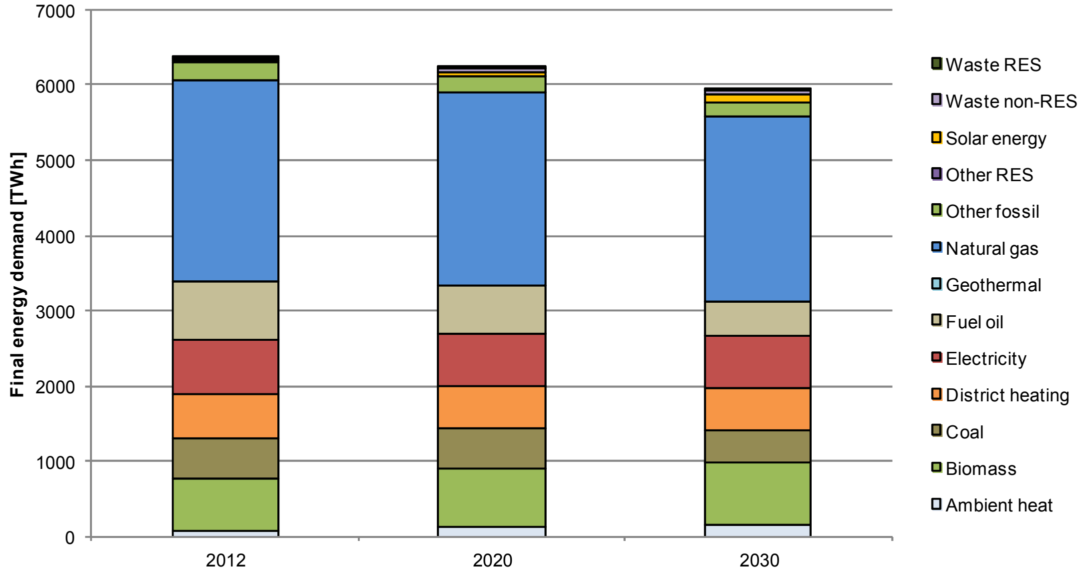
Consequently also the **RES-H/C share** increases from 16.7% in 2012 to 25.9% in 2030, mostly driven by increased deployment of RES but also as a result of falling final energy demand.

Primary energy use also decreases substantially, from 7,495 TWh in 2012 to 6,823 TWh in 2030. The energy mix continues its past trend and shifts towards higher RES shares. E.g. biomass provides 17% of all FED-H/C in 2030, whereas it was only 12% in 2012. Ambient heat and solar energy increase to 3% and 2%, respectively. Fossil fuel use is decreasing continuously. E.g. the share of coal falls from 15% in 2012 to 12% in 2030.

Total **CO_2 emissions** related to H/C drop by about 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 industrial sector emissions only fall by about 5%. CO_2 emissions are calculated based on the primary energy demand of the sectors industry, tertiary and residential and thus include also CO_2 emissions from the production of electricity and district heating. Lifecycle emissions e.g. from biomass use are not considered.

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

Figure 6: Current Policy scenario final energy demand for H/C in the EU28 in all sectors by energy carrier [TWh]



