Policies for RES-H/C: Results of the quantitative assessment

(D4.2)

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The progRESsHEAT project

The progRESsHEAT project aims at assisting policy makers at the local, regional, national and EU-level in developing integrated, effective and efficient policy strategies to achieve a rapid and widespread penetration of renewable and efficient heating and cooling systems. Together with 6 local authorities in 6 target countries across Europe (AT, DE, CZ, DK, PT, RO), heating and cooling strategies will be developed by a detailed analysis of (1) heating and cooling demands and future developments, (2) long-term potentials of renewable energies and waste heat in the regions, (3) barriers & drivers and (4) a model-based assessment of policy intervention in scenarios up to 2050. progRESsHEAT will assist national policy makers to implement the right policies based on a model-based quantitative impact assessment of local, regional and national policies up to 2050.

Policy makers and other stakeholders will be strongly involved in the process, learn from experiences in other regions and gain a deeper understanding of the impact of policy instruments and their specific design. They are involved in the project through policy group meetings, workshops, interviews and webinars targeted to the fields of assistance in policy development, capacity building and dissemination.

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Abstract

In course of the progRESsHEAT project an integrated and participatory assessment of policies to enforce the use of renewable and efficient heating and cooling solutions in Europe has been performed. This included a quantitative model based assessment at the local as well as at the national level for each of the municipalities and countries under investigation[1], and a continuous integration of different stakeholders and policy makers.

The objective of this report is to provide a description of the quantitative assessment of policies for renewable and efficient heating, cooling, district heating and electricity generation for the six target countries of progRESsHEAT (Austria, Czech Republic, Germany, Denmark, Portugal and Romania). In this assessment the energy systems for heating and cooling as well as electricity generation have been modelled and the impact of policies on the systems has been assessed at a national scale in scenarios until 2050.

On the national level, we compared the impact of an ambitious policy package to a current policy scenario. In the ambitious policy scenario integrated and advanced policy packages are assumed to be implemented in all considered countries. This includes a rising CO_2 price level, more stringent building codes, higher subsidies for building renovation and individual heating systems using renewable energy, cheap financing of investments in renewable district heating and electricity generation, OPEX support, extension of the ETS and material efficiency as well as circular economy in industry and favourable institutional and financing conditions for renewable district heating.

The analyses are based on a modelling framework combing three tools: The model Invert/EE-Lab was used for the modelling the energy demand for space heating, cooling and hot water preparation in residential and non-residential buildings, the model FORECAST-Industry was applied to the industrial heating and cooling demand. Finally, the TIMES models estimates cost-optimal investments and operation of the district heating and power generation sector. For all three sectors, the resulting GHG-emissions, demand for energy carriers, share of renewable energy and economic indicators were assessed in the two policy scenarios.

Although the current policy framework leads to a remarkable decarbonisation of H/C in particular in buildings in the analysed countries until 2050, more ambitious policies are needed to meet the emission reduction targets as set out in the Paris Agreement. Thus, faster and deeper decarbonisation of H/C in buildings is needed. An important measure to reach this is an intensified RES-H obligation: on the one hand the obligation should not only apply for buildings that are newly constructed, but also for buildings undergoing a major renovation and in case that the heating system is changed. The potential for reducing the heat demand in buildings is remarkable in many EU countries. In order to stimulate the realisation of building retrofit the public budget might be increased, but also could be set mandatory after a certain timeframe.

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[1] Please find more details on target countries and municipalities at the progRESsHEAT website: www.progressheat.eu

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Also in the industry sector, current policy is not on track towards decarbonisation in all analysed countries, though, a slow decrease of industrial CO_2 emissions is expected. Although, the ambitious policy scenario achieves substantial additional emission cuts, also this scenario is not in line with the Paris agreement in all countries analysed. Deep emission cuts require substantial changes in the iron and steel, cement and chemicals industries, but also support for RES and energy efficiency in other sectors. Excess heat potentials from industrial activity are available and should be exploited. Biomass is the most important RES in industry, particularly in the medium term. OPEX support of RES seems more effective than CAPEX support for steam and hot water generation. Finally, improved material efficiency and circular economy provide a huge mitigation potential, e.g. via the substitution of oxygen steel by electric steel. Although, the ambitious policy scenario achieves substantial additional emission cuts, also this scenario is not in line with the Paris agreement in all countries analysed. More mitigation options will be required in the long-term. These include a more intense use of electricity for process heat generation (power to heat), power to gas, new production processes and products and maybe carbon capture and storage.

Even though some countries can achieve renewable electricity and district heating generation only because of decreasing costs of technologies using renewable energy and taxes on fossil fuels, higher CO_2-prices and support for renewable electricity generation is often needed. High shares of renewable district heating can be achieved by measures implemented in the ambitious policy scenario, but higher CO_2 prices and more favourable financing for renewables is needed to reach 100% renewable district heating generation. Additionally, a strong link between electricity and district heating generation through large-scale heat pumps can be utilised to indirectly support renewable district heating generation by supporting renewable electricity generation.

More policy conclusions, derived from this work and the corresponding stakeholder discussion in this project are documented in the report “Policy recommendations to decarbonise European heating and cooling systems”[2].

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[2] This report can be downloaded here: http://www.progressheat.eu/Policy-recommendations.html

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1. Introduction and method

The objective of this report is to provide a description of the quantitative assessment of policies for renewable and efficient heating, cooling, district heating and electricity generation for the six target countries of progRESsHEAT (Austria, Czech Republic, Germany, Denmark, Portugal and Romania). In this assessment the energy systems for heating and cooling as well as electricity generation have been modelled and influence of various policies on these systems has been assessed at a national scale.

In course of the progRESsHEAT project an integrated and participatory assessment of policies to enforce the use of renewable and efficient heating and cooling solutions in Europe has been performed. This included a quantitative model based assessment at the local as well as at the national level for each of the municipalities and countries under investigation[3], and a continuous integration of different stakeholders and policy makers (Figure 1).

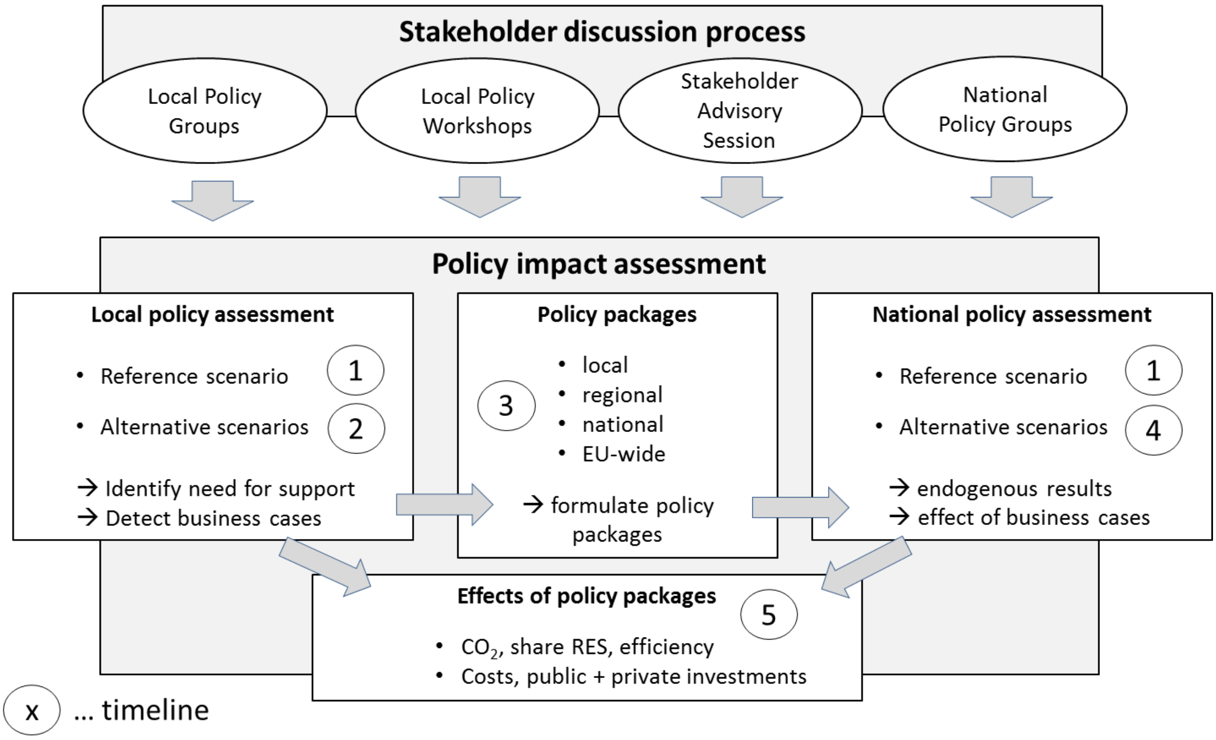

Figure 1: Integrated and participatory approach of policy assessment on national and local level in the project progRESsHEAT

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[3] Please find more details on target countries and municipalities at the progRESsHEAT website: www.progressheat.eu

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In course of the model based quantitative policy assessment the following steps have been performed:

1. Reference scenario local and national: for each municipality / local cases and each country a reference scenario has been calculated until 2050 reflecting the current state of political frameworks.
2. Alternative scenarios local: For each of the municipalities / local cases the influence of various policy measures has been assessed in their ability to make renewable and efficient solutions for heating and cooling a business case. This gave indication of which level of policy influence is needed in order to allow such solutions being feasible for business.
3. Definition of policy packages at different levels: with the input of step 2 policy packages for the local and national level have been formulated.
4. Alternative scenarios at national level: For each of the countries an ambitious policy scenario based on step 3 has been calculated in order to show the effect of ambitious policies on the national heating and cooling systems.
5. Assess effects of policy packages at local and national levels: the assessment of policy influence from local, regional, national and EU level on both local and national heating and cooling systems has been assessed using a set of emission and energy related key indicators. The indicators used for the national policy assessment are defined in chapter 1.3.

The definition of relevant policy measures for each of the local and national cases, preliminary results and recommendations drawn from the modelling exercise have been presented and discussed continuously during the 2 ½ years duration of the project. This was done in small policy groups at local and national level and in various workshops at local as well as EU level.

This report, as written above, focuses on the quantitative model based assessment of policy influence on the national heating and cooling systems. The detailed documentation of the model based quantitative assessment at local level is presented in separate reports for each of the municipalities and is available via the project website[4].

From this assessment of policy impact at local and national levels together with experiences and results from other ongoing and finished research work in Europe we derive recommendations for the design and implementation of policies at local, regional, national and EU level to enforce the use of renewable and efficient heating and cooling solutions. These are compiled in the report "Policy recommendations to decarbonise European heating and cooling systems".[5]

In the following we will outline the general assumptions in the two policy scenarios. Moreover, we will document the main methodological aspects of the modelling framework and the indicators that were used to assess the effects of the different policy packages on the different sectors related to heating and cooling systems.

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[4] http://www.progressheat.eu/Publication-materials.html

[5] http://www.progressheat.eu/Policy-recommendations.html

1.1 Scenarios and assumptions

In order to assess the influence of policy frameworks on the national heating and cooling systems two scenarios were defined: a current policy scenario reflecting the current state of policy frameworks, and an ambitious policy scenario reflecting more ambitious policy making towards the transition of the heating and cooling systems towards decarbonisation. Table 1 gives an overview of the general outline of the two policy scenarios as implemented in the quantitative models.

Table 1: Overview of policy intensity in the two policy scenarios

	CO_2 taxes/ prices	Building codes etc.	Subsidies and favourable financing	Heating and cooling planning, zoning, regulatory instruments
Current policy scenario	Low	Current state and nZEB-plans	Current policies	Current policies
Ambitious policy scenario	High	High	Higher subsidies for building retrofit, RES-H and DH and favourable financing conditions	Zoning and DH priority areas, leading to higher efficiency and lower costs of district heating

In the **current policy scenario** in general it is assumed that the policy frameworks are kept at their current state. For penalising CO_2 emissions no further action and a not properly functioning EU-ETS is assumed resulting in low prices for CO_2 staying at the 2015 level of 7,5 EUR/tCO_2 for all sectors until 2050. Building codes in this scenario reflect currently implemented building codes and nZEB-plans in the different countries. For industrial facilities the EU Ecodesign directive for energy using products is assumed to stay in its current form and the energy taxes as reported by Eurostat in 2015 will not change. Subsidies and financing conditions for industry and buildings reflect currently available support available in the different countries, and regulatory instruments as well as heating and cooling planning is not changing its current form. For investments in district heating infrastructure and plants for electricity generation financing is calculated with an interest rate of 4%.

In the **ambitious policy scenario** integrated and advanced policy packages are assumed to be integrated in all countries and at EU-level. This includes a rising CO_2 price level according to the PRIMES reference projection for all sectors (EC, 2016). Additionally a strong political commitment to these rising prices is given, which let investors consider the CO_2 price 10 years ahead for their investment and ensuring secure conditions. Building codes in this scenario include obligatory shares of renewable supply for new buildings from 2020 on, and also for major renovations beginning in 2030. On the other hand higher subsidies for building renovation and renewable heating and district heating are available compared to the current levels or subsidies made available, if these are not currently in place. Advanced policy frameworks in industry include increased subsidies as well as support of the running costs for RES-H and efficient technologies, the inclusion of all industrial activities in the EU ETS system, the exploitation of industrial excess heat potentials and a comprehensive support of material efficiency and circular economy. Investments in district heating infrastructure and plants for electricity generation are assumed to be possible at an interest rate of 0% due to improved financing conditions.

More details on the implementation of policy measures as well as important assumptions (e.g. on capacity restrictions for district heat or electricity generation) specific to the different countries and sectors are given in the description in the related subchapters of chapter 2.

The assumptions regarding developments of energy carrier and CO_2 prices and product quantities in the different countries as well as the assumptions and method for calculating excess heat potentials from industrial activity is presented in the Annex of this report.

The main sources for the current state of demand and technology use for the different sectors and countries as well as the assumptions for splitting district heat demands from buildings and industry to large and small DH areas can be found in the report (Pedersen et al 2016). The classification of DH areas into Central and Decentral is used in Denmark. Since the development of national TIMES models started from the Danish TIMES model, the DH areas in the report (Pedersen et al, 2016) are named Central and Decentral DH areas. In order to make the names of DH areas illustrative outside Denmark, Central and Decentral areas are renamed into Large and Small DH areas in the present report, respectively.