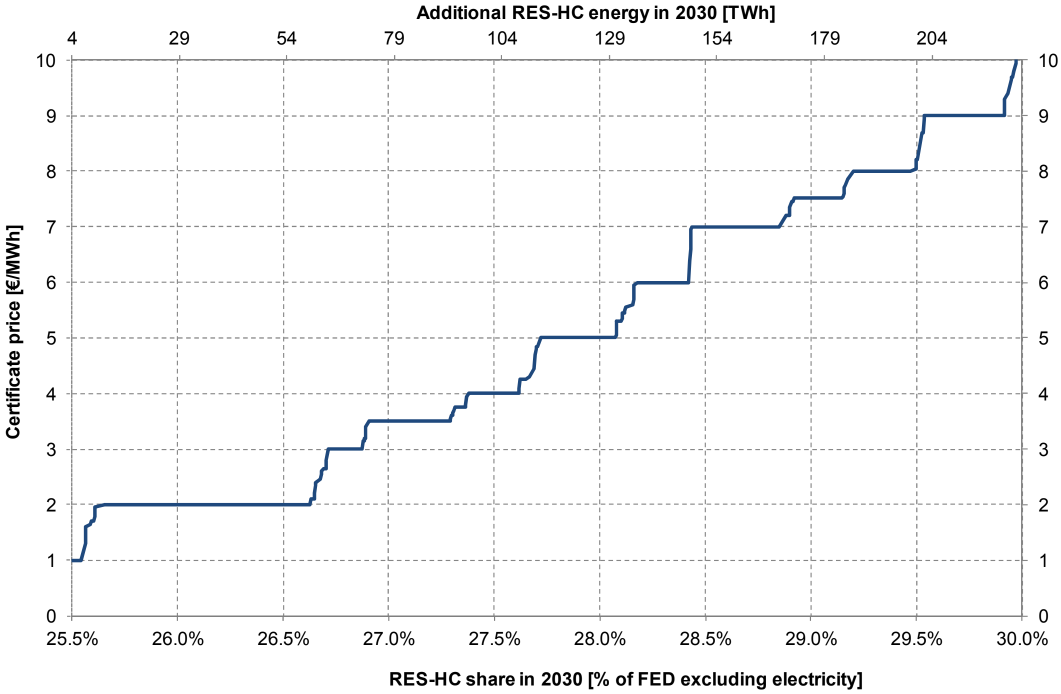
In summary, the Current Policy scenario already reflects a substantial change in the entire H/C sector towards higher use of RES driven by existing policy initiatives mostly at the EU level. The model results of course also contain a certain degree of uncertainty. If e.g. fuel prices were to develop differently or policies are not enforced the RES deployment could also develop less dynamically.

The calculation of the two obligation scenarios is based on a least cost approach, which assumes sequential implementation of RES options beginning with the "cheapest". In order to determine the least cost options, a marginal RES deployment cost curve is calculated for each sector and member state. The cost curve does not only show the H/C system costs, but also takes consumer and company preferences and barriers to RES investment into account.

The **results** of the **scenario 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 but Cyprus (0.1%/a) and Italy (0.54%). On the other hand some countries even reach the target without additional support level; that is a RES certificate prices or zero. Many countries arrive at average annual increases between 0.55 and 0.6%. Consequently, also the required certificate price to induce the RES increase varies significantly by country from 0 to nearly 10 euros/MWh. The average EU28 price is 7.4 euros/MWh and in total an RES-H/C share of 27.6% is reached.

The **scenario 2030 Quota EU** results in an RES share of 27.2% and a related certificate price of 3.5 euros/MWh in all member states (reflecting EU-wide trade). Figure 7 shows the resulting RES deployment cost curve for all member states and all sectors.

Figure 7: RES-HC deployment cost curve: RES-HC certificate prices, RES-HC share and additional quantities for the EU28; all sectors



A comparison of the scenarios shows that for the EU28 as a whole the achieved RES-H/C share is 1.7 (Q0.55) and 1.4 (Q27) 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% in 2030. However, the cost curve indicates that until 2030 the contribution of an obligation scheme could be substantially higher achieving e.g. a 30% RES H/C share with about 10 euros/MWh.

Biomass contributes most to this RES increase with 41 (Q27) and 81 TWh (Q0.55) more than in the Current Policy scenario in 2030, but also solar energy increases substantially (+22% in both scenarios). Among the fossil fuel technologies natural gas shows the largest decrease while others like 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 among fossil technologies.

In order to compare the **cost-effectiveness** of the individual systems, the ambition level of the policy target (RES-H/C share) has to be equalled. We have calculated three variations with varying RES-H/C shares for the two obligation system designs (Uniform quota 2030 on EU level with trade versus gradual quota on MS level). Results show that for all three target levels the system design with the EU-wide quota and trade has a lower certificate price as well as a lower additional system cost. The certificate price (and thus also the consumer expenditure) is 32 to 38% lower in case of EU-wide trade and the RES deployment cost decreases by 11 to 29%.