The electricity trade is enabled in the national TIMES models. The electricity interconnections with neighbouring countries are represented with technical capacities and import/export price projections from/to each of the neighbouring countries. The existing capacities and planned expansions of transmission capacities are adopted from the Ten Year Development Plan 2014 conducted by ENTSO-E (ENTSO-E, 2014). More details can be found in Section 7.1 of the report (Pedersen et al, 2016).

The future average annual electricity prices in the neighbouring countries are estimated based on (EC, 2016). However, TIMES models in progRESsHEAT project require temporal price profile, i.e. price of importing/exporting electricity from/to neighbouring countries on a time-slice level. The electricity prices per time slice are obtained by aggregating hourly electricity prices. Hourly electricity prices for the surrounding countries are extracted from the ENTSO-E transparency platform (ENTSO-E, 2016). More details can be found in Section 8 of the report (Pedersen et al 2016).

Export and import of electricity to/from one of the neighbouring countries is not constrained by the technical capacity but by the maximal achieved value in the past five years (ENTSO-E, 2016).

In all scenarios, electricity import is considered as emission-free, i.e. there is no CO_2 emissions associated with import of electricity.

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1.2 Modelling framework

The scenarios described in the previous chapter were calculated with a framework of three models each focusing on different parts related to the heating and cooling systems in the countries under analysis:

(1) Invert/EE-Lab reflecting the buildings in the residential and tertiary sectors
(2) Forecast-Industry reflecting industrial production facilities
(3) TIMES reflecting the supply structures in the district heating and power sectors

The following Figure 2 shows an overview of the use of the different models and their linkages as used for the analysis in course of this assessment exercise.

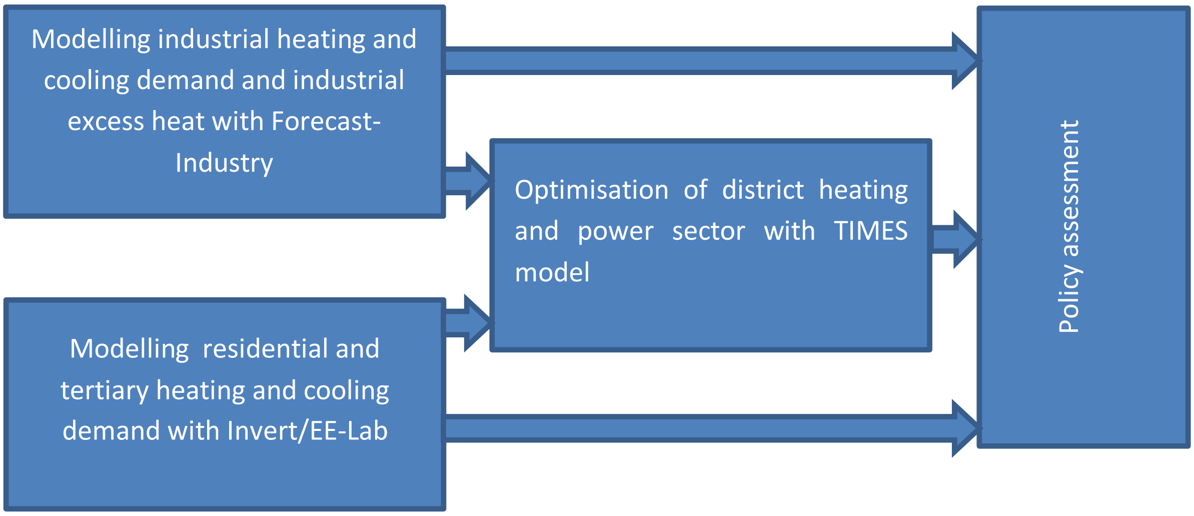

Figure 2: Model linkages used for policy assessment on national level in the project progRESsHEAT

In a first step the developments of the energy demand by energy carriers in buildings and industry as well as excess heat potentials are simulated with the Invert/EE-Lab and FORECAST-Industry model, respectively. For buildings the demand for energy carriers related to space heating, space cooling and hot water preparation is calculated, for industry the demand for energy carriers for all uses in the production facilities is calculated. Then the energy demand developments for district heat in these sectors as well as the excess heat potentials from industrial activity are fed into the TIMES model, which optimises the supply mix for district heat and electricity in a subsequent step. The development of the electricity demand is taken from the PRIMES reference scenario (EC,2016). This is done for each of the two policy scenarios in each of the countries.

In the following subchapters the three different models are shortly introduced and it is linked to further model descriptions.

1.2.1 Buildings – Invert/EE-Lab

The model Invert/EE-Lab is a bottom-up building stock simulation model covering EU-28 countries. It is a dynamic bottom-up model, which is designed to simulate scenarios and thereby compute future trends of the energy demand for space heating, cooling and hot water in the residential and service sector at a national and regional level under different framework conditions like energy consumer prices, stock developments and policies related to heating and cooling in buildings.

The basic idea of the model is to describe and simulate developments in the building stock and the related heating, cooling and hot water systems on a highly disaggregated level. The model calculates energy needs and delivered energy, determines reinvestment cycles and new investments in building components and heating and cooling technologies and simulates the decisions of various agents (i.e. owner types) in case that an investment decision is due for a specific building component or technology in a specific part of the building stock. The core of the simulation model is a nested logit approach in order to calculate market shares of heating systems and energy efficiency measures depending on building and investor type. In this the objectives of agents under imperfect information conditions are optimised, thereby also considering diffusion restrictions in the change of technologies. Input data for the base year and results from the model are split up by energy carrier. A detailed description of the Invert/EE-Lab model is available in (Müller, 2015) and further information on the model and related previous projects can be found at the website of the model: http://www.invert.at/

1.2.2 Industry – FORECAST-Industry

The model FORECAST-Industry simulates industrial heating and cooling demand as well as excess heat potentials from industrial activity.

The FORECAST modelling platform aims to develop long-term scenarios for future energy demand. It is based on a bottom-up modelling approach considering the dynamics of technologies and socio-economic drivers. The model allows addressing research questions related to energy demand including scenarios for the future demand of individual energy carriers like electricity or natural gas, calculating energy saving potentials and the impact on greenhouse gas (GHG) emissions as well as abatement cost curves and ex-ante policy impact assessments (http://www.forecast-model.eu).

1.2.3 District heating and power sector - TIMES

TIMES models are linear programming models that consist of minimization of the objective function defined as a mathematical expression of decision variables, subject to mathematical constraints. In other words, TIMES models optimize the investments, operation, primary energy supply and

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imports/exports across all implemented regions and for all time periods in an energy system, minimizing the objective function. The objective function in TIMES models represent the total system costs discounted to a reference year.

TIMES models are multi-regional, technology-rich, bottom-up models used for long-term analysis and planning of regional, national and multi-national energy systems[6]. In addition to that, TIMES models are a techno-economic, partial equilibrium models assuming full foresight and perfectly competitive markets. Thus, they are well suited for incorporating "4E" foundations of energy systems – energy, economy, environment and engineering. TIMES is usually used for simultaneous analysis of the whole energy system (power and heating, industrial, transportation, residential sector, etc.), but can be also used for analysis of specific sectors. The outputs from the model include region and time-specific investment, operation and import/export levels optimal for the energy system as a whole. In addition to that, the costs, environmental indicators, prices of commodities, etc. are obtained alongside the optimal solution. The Integrated MARKAL-EFOM System (TIMES) model generator is developed and maintained by the Energy Technology Systems Analysis Programme (ETSAP)[7], a Technology Collaborative Programme of the International Energy Agency (IEA), established in 1976. The TIMES model generator source code, written in GAMS, is open and available for download to anyone free of charge upon signing the ETSAP Letter of Agreement.

Information about Danish TIMES model (TIMES-DK) which is used as a basis for the other national TIMES models in progRESsHEAT project can be found at (Balyk et. al.) and (DEA, 2017)

1.3 Definition of key indicators

In this chapter the indicators are defined that we use in the policy assessment to quantify the effects of policy influence. The indicators are described for the different sectors in the following sub-chapters.

1.3.1 Buildings

The calculations in this analysis for the building sector include buildings from the residential and the tertiary sector (services). Industrial buildings, however, are not included in the building sector calculations. The energy demand, resulting emissions and costs are related to space heating, space cooling as well as hot water preparation. In contrast, the use of appliances in buildings and its effects on energy demand, emissions and costs are not included. Thus, the indicators and figures for the building sector in this analysis reflect the entire and solely the H/C part in this sector.

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[6] TIMES Documentation and Demo Models http://www.iea-etsap.org/index.php/documentation; Example of TIMES applications http://www.iea-etsap.org/index.php/applications

[7] ETSAP homepage available at: http://www.iea-etsap.orghttp://www.iea-etsap.org

CO_2 emissions

The CO_2 emissions shown for the building sector only take into account direct emissions generated in the buildings. Thus, main emission sources are fossil fuels used in boilers in the buildings. Emissions from the generation of electricity and district heat, which is used in the buildings for H/C purposes, are counted in the emissions of the district heating and power sectors (see chapter 1.3.3). Therefore, the emissions resulting from electricity use in cooling devices in the buildings is also not included in the building sector, but in the emissions of the power sector.

Final energy demand

Final energy demand in the building sector as indicated in this analysis comprises all energy carriers used in the buildings for H/C purposes. This includes energy carriers used in boilers, the electricity used in direct heaters and heat pumps, the solar thermal energy fed into the heat distribution systems, the ambient heat that is used in heat pumps and the district heat that is fed into the transfer stations.

Share of renewable energy sources (RES)

The share of renewable energy sources (RES) for the building sector is calculated similar to Eurostat definition as the share of RES on the final energy demand for H/C. This includes the share of RES in the generation of DH (see chapter 1.3.3), but does not include the share of RES on the electricity generation. This is mainly due to the fact that DH is mainly consumed in the buildings, while electricity used for H/C purposes in buildings is only a minor share of the overall national electricity demands.

Investment and running costs

The costs for the provision of H/C in the buildings in this analysis comprises of investment costs, operation and maintenance costs and fuel costs for devices generating space heating and hot water. The devices providing space cooling (i.e. air conditioning systems) are not included in this indicator.

Programme costs

For the building sector also the annual costs of funding programmes are provided. The indicator of programme costs hereby includes funding schemes for technologies using renewable energy sources (also including heat pumps), as well as funding schemes for subsidising the retrofit of existing buildings and for subsidising the additional costs of constructing new buildings at heat demands lower than stated in the national building codes.

1.3.2 Industry

The industry sector is defined according to the Eurostat energy balances as final energy. Thus, energy demand is calibrated to Eurostat 2012 final energy. According to the definition of final energy demand, the petrochemical/refinery industry is not part of the industrial sector and not included in this analysis in this report.

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The report contains the following main indicators for industry.

Final energy demand

Defined as in Eurostat, final energy demand of the manufacturing industry (excluding refineries).

GHG emissions

Energy related GHG emissions are calculated based on final energy demand. Only direct emissions are accounted for, thus, emissions from electricity and district heat use are not accounted in industry, but in the combined "district heating and power generation sector". Further, emissions from chemical processes (not related to energy conversion) are accounted for. Major sources of processes emissions are clinker, adipic acid, nitric acid and ammonia production, but also some minor sources like glass and aluminium production are included. Note that the emissions balance shows substantial differences compared to the UNFCCC accounting of industrial emissions.

Share of renewable energy sources (RES)

The share of RES is calculated similar to Eurostat definition (SHARES project): Sum of all renewable energy carriers divided by the sum of total final energy demand excluding electricity. Shares of district heating or electricity produced by RES are not accounted for.

Industrial excess heat potential:

See detailed description in annex 0: Calculated for selected processes for excess heat above 100°C available from flue gasses.

1.3.3 District heating and the power sector

The district heating and power sector are responsible for production of electricity and district heating in Small and Large district heating areas. The fuel input to power and district heating sector, CO_2 emissions from the sector and total costs of electricity and district heating sector are the outputs from TIMES models. The RES is calculated based on the fuel input.

Fuel input

The fuel input to electricity-only and DH-only plants and CHPs is the output from TIMES models. For electricity-only and DH only plants, the fuel input is allocated entirely to electricity and DH, respectively. Fixed-heat-efficiency approach is used to allocate fuel input to CHPs into fuel input to electricity and fuel input to DH production. In this approach, the efficiency of heat generation is fixed to allocate the fuel input to DH production. The fuel input to electricity production is calculated as a residual from the total input. The standard heat efficiency was set to that of a typical heat boiler, 90% (International Energy Agency, 2017)

In the other parts of this report hydro, wind, solar (PV and solar heating) and wave are presented as inputs to electricity and DH production. It should be noted that the processes converting these inputs into electricity and DH have the efficiency of 1, i.e. the fuel input is equal to electricity or DH at the output of the plants.

CO_2 emissions

The CO_2 emissions from electricity-only and DH-only plants and CHPs is the output from TIMES models. For electricity-only and DH only plants, the CO_2 emissions are allocated entirely to electricity and DH, respectively. For CHPs, CO_2 emissions are allocated proportionally to fuel input, while the fuel input is allocated according to fixed-heat-efficiency approach.

It is assumed that combustion of fossil fuels and waste result in CO_2 emissions. Biomass is assumed carbon-neutral, i.e. the CO_2 emissions for combustion of biomass are not accounted.

Share of renewable energy sources (RES)

Renewable energy share (RES) is calculated from the fuel input as a share of renewable energy in the total energy mix. RES is first calculated for electricity and after that for DH, because electricity can be input to DH production (electric boilers and large-scale heat pumps). Fossil and nuclear fuels are considered non-renewable, while other energy carriers (biomass, solar, wind, geothermal, wave, etc.) are considered renewable. Waste is accounted as renewable energy carrier.

Total costs

The costs of the power and DH system divided into variable O&M, fixed O&M, fuel costs, electricity import costs and earnings from electricity export and investment costs for each year of the analysed period and are outputs from the national TIMES models.

1.3.4 Overall heating and cooling

Apart from the indicators for the assessment of policies in the different sectors (buildings, industry as well as DH and electricity generation) as described in the chapters before, we also display indicators comparing all sectors in the countries related to heating and cooling. These are described in the following.

CO_2 emissions

The overall CO_2 emissions comprise the direct emissions from the buildings and the industry sector, the emissions from the district heating sector and the emissions of the power sector originating from electricity used for heating and cooling.

Primary energy demand

The reflected energy demand in this indicator comprises the fuel demand for heating and cooling from the buildings and industry sector (excluding electricity and district heating) plus the primary energy input into the district heating sector plus the primary energy input into the power sector for electricity used for heating and cooling purposes.

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Share of renewable energy sources (RES) in the different sectors

For the buildings and industry sector this share is calculated excluding electricity both in the overall demand for heating and cooling and in the amount of renewable energy used to generate electricity. The share of renewable energy in district heating, however, is taken into account in the calculation of the share of RES in industry and buildings. The share of RES in DH generation takes into account all energy carriers used in DH generation. The same applies to the calculation of the share of RES in electricity generation.

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2. Country specific scenario and policy analyses

In this chapter the policy assessment of the national heating and cooling systems with the modelling approach described in chapter 1.2 are presented separately for each of the analysed countries: Austria, Czech Republic, Germany, Denmark, Portugal and Romania. The assessment results are presented based on defined key indicators (see chapter 1.3) in three separate subchapters for the buildings sector, the industry sector and the power and district heating sectors. These subchapters also include a description of country specific policy measures implemented in the different models, while the overall storyline, policy measures and assumptions on main input parameters for the modelling are presented in chapter 1.1 and in the annex. In two subsequent subchapters key indicators for the overall heating and cooling systems of the countries are presented, and conclusions as well as policy recommendations from the modelling of the national cases are described.

2.1 The case of Austria

2.1.1 Buildings

This chapter documents selected indicators for the current and ambitious policy scenario related to buildings in the residential and tertiary sector.

For buildings the **current policy scenario** includes the following policies that are already in place in Austria:

- U-values or overall performance indicators have to be reached as stated in (OIB, 2015).
- New buildings are constructed according to the current national building codes and the foreseen changes until 2021. This includes the national definitions of “Nearly Zero Energy Buildings”.
- Subsidies of 20-23% of the investment costs for different individual biomass heating systems, 15% for connection to district heating, 5-15% for different types of heat pumps and 20-25% for solar thermal collectors are available. Each of these subsidies has a cap between 1 000 and 3 500 EUR per device.
- Subsidies for building renovation are currently between 17-32% depending on the implemented depth of renovation and available budgets are expected to decline (see also Müller et al, 2017).

The **ambitious policy scenario** for the building sector includes additional policies in order to reach a remarkable CO_2 reduction of around 80% in the scenario timeframe. The following policies are implemented for the case of Austria:

Spatial and energy planning and construction policy:

1. Increase of the density of settlements and reduction of floor area per household by around 19% in new buildings.

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Regulative instruments:

2. Existing buildings not renovated within the last 30 years and exceeding a certain specific heat demand are obliged to undertake renovation measures within the next 10 years after 2022.
3. Existing individual fossil heating technologies older than 27 years and based on coal or oil have to be replaced within 10 years after 2025.
4. In new buildings the installation of individual fossil heating technologies based on coal or oil will be banned after 2022 and in existing buildings after 2025.
5. A renewable heat obligation forces to supply a certain share of the heat demand by renewable heating sources. This starts with a low share in 2021 both in new buildings and for major building retrofit, and will be continuously strengthened to higher shares until 2050.
6. Specific regulations regarding the installation of different heating systems are implemented in so-called “immission control areas”. Whereas there is no strict implementation of district heating priority areas, the new installation of individual gas boilers outside of immission control act areas is forbidden if district heating is available.

Economic incentives:

7. As stated in the general scenario assumptions in chapter 1.1 all sectors have to pay a rising CO_2 price according to the PRIMES projection.
8. In contrary to the current policy scenario, the budgets for subsidising renovation measures will not decline but rise again after 2030. This will result in around 600 MEUR of available subsidies in 2050, which corresponds to the currently available subsidies, if calculated inflation-adjusted. Subsidies for new buildings stay the same as in the current policy scenario.

Information campaigns:

9. Information campaigns will lead to decision-makers being aware of the continuous increase in prices for fuels and CO_2 emissions certificates. This causes that rising prices will be taken into account in their investment decisions.

In the following figures key indicators for the current and ambitious policy scenario for buildings in Austria are compared: direct CO_2 emissions, final energy demand, share of renewables (excluding electricity), total annual running and investment costs and the direct costs (of subsidies) for the described policy programmes.

Figure 3 shows the development of the direct CO_2 emissions from the building sector in Austria. As emissions from district heating and electricity are not included in this figure the emissions only result from the use of individual natural gas and oil boilers and very few coal boilers used in Austria. A decrease in CO_2 emissions in the building sector from almost 8 Mt in 2012 to 1,4 Mt (-83%) in 2050 can be achieved in the current policy scenario and to 0,8 Mt (-90%) in 2050 in the ambitious policy scenario. This difference between the two policy scenarios originates to one part from a higher level of heat savings reached due to the ambitious policies and to another part from the phase out of oil

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and the lower amount of natural gas that will remain in the 2050 heat supply in the ambitious policy scenario. At least a part of the remaining gas demand could also be covered by renewable energy sources, which would further reduce CO_2-emissions. However, this aspect was not further analysed in this project.

The considerable GHG-emission reductions already in the current policy scenario are mainly due to currently implemented (or expected) building codes and nZEB standards as well as existing renewable heat obligation and subsidy schemes. Also increasing energy prices contribute to the result. Thus, the result should not be understood in a way that this will happen anyway. First, continuous (and maybe even enhanced) efforts will need to be taken to ensure a proper compliance with existing building codes and regulations. Second, other existing instruments will need to be kept in place and the corresponding public budgets for subsidies will need to be provided. Third, in case of lower energy prices than expected, higher efforts will be required to achieve the result presented here as current policy scenario.

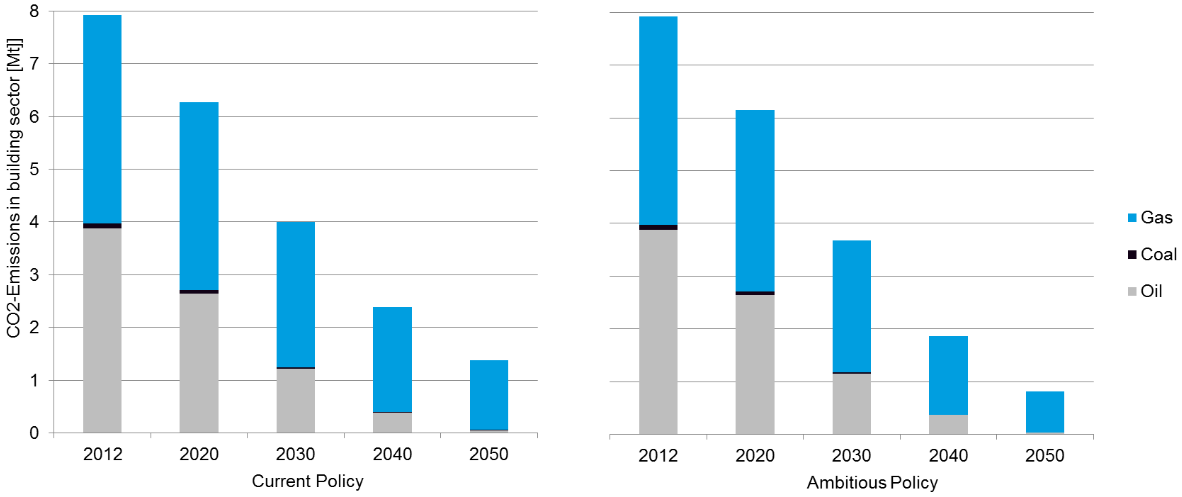

Figure 3: Direct CO_2-emissions for space heating and hot water preparation per energy carrier in the residential and tertiary sector, Austria

Figure 4 shows a decrease in final energy demand for heating and cooling from 88,3 TWh in 2012 to 64,6 TWh (-27%) in 2050 in the current policy scenario and to 53,4 TWh (-40%) in the ambitious policy scenario. On the secondary axis the figure shows the share of RES in the building sector. For the heat delivered by district heating the respective renewable share of the district heating sector as shown in chapter 2.1.3 is used. Electricity used for H/C is not included in the calculation of this share, but the share of RES in the power sector is also shown in the respective chapter. While with current policies a share of RES of 77% can be achieved in 2050, the share rises even up to 89% with ambitious policies. This increase derives mainly from less individual natural gas boilers and a higher share of RES in the district heating sector.

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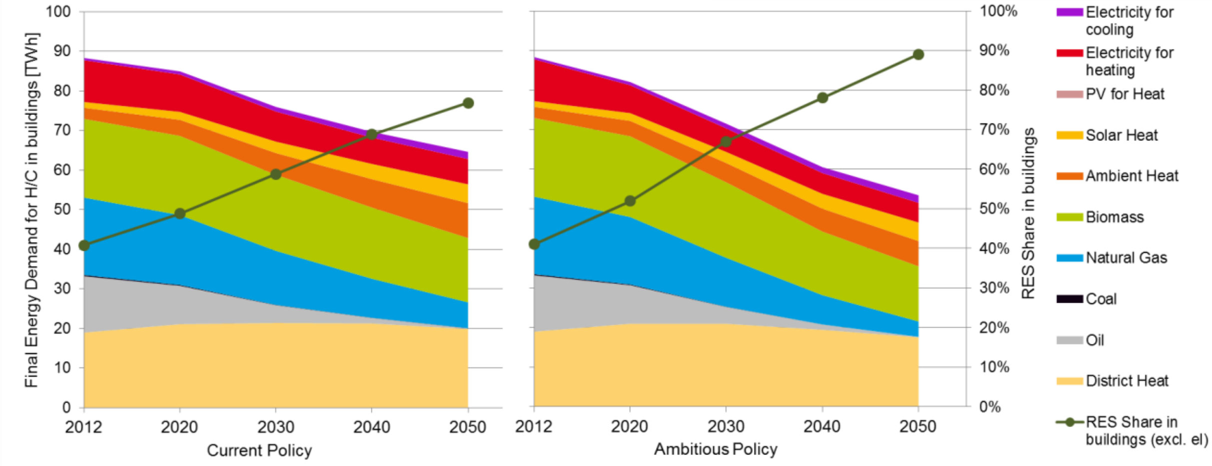

Figure 4: Final energy demand and share of renewables for space heating, hot water preparation and space cooling by energy carrier in the residential and tertiary sector, Austria

Figure 5 shows the development of the annual investment and running costs for all buildings in the residential and tertiary sector for both policy scenarios. The shift from fossil fuelled technologies to technologies using RES results in a shift from running costs to investment costs. Due to the higher available subsidies after 2030 in the ambitious policy scenario a high number of retrofitting activities will take place after 2030 leading to the heat demand reduction shown in Figure 4.

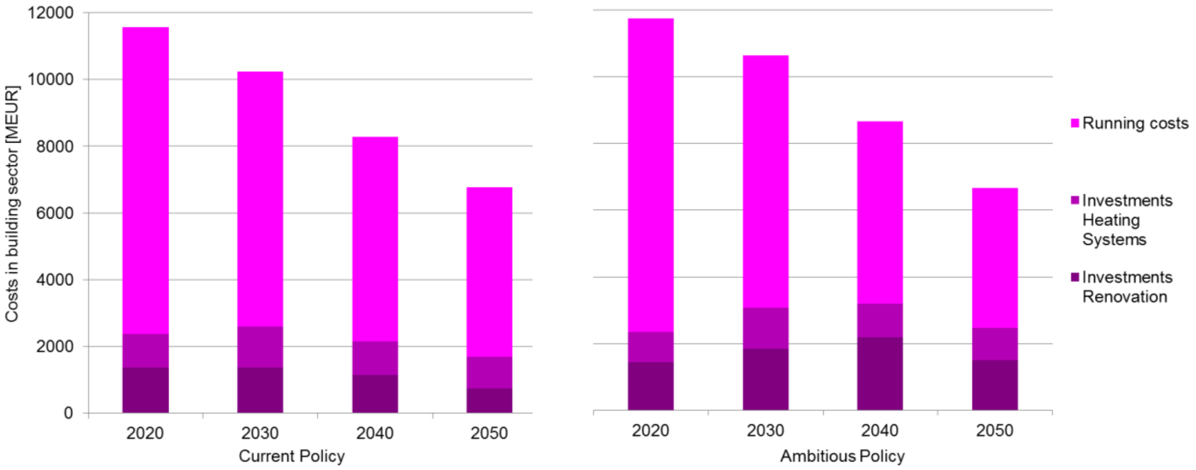

Figure 5: Investments and running costs for building renovation and heating and hot water systems in the residential and tertiary sector, Austria

Figure 6 shows the policy programme costs for both policy scenarios. These costs include subsidies for retrofit measures and subsidies for heating technologies using RES, also including solar thermal systems. In contrast to the current policy scenario, subsidies for retrofit measures will not decline but

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rise again after 2030. This leads to around 600 MEUR of available subsidies in 2050, which corresponds to the currently available subsidies, if calculated inflation-adjusted. Subsidies for new buildings stay the same as in the current policy scenario.