To summarize, 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-HC shares are available and can theoretically be exploited with an obligation scheme: with 10 euros/MWh about 30% RES-H/C share would be achieved.
- The starting point and remaining RES-H/C potentials vary strongly among countries and an obligation system can be a high burden for some countries while it hardly affects others – depending on system design.
- An EU-wide obligation scheme can have efficiency gains compared to national targets that do not allow trading between countries – if markets work efficiently.
- While the obligation scheme can follow a least cost RES deployment in the short term, it is not evident that this also is in line with a long-term sustainable path or if it steers into lock-ins where e.g. high shares of available biomass are used in the space heating sector although more urgently needed in other sectors.
- If the introduction of an RES-H/C obligation scheme also involves the phase out of existing subsidies for H/C technologies like efficient natural gas boilers, the system could substantially reduce the use of natural gas.

5 Work package 4: Economic impacts up until 2030

The objective of WP4 is to assess major macro-economic impacts such as changes in GDP and employment induced by the integration of increasing shares of RES-H/C on EU member state level. In order to enable this assessment the System Dynamics model ASTRA-EC has been applied. The analysis focuses on the following economic impacts.

- GDP and full-time equivalent employment.
- Investment costs replacing the fossil fuel H/C by RES-H/C on member state level by the applied technology-specific bottom-up models.
- The comparison of costs and benefits of replacing currently used heating and cooling technologies with state-of-the-art technologies

The economic impacts are distinguished by economic sectors.

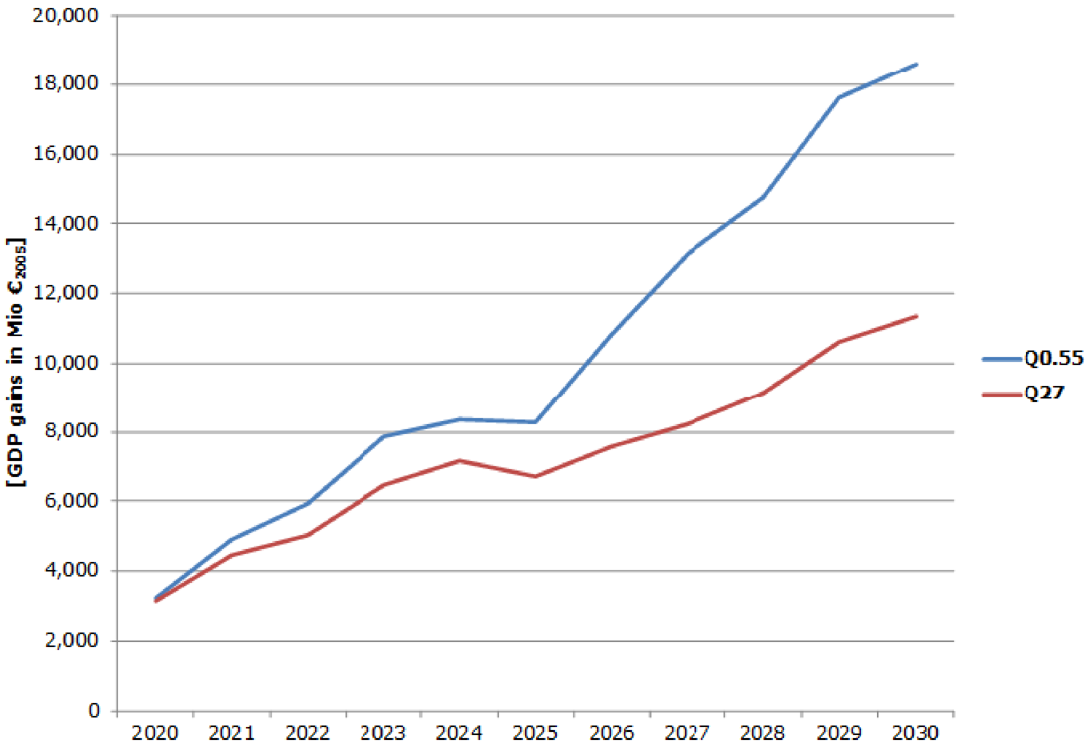
Micro-economic inputs (investments, energy costs, subsidies and net imports) for the three scenarios calculated are the result of WP3 based on the use of the sector specific bottom-up models. The macro-economic impacts are calculated for the two target scenarios *Quota MS 0.55* and Quota EU 27 as compared to the Current Policy scenario.