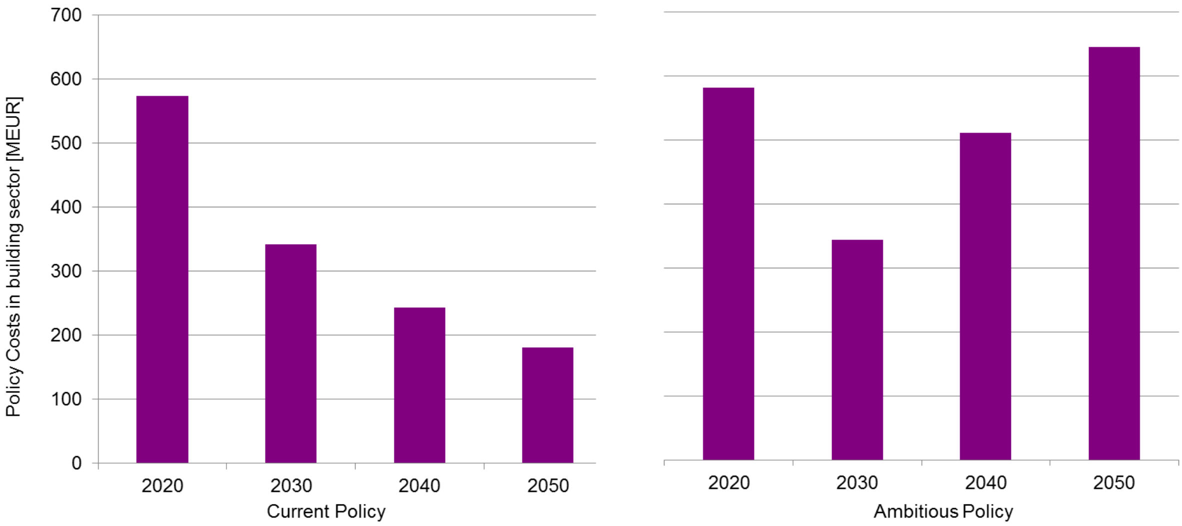

Figure 6: Policy programme costs for the residential and tertiary sector, Austria

2.1.2 Industry

This chapter documents selected indicators for the current and ambitious policy scenario in the Austrian industry sector.

- The **current policy scenario** considers policies implemented by 2015. This includes among others the CO_2 price, EU Ecodesign Standards for energy using products as well as Energy taxes as reported by Eurostat in 2015.

The **ambitious policy scenario** represents a much more ambitious policy mix towards the transformation of the industrial H/C sector. It comprises of the following main elements:

1. Policy package addressing classical non-financial barriers to energy efficiency including the roll-out of energy management systems, energy audits, soft loans, etc.
2. Extension of Ecodesign Minimum standards to additional equipment including steam boilers and industrial furnaces
3. Increasing investment grants for RES-H technologies including power-to-heat using heat pumps or electric boilers for steam generation
4. RES OPEX support: ~5 Euros/MWh for RES-H including district heating, heat pumps and electric boilers

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5. CO_2 price: extending the CO_2 price beyond the ETS (same level) and changing price expectations: Companies now consider the CO_2 price 10 years ahead for their investment appraisal. This is achieved via a transparent and defined tax increase and/or a floor price for the EU ETS
6. Comprehensive support of material efficiency and circular economy: Reduced production of basic materials products due to efficiency improvements along the value chain and shift towards secondary production (e.g. electric steel replacing oxygen steel, more recycled paper, etc.). This is included in the model via changes in the exogenous assumptions on material production. E.g. in Austria it is assumed that the share of electric steel in total crude steel production increases from 9% in 2012 to 45% in 2050 in the ambitious policy scenario compared to 9%in the current policy scenario. See table below and Table 9 and Table 10 in the annex for an overview on recycling and secondary production assumptions.

Table 2: Assumptions on use of recycled materials for steel, cement, aluminium and paper in Austria [%]

Indicator		Current policy scenario		Ambitious policy scenario	
	2012	2030	2050	2030	2050
Share of electric steel in total crude steel production	9%	9%	9%	24%	45%
Share of clinker in total cement production	72%	69%	67%	63%	55%
Share of secondary aluminium in total aluminium production	100%	100%	100%	100%	100%
Share of recovered fibres in total pulp production	60%	66%	70%	76%	89%

7. Exploitation of industrial excess heat potentials of heat >100°C for use in district heating or, where district heating networks are not nearby, for electricity generation. This can be implemented via financial support but also via regulation (e.g. related to pollution control)
8. Innovation support to speed-up the market introduction of low-carbon production processes for the basic materials industries. This includes various strategies from niche markets via requirements for public procurement, to research, development and innovation (R&D&I) support as grants and soft loans (see e.g. proposal of an EU ETS Innovation Fund to support market introduction of low-carbon industry technologies among others) a minimum CO_2 price path and more.

Results of the current policy and the ambitious policy scenarios are presented and compared below, beginning with CO_2 emissions, before discussing final energy demand and excess heat potentials from industrial activity. Results are shown for the entire industrial sector including non-H/C applications like mechanical energy. However, non-H/C applications are nearly exclusively found in electricity use, while fuel consumption can be attributed to H/C. In total, H/C accounted for about 77% of industrial final energy demand in Austria in 2012.

The Industrial sector emitted about 27 million tonnes of CO_2[8] in 2012 (see Figure 7). The current policy scenario shows a slow reduction of about 16% until 2050. Due to relatively low coal prices, emissions from coal are even increasing. The increase in coal-related emissions is also driven by a slow increase of oxygen steel production until 2030 of about 8% compared to 2012. Emission reductions take place in fuel use and other fossil fuels. The ambitious policy scenario shows a different pattern. It experiences a drastic decrease of CO_2 emissions by about 62% resulting in about 11 Mt CO_2-equ in 2050. Reductions are driven by a decrease in fuel oil, natural gas and coal emissions compared to the current policy scenario.

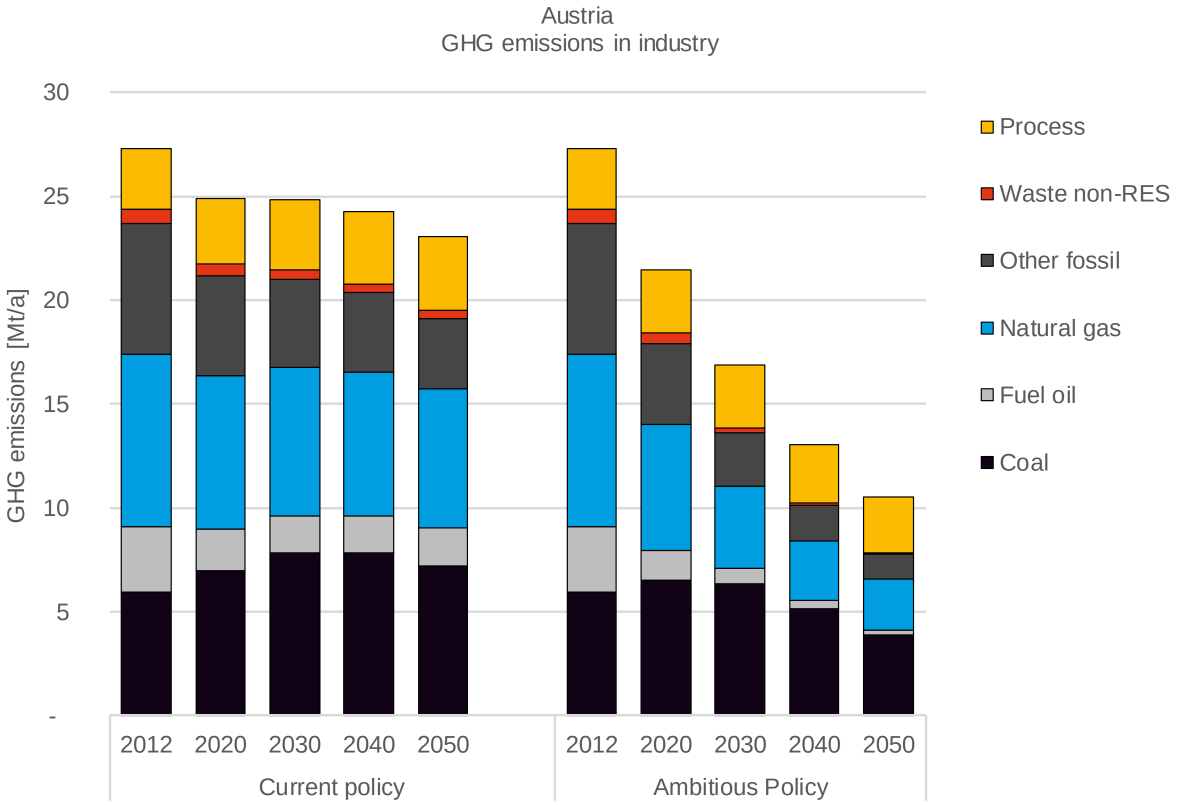

Figure 7: Direct GHG emissions in industry by energy carrier (including process emissions), Austria

Figure 8 reveals the importance of the individual sub-sectors showing that in 2012 the iron and steel industry was responsible for nearly 50% of industrial (direct) GHG emissions (~13 million tonnes). Accordingly, ambitious reductions in GHG emissions can only be achieved if the iron and steel industry decarbonises as well. In the ambitious policy scenario, all sub-sectors reduce GHG emissions substantially. The steel industry undergoes a major change and increases the share of electric steel

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[8] direct emissions, including process related emissions, excluding emissions from electricity and district heating

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from 10% in 2012 to 45% in 2050 resulting in a decrease of coal consumption and a (slower) increase in electricity consumption. Remaining emissions in 2050 come from the non-metallic minerals (cement), the iron and steel industry and to a lower extent from the chemicals and paper and paper industries.

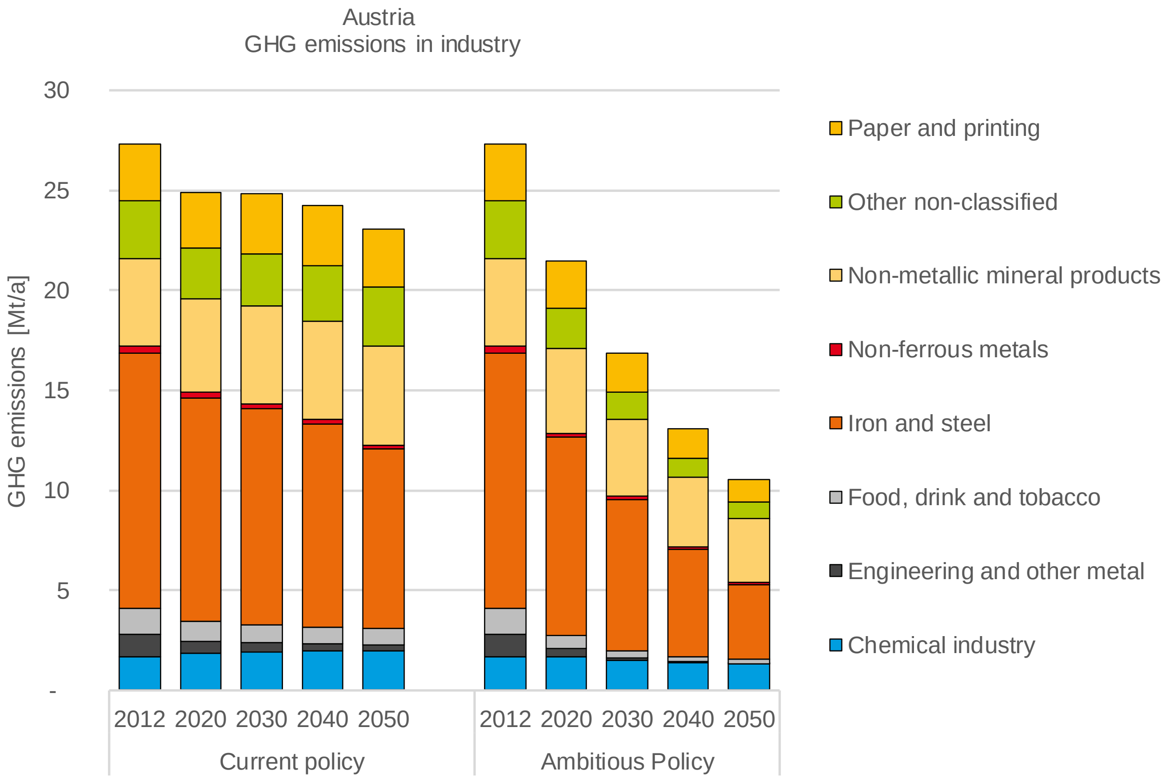

Figure 8: Direct GHG emissions in industry by sub-sector (including process emissions), Austria

The corresponding evolution of final energy demand (FED) by energy carrier is depicted in Figure 9. The current policy scenario observes a nearly constant FED, while in the ambitious policy scenario a continuous reduction from about 108 TWh in 2012 to 78 TWh in 2050 (-28%) is achieved. This reduction is driven by intensified energy efficiency improvements, but also by an increased material efficiency along the value chain.

In total, the share of RES is increasing from 16 to 47% in the ambitious policy scenario, whereas it only shows a minor increase in the current policy scenario. The increased RES share is the direct result of a higher biomass use, but also driven by the reduction in demand. In the ambitious policy scenario biomass and electricity become the two most important energy carriers in 2050 and even natural gas is decreasing rapidly. The use of district heating increases substantially, but of course it remains restricted to the temperature level below 100°C. Other RES like ambient heat or solar thermal energy only play a marginal role in 2050 even in the ambitious policy scenario.

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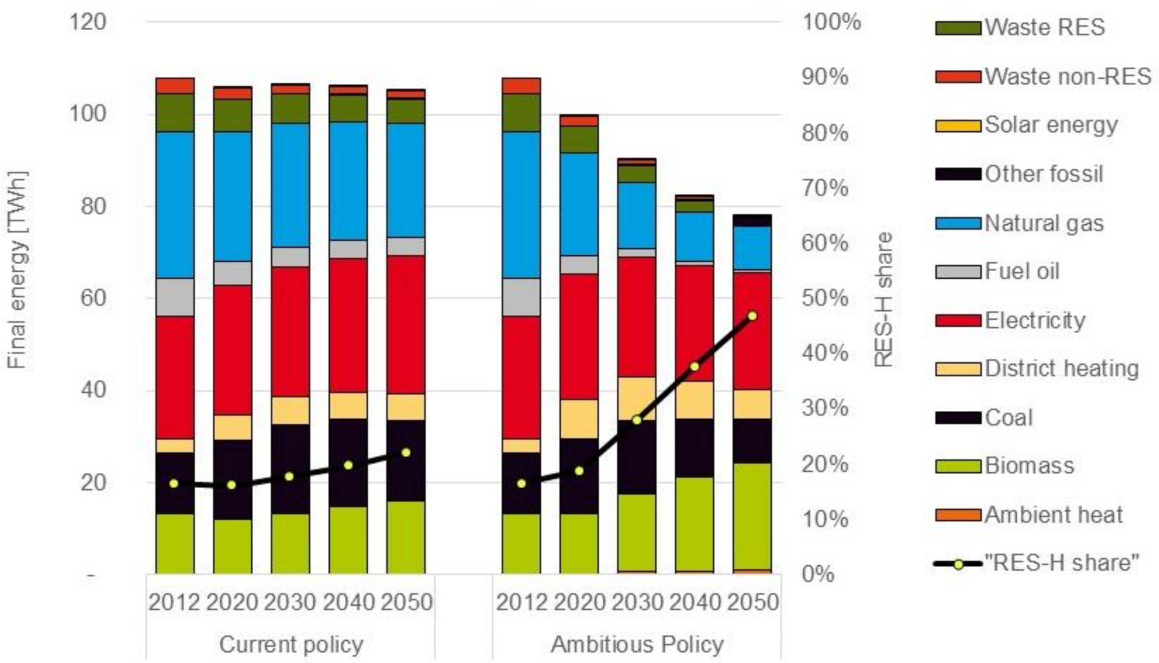

Figure 9: Final energy demand and share of renewables in industry by energy carrier, Austria

A particular focus of the analysis was on the potentials and use of industrial excess heat in district heating or for electricity generation. The assumptions and method used to estimate excess heat potentials is described in annex 0, while in the following the main results are discussed. The use of excess heat is only considered for the ambitious policy scenario. Figure 10 shows the resulting excess heat potentials available by industrial process/product for the years 2012, 2030 and 2050. Changes over time are driven by changes in industrial production and energy efficiency. Sectors/products with the highest potentials are iron and steel, pulp and paper, cement and ethylene. In total, we find about 3,4 TWh of available excess heat (>100°C and for selected processes), which equals about 4,5% of industrial FED in 2050. From the available excess heat, we assume 1,7 TWh to be used in DH in 2050. The remaining excess heat is used to generate about 0,4 TWh of electricity in 2050.

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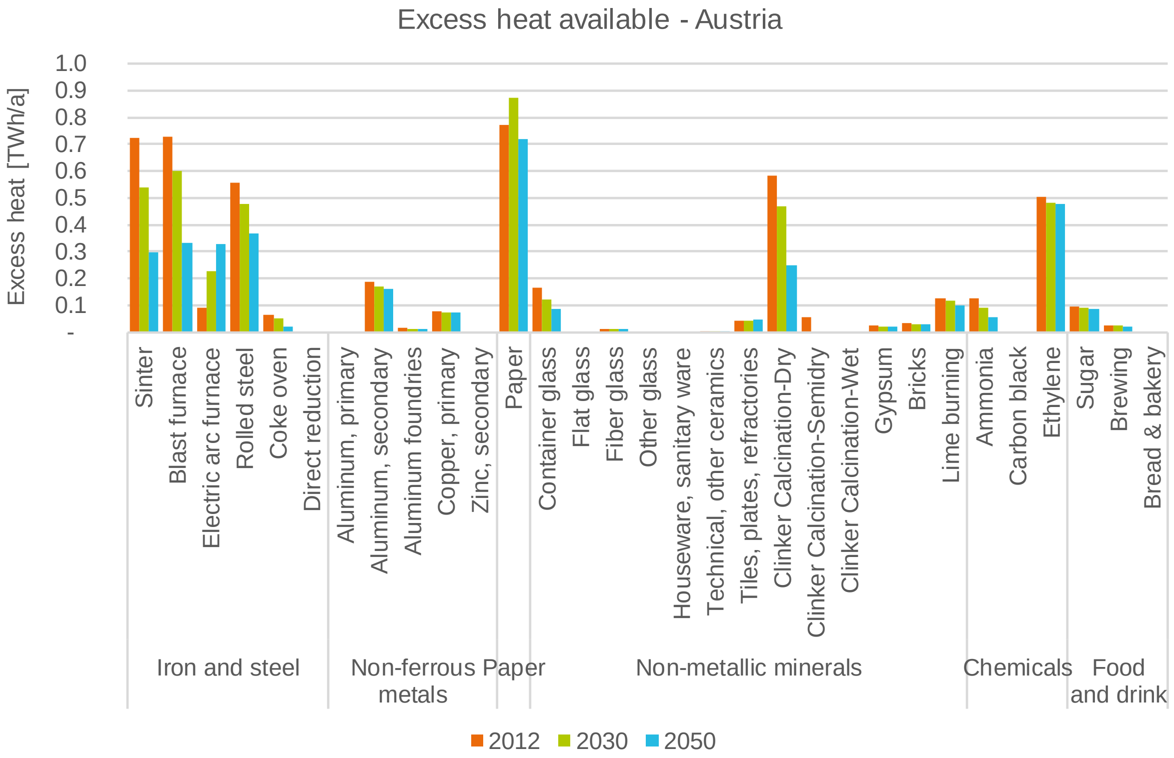

Figure 10: Industrial excess heat potential (>100°C) by process in the ambitious policy scenario, Austria

To better understand the individual impact of the various elements of the policy mix defined for the ambitious policy scenario, Figure 11 shows the impact by type of policy. 6 policy packages are distinguished. From the current policy scenario to the current policy plus 6 (= ambitious policy scenario), the policy mix is extended stepwise. E.g. current policy plus 3 includes financial OPEX support for RES, but also considers all elements included in the scenarios current policy plus 1 and 2.

A particularly high impact on CO_2 emissions is observed by reduced barriers (to simulate policies like energy management systems, soft loans or audits) and material efficiency and circular economy. Further, it can be observed that OPEX support for RES seems a much more effective measure than CAPEX support. One explanation can be the relatively low share of investment costs in the total cost of ownership (due to the large size of installations). The impact from allowing new technologies (innovations) is surprisingly low, but this might also result from the fact that only a few innovations were included.

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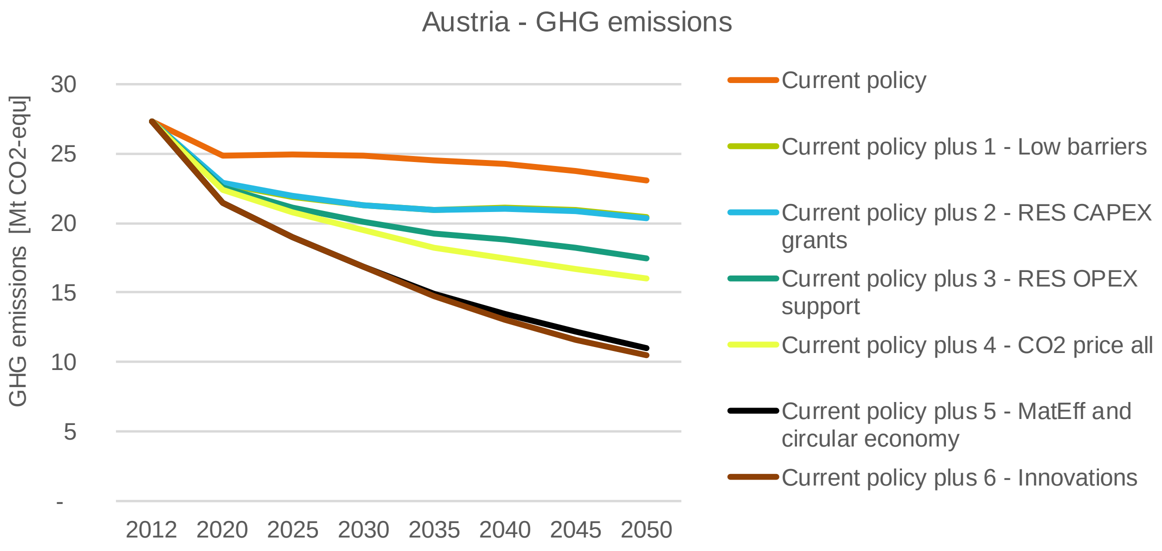

Figure 11: Direct GHG emissions in industry by policy variant, Austria

To summarize, a substantial reduction in final energy demand and an increase in biomass and district heating results in drastically falling GHG emissions in the ambitious policy scenario (-62% by 2050 compared to 2012).

2.1.3 District heating and the power sector

This chapter documents selected indicators for the current and ambitious policy scenario in the Austrian district heating (DH) and power sectors. As described in the methodology section, the results are based on an optimisation model (TIMES), which does not necessarily include all relevant and realistic barriers and diffusion constraints. Thus, the results illustrate the cost-optimal investments and operation of the electricity and district heating system, while some non-economic factors (diffusion constraints, social acceptance, political factors, etc.) might not be represented in the results

In addition to the scenario assumptions outlined in chapter 1.1, the following assumptions are specific for the case of Austria:

- The increase and maximum use of coal is limited in both policy scenarios
- The capacity growth of large-scale heat pumps is limited in both scenarios
- The capacity of waste incineration plants is kept at the current level

The energy demand in plants for the generation of DH in large and small DH areas is presented for the two policy scenarios in Figure 12 and Figure 13. For large DH areas, the most considerable difference between the two policy scenarios is the increase in the share of large scale heat pumps and the decrease of natural gas plants in the ambitious policy scenario compared to the current policy scenario. Energy demanded by heat pumps (electricity and ambient heat) increases from

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2,4 TWh in the current policy scenario to around 4,3 TWh in the ambitious policy scenario in 2050 (41% of the total energy demand for the generation of DH in large DH areas). Other RES witness a slight increase in both policy scenarios, with solar thermal energy reaching 1,7 TWh in 2050 and geothermal energy increasing from 0,14 TWh in 2012 to around 1,4 TWh and 2,5 TWh in the current and the ambitious policy scenario, respectively. The demand for biomass remains low in both scenarios: by 2050, wood pellets and wood chips are not used any more in both scenarios, straw is almost completely abandoned in the ambitious policy scenario, while demand for straw of around 1,5 TWh remains in the current policy scenario. The demand for coal to generate DH in large DH areas does not change significantly in the time horizon and between the two policy scenarios with around 1,5 TWh coal demand in 2050 in both scenarios. The remaining coal to reach the maximum of the limited use is used for electricity production in condensing (electricity-only) units.

According to the model results coal would be a cost effective solution in larger district heating systems and the use of coal would increase to the maximum allowed use. However, this does not reflect the current situation in Austria where a phase out of coal is expected within the next decade. Therefore, the increase of coal in the supply mix may not be expected in reality. Nevertheless, it shows that instruments may be required to make sure that district heating companies do not shift to coal. Also the strong increase in the use of heat pump and geothermal energy is due to the cost optimisation and constraints and barriers not included in the model.

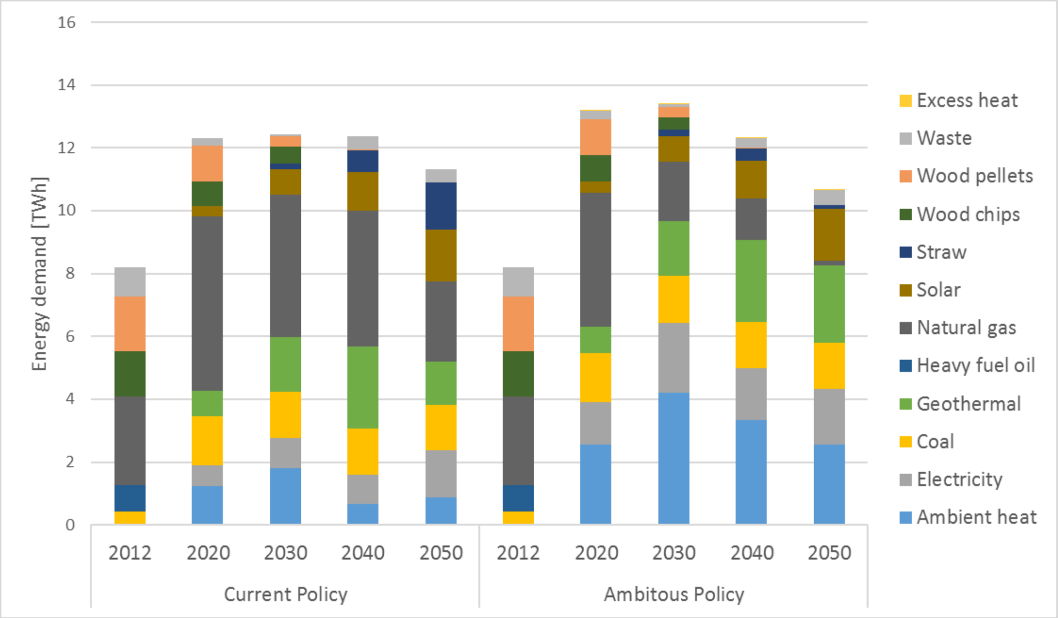

Figure 12: Energy demand in large district heating areas by energy carrier, Austria

As a result of the projections made by the FORECAST-Industry model, excess heat from industrial activity does not play a role in the supply of DH within the large DH areas in neither scenario, while 0,5 TWh of industrial excess heat supply small DH areas under the ambitious policy scenario in 2050 (see Figure 13).

Similar as in large DH areas, a larger share of DH in small DH areas is supplied by heat pumps in the ambitious policy scenario at the expenses of natural gas. The main reason for the attractiveness of large scale heat pumps is the high share (almost 100%) of renewables with negligible marginal generation cost in the electricity generation mix (wind, solar, hydro). As a result of the constraints outlined in the beginning of this chapter, waste and biomass follow similar paths towards 2050 in both scenarios, with a larger share of straw demanded in the ambitious policy scenario (2 TWh).

The overall energy demand for the generation of DH in large DH areas grows from 8,2 TWh in 2012 to 11,3 and to 10,6 TWh in 2050 in the current and the ambitious policy scenario, respectively. The reason for the increase in the absolute values compared to 2012 is the projected increase in industrial demand for DH calculated by the FORECAST-Industry model (see chapter 2.1.1). The DH demands in the building sector (calculated by INVERT/EE-Lab model) are relatively stable throughout the analysed period. The reason for the lower DH demand in the ambitious compared to the current policy scenario is driven by decrease of demand for DH in buildings (calculated by INVERT/EE-Lab model), while the industrial DH demand is slightly higher in the ambitious scenario. The average conversion efficiencies remain similar in both scenarios (around 85% in 2050).