Results for the *Quota MS 0.55 scenario are as follows.* ASTRA-EC calculates a +0.12% higher GDP for EU28 in 2030 compared with the *Current Policy scenario*. Full-time equivalent (FTE) employment in EU28 is expected to increase marginally by +0.04% in 2030 compared with *Current Policy scenario*. The sum of direct, indirect and second-round impacts on investments sums up to an increase of +0.3%. Consumption of private households follows this trend and ends up in Q0.55 at a +0.3% higher level than in the CP for EU28.

According to the simulation results for the *Quota EU 27 scenario*, the GDP is only by 0.07% higher in the year 2030 compared with the *Current Policy scenario*. Employment in EU28 is expected to be by 0.02% higher than in the *Current Policy scenario*. The scenario impulses lead to increasing investments up to +0.24% higher than in the *Current Policy scenario*. Consumption of private households increases as well (+0.12% in 2030 compared with CP).

Figure 8 shows the resulting impact on GDP for both quota scenarios as compared to the Current Policy scenario.

Figure 8: GDP gains/loss in EU28 for the Quota MS 0.55 scenario (Q0.55) and the Quota EU 27% scenario (Q27) as compared with the Current Policy scenario



To summarise, both quota scenarios show a positive impact on GDP and on employment. However, the change is relatively small, mainly due to the fact that the two quota scenarios are only little more ambitious than the Current Policy scenario.

6 Work package 5: Barriers, best practices and policies

In this work package an analysis of barriers and bottlenecks that prevent the use of RES for H/C purposes is conducted. The role of successful best practices is documented and policy instruments towards a reduction of barriers and bottlenecks are recommended.

Based on the existing literature on barriers for energy efficiency and RES_H/C we define a barrier *as inhibitive factor for the use and the implementation of RES-H/C technologies that could be overcome by suitable policies.* On purpose we use a broad definition.

As barriers are related to decision-making behaviour and involve numerous different actors, the overall picture is very complex and many factors need to be taken into account. Observed barriers and recommendations are often only suitable for particular actors or technologies. To cope with this situation, structure our analysis along the following dimensions.

- Sector: Buildings, industry, district heating
- Stakeholders:
    - Investors/decision-makers: owners, owner-occupiers, owner communities, housing companies, management
    - Providers: energy suppliers, craftsmen, construction companies, contractors, manufactures
    - Intermediaries/other actors: finance corporations, insurance companies, planner, energy advisors, installer, customers, etc.
- Technology: Biomass (boilers and CHP), solar thermal, heat pumps, solar cooling

Relevant barriers include the owner-landlord dilemma, lack of information and mistrust in the performance of new technologies and a limited access to capital for certain stakeholder groups.

Selected best practice cases for the use of RES in H/C are provided in the report. These include specific cases as the use of biomass in process heating but also broad policy regimes as the support for RES in district heating in Denmark.

The scenario analysis in WP3 assesses the impact of alternative RES-H/C supply obligation schemes. Such supply obligation schemes mainly aim to improve financing and cost-effectiveness for RES via RES certificates that can be used by suppliers to fulfil the targeted RES quota. Furthermore, RES certificates might foster the entire RES-H/C market by improving the business model for ESCOs and RES-installers. While such obligations can be an important element in the RES-H/C policy mix, further instruments are needed as underlined by the analysis of existing barriers. Beside the already established standards for new buildings and the introduction of the uniform terminology of “Nearly Zero Energy buildings”, ambitious and uniform standards need to be implemented for existing buildings as well. Furthermore, such ambitious requirements need to be accompanied by renovation roadmaps for individual buildings providing a step-by-step implementation plan for the individual building owner.