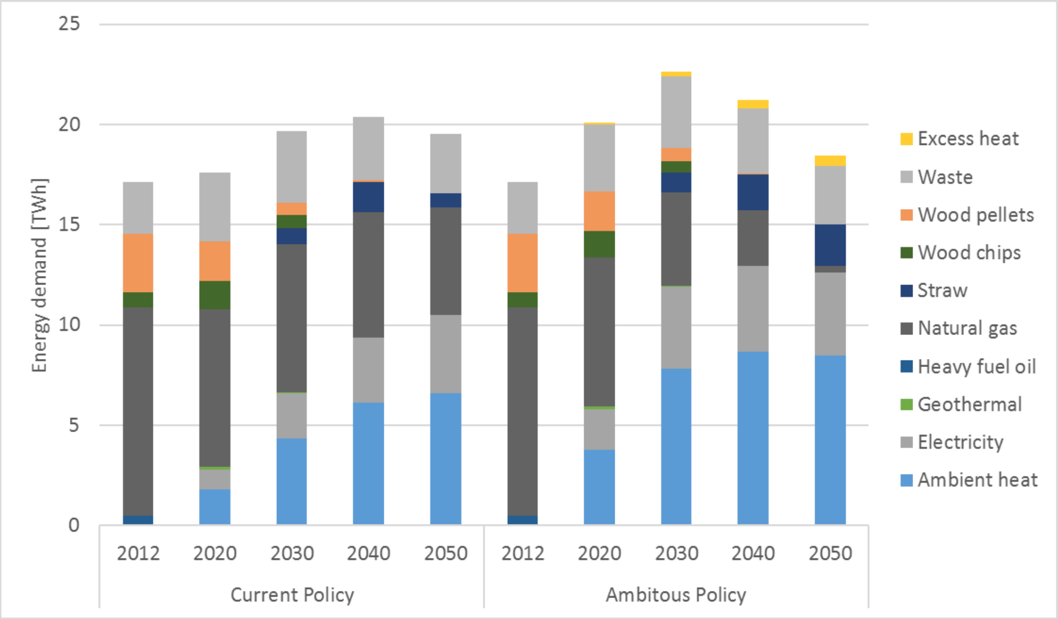

Figure 13: Energy demand in small district heating areas by energy carrier, Austria

The energy demand for the generation of electricity does not differ significantly between the two policy scenarios (Figure 14). In both scenarios a rapid and almost complete phase-out of natural gas and coal is observed by 2050. At the same time a strong penetration of RES (hydro, wind and solar power) can be observed. However, the overall energy demand for electricity generation increases in the ambitious policy scenario to around 120 TWh in 2050, compared to 116 TWh in the current policy scenario. The strong increase of wind capacity in both scenarios is driven by the high electricity prices in neighbouring countries (Slovenia, Italy and Switzerland). Starting from 2040, Austria becomes net

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exporter of electricity. The introduction of around 4,7 TWh of geothermal power in 2050 in the ambitious policy scenario partly contributes to this increase. The introduction of geothermal plants is the result of rising CO_2 prices.

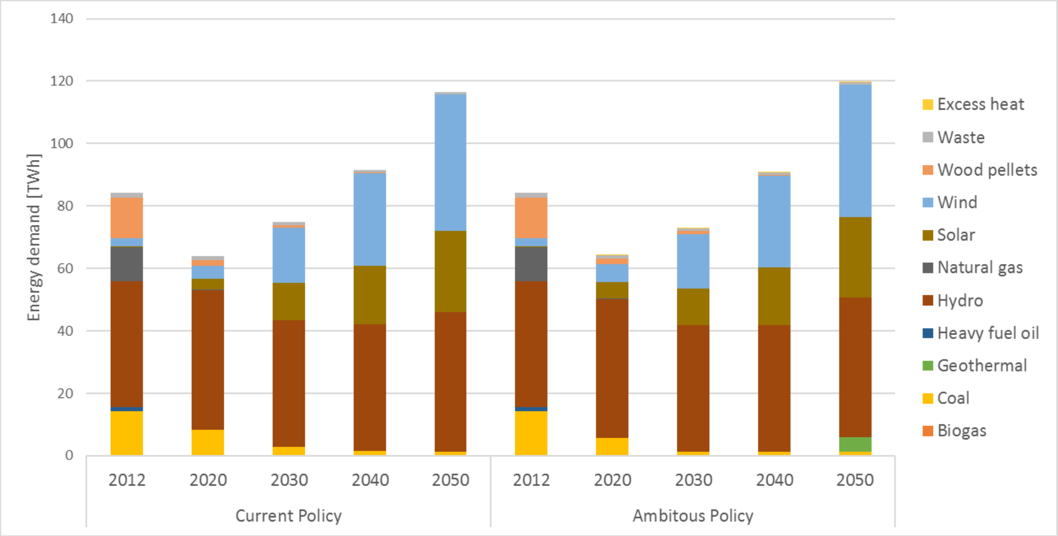

Figure 14: Energy demand for electricity generation by energy carrier, Austria

The annual CO_2 emissions from the generation of electricity and DH are shown in Figure 15 for the two analysed scenarios. In both policy scenarios the power and DH systems undergo a deep decarbonisation resulting in emission reductions from 11,3 Mt in 2012 to 3,1 Mt in the current and 1,6 Mt in the ambitious policy scenario in 2050. The deep cut in emissions from 2030 is due to a shift of the electricity generation from fossil sources to wind and solar power plants (hydro power plants remain constant) and the shift towards DH generation from large scale heat pumps.

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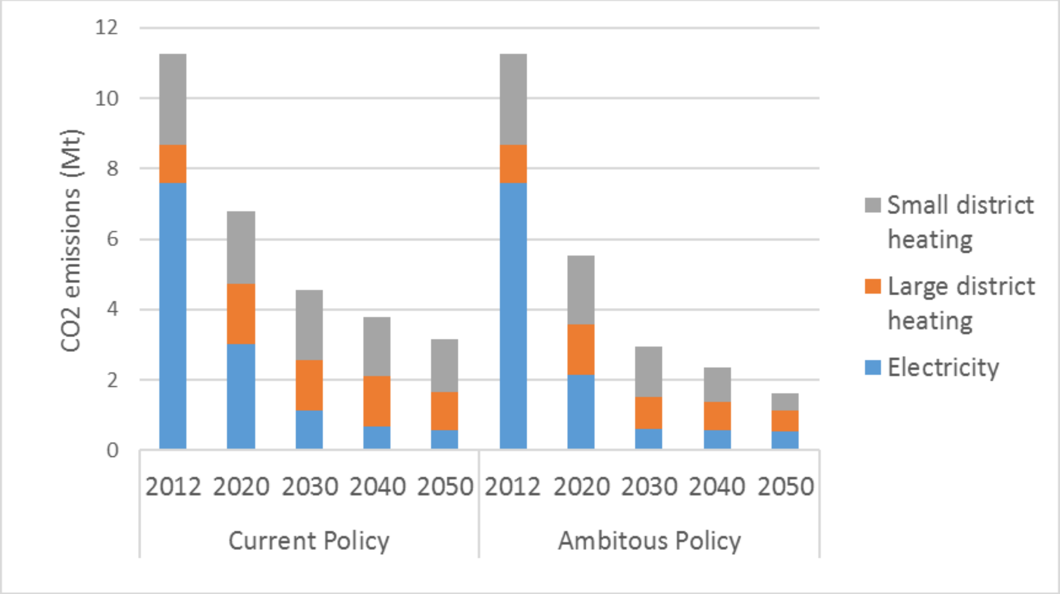

Figure 15: CO_2 emissions from generation of district heat and electricity, Austria

The share of RES in the energy demand for the generation of DH and electricity increases in both policy scenarios (Figure 16) towards 2050. The growing trend is caused by the increase of electricity generation from wind and solar PV and the increase of DH generation from large scale heat pumps. Consecutively, the use of fossil fuels declines.

In 2050, the share of RES reaches 93% and 98% in the current and ambitious policy scenario, respectively. The overall RES share is calculated as the weighted average of the RES shares in the generation of electricity and DH in large and small DH areas (Figure 16). The share of RES in the electricity generation evolves similarly in the current and ambitious policy scenario, while both large and small DH areas witness a faster increase in the share of RES in the ambitious policy scenario than in the current policy scenario. As a result, small DH areas are almost fully renewable-based in 2050 (98%), while a lower share of RES is reached in large DH areas (89%) due to the continued use of coal up to 2050.

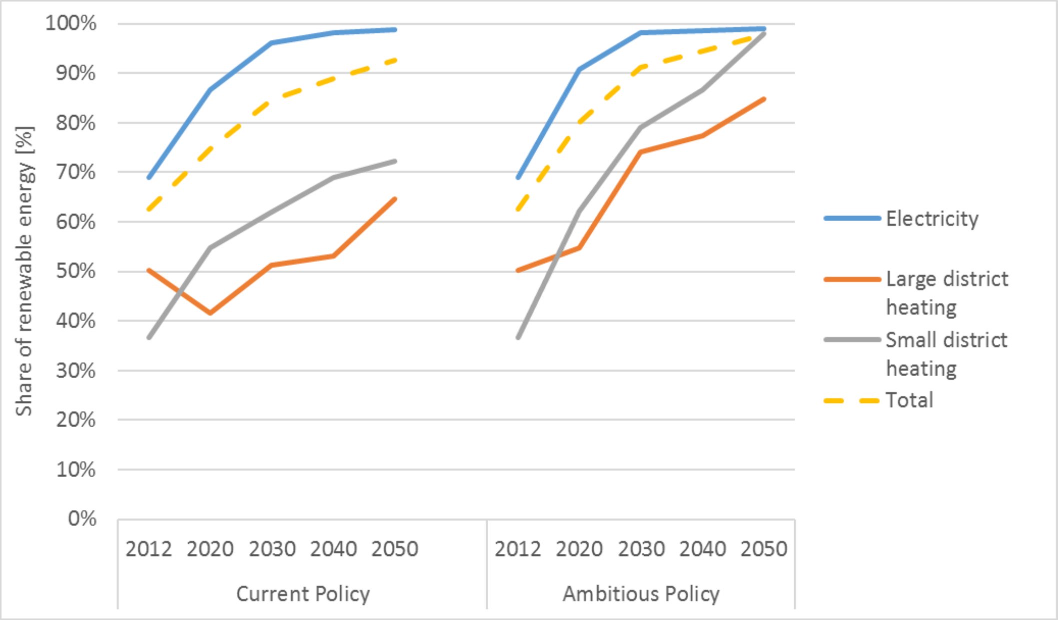

Figure 16: Share of renewable energy in district heat and electricity, Austria

The higher penetration of RES in the ambitious policy scenario in the generation of electricity and DH in Austria does not result in increased total costs (

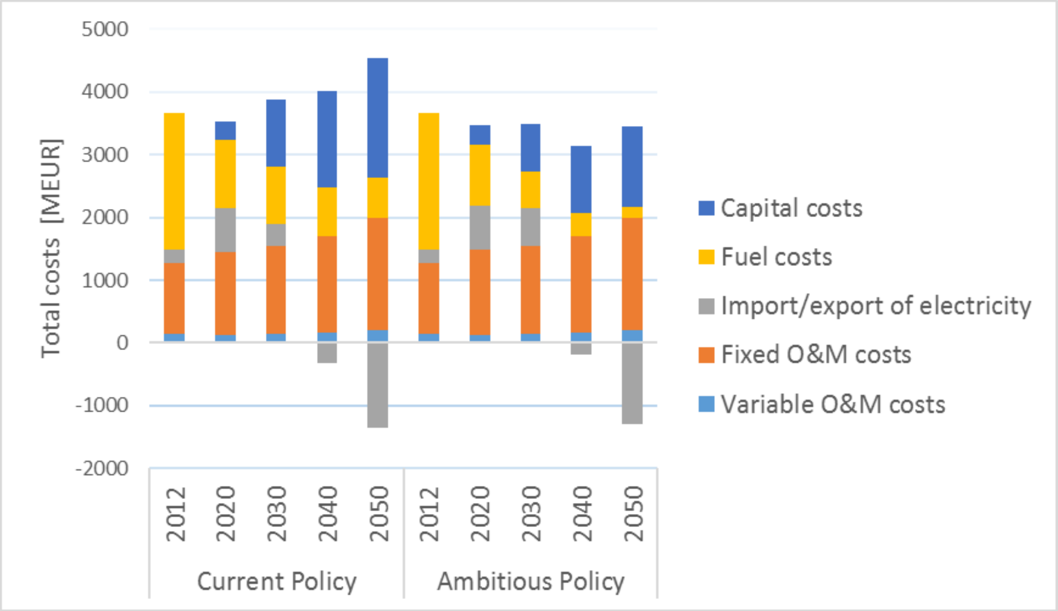

Figure 17). Compared to the current policy scenario, the ambitious policy scenario entails overall lower fuel costs due to a stronger shift to RES and increased revenues from exports of electricity in 2050. Moreover, the annual capital costs are generally lower in the ambitious policy scenario due to the low assumed interest rate of 0% for investments in technologies using RES.

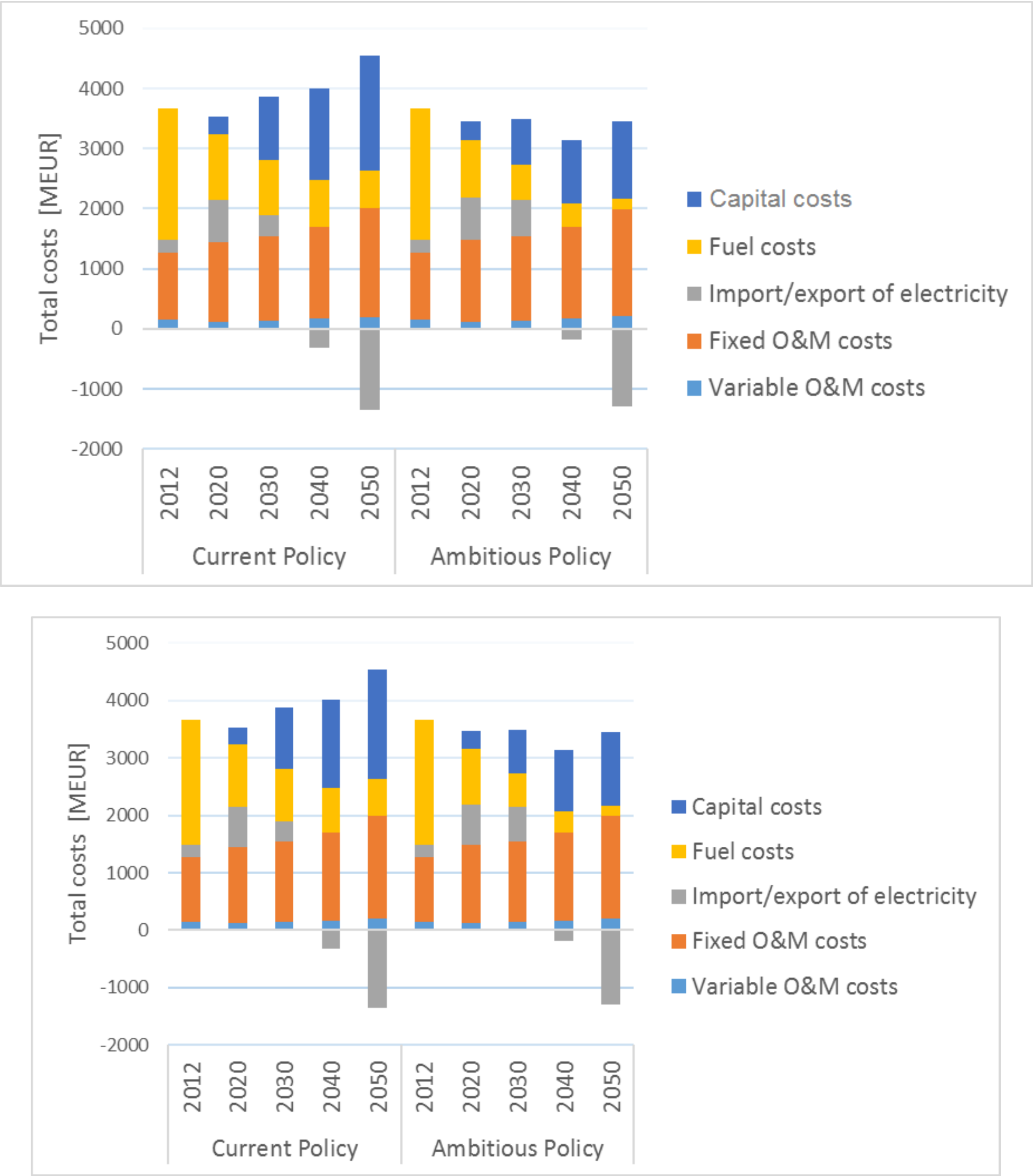

Figure 17: Total costs of district heat and electricity generation, Austria

2.1.4 Overall heating and cooling (H/C) indicators

In this chapter the indicators for countrywide heating and cooling are documented. This comprises the results of the modelling of the buildings, industry, district heating and power sector as documented in the previous chapters, but only taking into account the amounts of emissions, energy and the share of renewable energy related to heating and cooling.

Figure 18 shows the CO_2 emissions for heating and cooling purposes from the different sectors. The overall CO_2 emissions comprise the direct emissions from the buildings and the industry sector, the emissions from the district heating sector and the emissions of the power sector originating from electricity used for heating and cooling. High reductions can be achieved in all sectors in the ambitious policy scenario. In the current policy scenario the emission reductions in industry are relatively small. In both policy scenarios industry remains the main sector of CO_2 emissions in 2050. Overall an emission reduction of 38% is calculated in the current policy scenario. In the ambitious policy scenario the reduction reaches up to 74% compared to 2012.

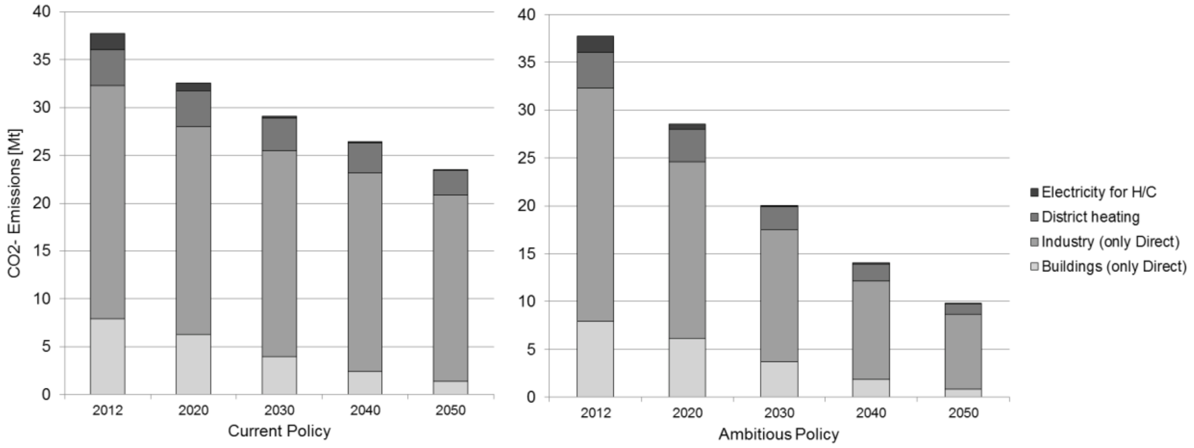

Figure 18: CO_2-emissions from heating and cooling by sector, Austria

Figure 19 shows the primary energy demand for space heating, hot water, cooling and process heat by energy carrier of all sectors. The reflected energy demand in this indicator comprises the fuel demand for heating and cooling from the buildings and industry sector (excluding electricity and district heating) plus the primary energy input into the district heating sector plus the primary energy input into the power sector for electricity used for heating and cooling purposes. In the industry sector in Austria around 77% of the final energy demand is used for heating and cooling purposes. Ambient heat is the ambient part of the heat from heat pumps. Biomass includes wood chips, wood pellets and straw. Other fossils include diesel. Other renewables include biogas, biodiesel, geothermal and wave energy. Solar include solar thermal and solar PV. Waste includes renewable and non-renewable waste.

At least a part of the remaining gas demand could also be covered by renewable energy sources, which would further reduce CO_2-emissions and increase the share of renewable energy. However, this aspect was not further analysed in this project.

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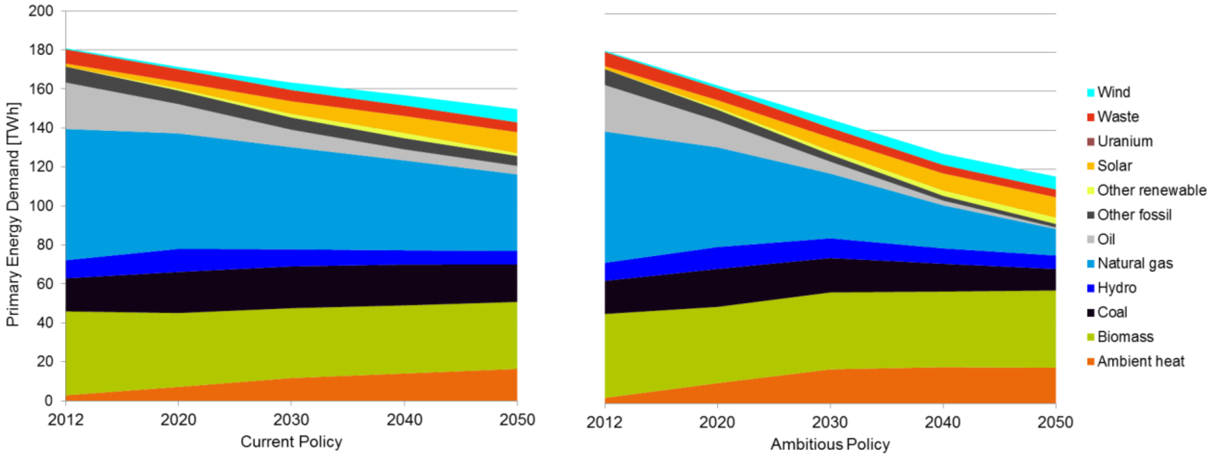

Figure 19: Primary energy demand for heating and cooling by energy carrier, including space heating, hot water, cooling and process heat, Austria

Figure 20 shows the share of renewable energy used in the different sectors. For the buildings and industry sector this share is calculated excluding electricity both in the overall demand for heating and cooling and in the amount of renewable energy used to generate electricity. The share of renewable energy in district heating, however, is taken into account in this calculation. While in electricity generation the share of RES in 2050 is well above 90%, in buildings and DH generation only in the ambitious policy scenario shares in the range of 90% are achieved. The share of RES in H/C demand of industry, however, is remarkably lower than in the other sectors in both scenarios. In the current policy scenario a share of around 28% is achieved. With the assumptions in the ambitious policy scenario a share of nearly 60% is reached.

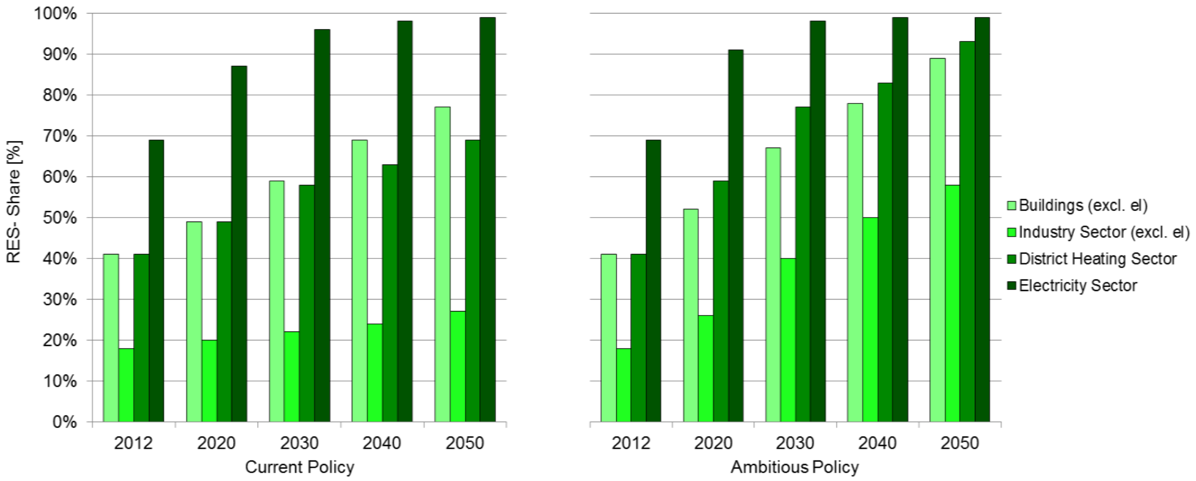

Figure 20: Share of renewables in heating and cooling by sector, Austria

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2.1.5 Conclusions and policy recommendations for Austria

In the previous chapters the results of the quantitative assessment of the influence of two policy scenarios on demand and supply of H/C and related sectors in Austria are documented. As shown in Figure 18 the CO_2 emissions for H/C are likely to be reduced with currently implemented policies at a low CO_2 price of 7,5 EUR/tCO_2 by 38% until 2050. More ambitious policies in the different sectors together with assuring a continuous increase of the CO_2 price to nearly 90 EUR/tCO_2 in 2050 might lead to a reduction of 74% until 2050. In the following key recommendations for policy making are described that result from the modelling of the national H/C systems within progRESsHEAT. A distinction is made between recommendations for policies targeting buildings, industry and DH and power generation.

The currently implemented and foreseen policies in Austria targeting **buildings** are likely to reduce direct emissions from H/C in this sector to a large extent (-83%) until 2050, and at the same time remarkably increase the share of RES in this sector (from 41% to 77%). Thus, the current shape of the national building codes and renovation standards, the foreseen RES-H obligation and the available public budgets for subsidising renovation and investments in technologies for RES-H are likely to show remarkable effects until 2050, even with a low price of CO_2. However, these emission reductions will only be achieved with the current policy framework, if a continuous monitoring of the compliance with national building codes and renovation standards is installed and non-compliance is penalised. Also, as the connection to DH is counted as an option to fulfil the RES-H obligation, it is important that DH generation is decarbonised in the mid to long term in order not to shift the source of emissions from buildings to DH. In this context it might be interesting to only allow accounting of DH for the compliance with the RES-H obligation, if for the DH system a commissioned decarbonisation roadmap exists.

Although the current policy framework leads to a remarkable decarbonisation of H/C in Austrian buildings until 2050, more ambitious policies are needed to meet the emission reduction targets as set out in the Paris Agreement. Thus, faster and deeper decarbonisation of H/C in Austrian buildings is needed. An important measure to reach this is an intensified RES-H obligation: on the one hand the obligation should not only apply for buildings that are newly constructed, but also for buildings undergoing a major renovation and in case that the heating system is changed. On the other hand, the share of the heat to be supplied by RES should be increased, so that it becomes less interesting to fulfil the obligation with a combination of fossil fuels and solar thermal systems or paying a penalty instead of compliance. At the same time the public budget for subsidising investments in technologies for RES-H should be increased to additionally trigger the technology shift.

As in many EU countries, the potential for reducing the heat demand in buildings is very high. In order to stimulate the realisation of building retrofit the public budget might be increased, but also could be set mandatory after a certain timeframe. Increased retrofit rates would also help to reduce biomass use for heating in buildings. This is important as on the one hand the amount of sustainable biomass resources might not be sufficient to supply large shares of heat demand in buildings in 2050, and on the other hand will biomass be more essential for the decarbonisation of the industry sector than for buildings. For increasing retrofit rates it is also important to drive standardisation of retrofit activities and awareness raising by implementing energy performance certificates (EPC) of buildings, so that retrofit costs decrease compared to current levels. Finally, information campaigns to increase the awareness of the continuous increase of fuel and emission certificate prices are important, so that this is taken into account in the investment decisions related to building retrofit and heating systems. This, however, is linked to a continuous increase of the CO_2 prices, which can be assured by the application of a CO_2 tax or levy for all sectors at national level, if not achieved by the EU ETS.

The following conclusions and policy recommendations can be drawn for the **industry** sector in Austria:

- Current policy is not on track towards decarbonisation, though, a slow decrease of industrial CO_2 emissions is expected. Although, the ambitious policy scenario achieves substantial additional emission cuts, also this scenario is not in line with the Paris agreement.
- A decarbonisation strategy for industry needs to focus on the iron and steel industry with about half of total industrial GHG emissions in 2012 and no simple/cheap mitigation options available in the short and medium term. In the medium term, a shift towards higher shares of electric steel (only 10% in 2012) seems a viable option, while the long term clearly needs additional mitigation options like CCS or hydrogen-based steel reduction.
- Excess heat potentials should be exploited in iron and steel, pulp and paper, cement and chemical industries. Though, with an estimated potential of 1,7 TWh for district heating and 0,4 TWh for electricity generation, the potentials are limited.
- Biomass is the central RES in industry.
- OPEX support of RES seems more effective than CAPEX support.
- Improved material efficiency and circular economy is a huge mitigation potential - though an effective policy mix is still to be proven and probably contains a bunch of individual measures.
- Implementing policies to overcome barriers to energy efficiency (energy management schemes, audits and soft loans) is a prerequisite also for other (price based) policies to work effectively.

The ambitious policy scenario describes a substantial step towards a transition of the industrial sector addressing various levers ranging from energy efficiency, via fuel switch to excess heat use, downstream material efficiency and innovation support. Still, it is not achieving reduction targets for industry that are be in line with the Paris goal of a nearly carbon neutral economy. To achieve even deeper emission cuts in the long term, more policies are needed that might include a prohibition of using coal where not technically needed, carbon capture and storage/use, more ambitious process innovations in cement, lime, chemicals and steel including the extensive use of synthetic fuels like RES-based methane or RES-H_2 and a more important role of power to heat.

Electricity demand in Austria is substantially higher than the demand for **district heating**. Therefore, a share of RES in electricity generation of close to 70% in 2012 determines the high RES share in electricity and DH generation of over 60%. This is mainly the result of large hydro power capacities. This is a very good starting point to reach high shares of RES in electricity and DH generation until 2050.

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Electricity generation reaches very high shares of RES in 2050 in both policy scenarios. The generation in both scenarios is based on wind, solar PV and hydro. Therefore, the declining costs of technologies using RES, namely wind and solar PV, are enough to decarbonize the electricity generation in Austria. The implemented policies are not necessary, especially regarding to the low interest rates of investments in technologies using RES, if the price for CO_2 emission allowances increase as projected in the PRIMES reference scenario. Thus, it could be more effective to use the public budget foreseen to allow a 0% interest rate for investments in technologies using RES from the electricity sector to DH generation or to another sector (industry, buildings, etc.).

In the current policy scenario the shares of RES in the generation of DH reach around 65% to 72% in 2050 in different types of DH areas. In the ambitious policy scenario these shares are between 85% and 98% for the same year. Therefore, the high CO_2 price and cheap financing of investments in technologies using RES prove to be effective. However, to reach fully renewable DH supply, CO_2 prices should be additionally elevated to completely phase out coal in large DH areas. Since the 0% interest rate for investment in technologies using RES is not necessary in the electricity sector, it can be converted into additional subsidies for RES DH generation.

2.2 The case of the Czech Republic

2.2.1 Buildings

This chapter documents selected indicators for the current and ambitious policy scenario related to buildings in the residential and tertiary sector.

For buildings the **current policy scenario** includes the following policies that are already in place in the Czech Republic:

- New buildings are constructed according to the current national building codes and the foreseen changes until 2021. This includes the national definitions of "Nearly Zero Energy Buildings".
- The building regulation includes a renewable heat obligation: after 2025 a small share of the heat demand in newly constructed buildings has to be covered by heating technologies using renewable energy.
- A public budget is available for subsidising the retrofit of existing buildings and for subsidising the additional costs of constructing new buildings at heat demands lower than stated in the national building codes.
- For investment subsidies of heating technologies using renewable energy only a small public budget of 10 to 20 MEUR per year is available.
- It is assumed that by standardisation, awareness rising through EPCs etc. a decrease of building renovation costs by almost 18% can be reached until 2050.

The **ambitious policy scenario** for the building sector includes additional policies in order to reach a remarkable CO_2 reduction of around 80% in the scenario timeframe. The following policies are implemented for the case of the Czech Republic:

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1. Building codes and nZEB-plans will be kept at current state.
2. The renewable heat obligation in the building regulation will be intensified: starting with a small share of heat demand that has to be covered by renewable energy after 2020, an increasing share has to be covered by renewables after 2030 and more than two thirds have to be renewable after 2035. This renewable heat obligation applies to new buildings only in the period from 2020 to 2030. Afterwards it also applies in case of a major renovation or a heating system replacement and district heating is counted 100% as an option to reach this share, even if district heating is not 100% supplied by renewable energies.
3. The annual public budget for subsidising the retrofit of existing buildings and for subsidising the additional costs of constructing new buildings at heat demands lower than stated in the national building codes will be increased by one third.
4. The annual public budget for subsidising investments in heating technologies using renewable energy will be increased to five times of the current budget.
5. Favourable financing conditions for district heating infrastructure will lead to a decrease of district heating costs by 10%.
6. As stated in the general scenario assumptions in chapter 1.1 all sectors have to pay a rising CO_2 price according to the PRIMES projection. This causes higher end consumer energy prices for fossil fuels.
7. Information campaigns will lead to decision-makers being aware of the continuous increase in prices for fuels and CO_2 emission certificates. This causes that rising prices will be taken into account in their investment decisions.

In the following figures key indicators for the current and ambitious policy scenario for buildings in Romania are compared: direct CO_2 emissions, final energy demand, share of renewables (excluding electricity), total annual running and investment costs and the direct costs (of subsidies) for the described policy programmes.

Figure 21 shows the development of the direct CO_2 emissions from the building sector in the Czech Republic. As emissions from district heating and electricity are not included in this figure the emissions only result from the use of individual natural gas and coal boilers and very few oil boilers used in Czech Republic. A decrease in CO_2 emissions in the building sector from 10 Mt in 2012 to 2,7 Mt (-73%) in 2050 is achieved in the current policy scenario and to 1,4 Mt (-86%) in 2050 in the ambitious policy scenario. This difference between the two policy scenarios originates to one part from a higher level of heat savings reached with the ambitious policies and to another part from the phase out of coal and the lower amount of natural gas that will remain in the 2050 heat supply in the ambitious policy scenario. At least a part of the remaining gas demand could also be covered by renewable energy sources, which would further reduce CO_2-emissions and increase the share of renewable energy. However, this aspect was not further analysed in this project.

The considerable GHG-emission reductions already in the current policy scenario are mainly due to currently implemented (or expected) building codes and nZEB standards as well as existing renewable heat obligation and subsidy schemes. Also increasing energy prices contribute to the result. Thus, the result should not be understood in a way that this will happen anyway. First, continuous (and maybe even enhanced) efforts will need to be taken to ensure a proper compliance

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with existing building codes and regulations. Second, other existing instruments will need to be kept in place and the corresponding public budgets for subsidies will need to be provided. Third, in case of lower energy prices than expected, higher efforts will be required to achieve the result presented here as current policy scenario.

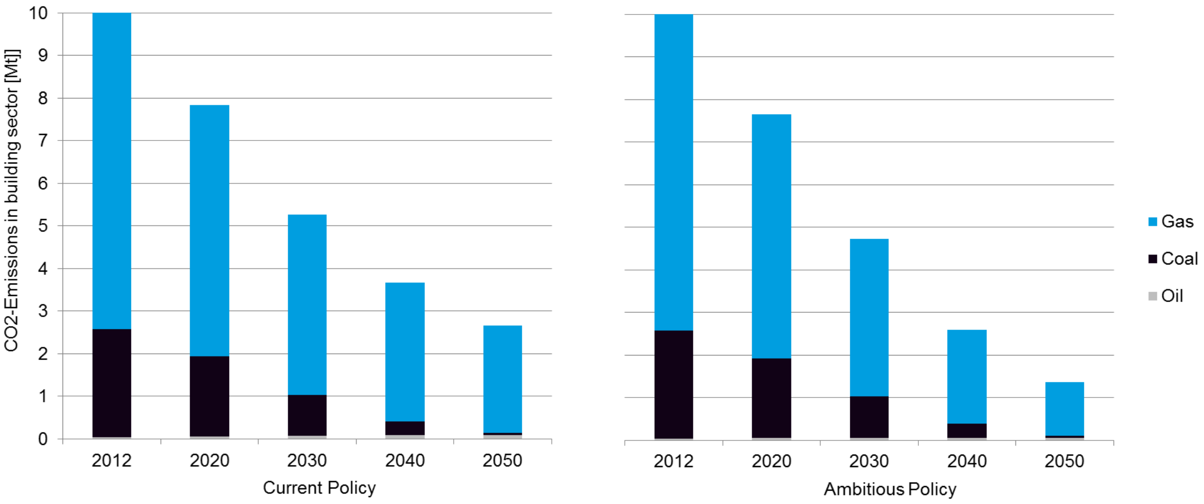

Figure 21: Direct CO_2-emissions for space heating and hot water preparation per energy carrier in the residential and tertiary sector, Czech Republic

Figure 22 shows an increase in final energy demand for heating and cooling from 84,8 TWh in 2012 to 87,5 TWh until 2020 and then a decrease to 68,6 TWh (-19%) until 2050 in the current policy scenario and to 64,1 TWh (-24%) in the ambitious policy scenario. On the secondary axis the figure shows the share of renewable energy in the building sector. For the heat delivered by district heating the respective renewable share of the district heating sector as shown in chapter 2.2.3 is used. Electricity used for heating and cooling is not included in the calculation of this share. The share of renewable energy in the power sector, however, is also shown in chapter 2.2.3. While with current policies a renewable share of 69% is reached in 2050 in the current policy scenario, a share of 84% is reached with outlined ambitious policies.

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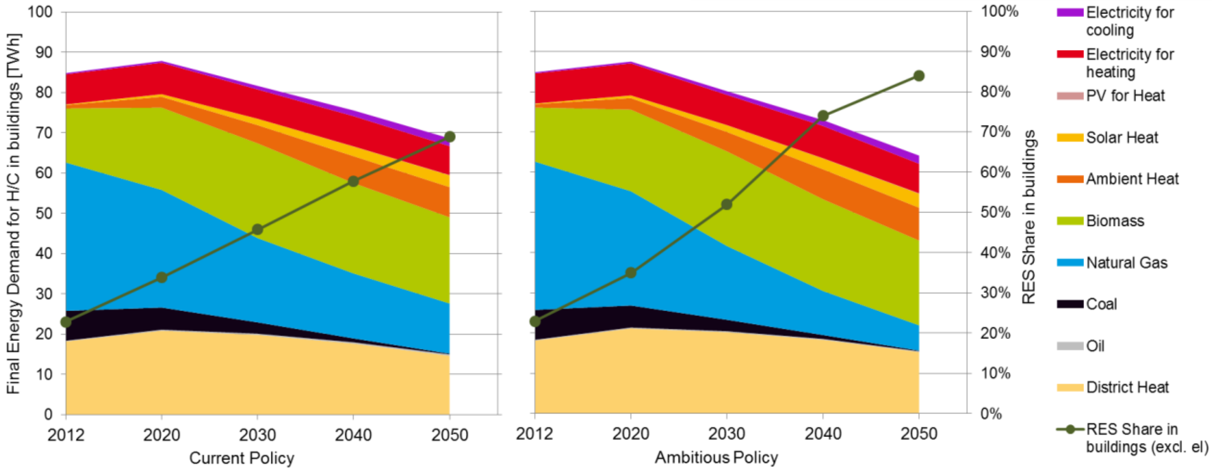

Figure 22: Final energy demand and share of renewables for space heating, hot water preparation and space cooling by energy carrier in the residential and tertiary sector, Czech Republic

Figure 23 shows the investment and running costs for heating and cooling in buildings in the Czech Republic. While the overall amount of costs is similar between the two scenarios (with the ambitious policy scenario causing higher costs), a shift from running costs to investment costs in the ambitious policy scenario can be observed even under the assumption of rising energy prices in the ambitious scenario. This is due to the switch from fossil fuelled technologies with high running costs to technologies using renewable sources with higher investment costs but low running costs.

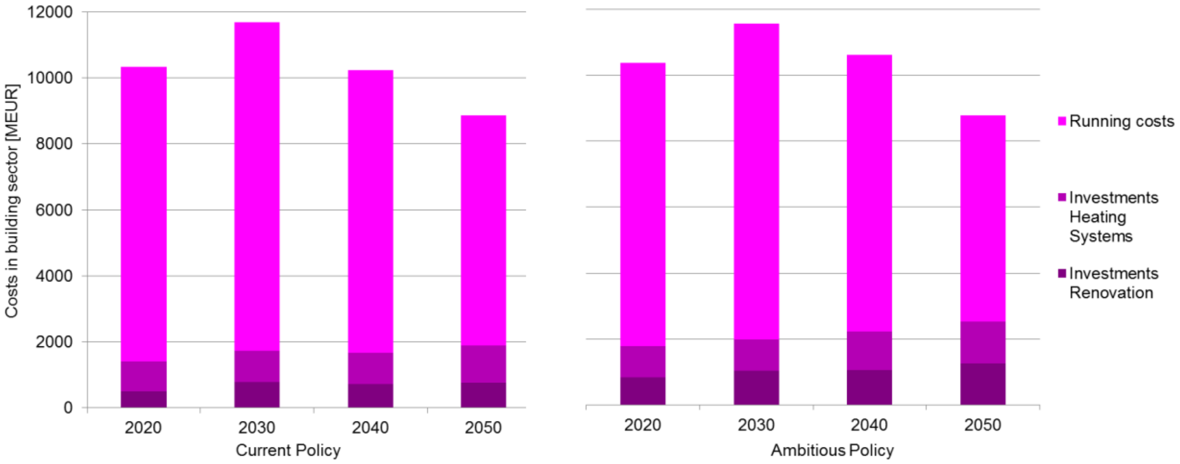

Figure 23: Investments and running costs for building renovation and heating and hot water systems in the residential and tertiary sector, Czech Republic

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Figure 24 shows the increasing policy programme costs for the ambitious policy scenario compared to the current policy scenario. These costs include subsidies for renovation measures and subsidies for heating technologies using renewable energies, also including solar thermal systems. The renewable heating subsidies mainly will be used for replacement of individual natural gas boiler to achieve an additional CO_2 reduction of almost 50% compared to the current policy.

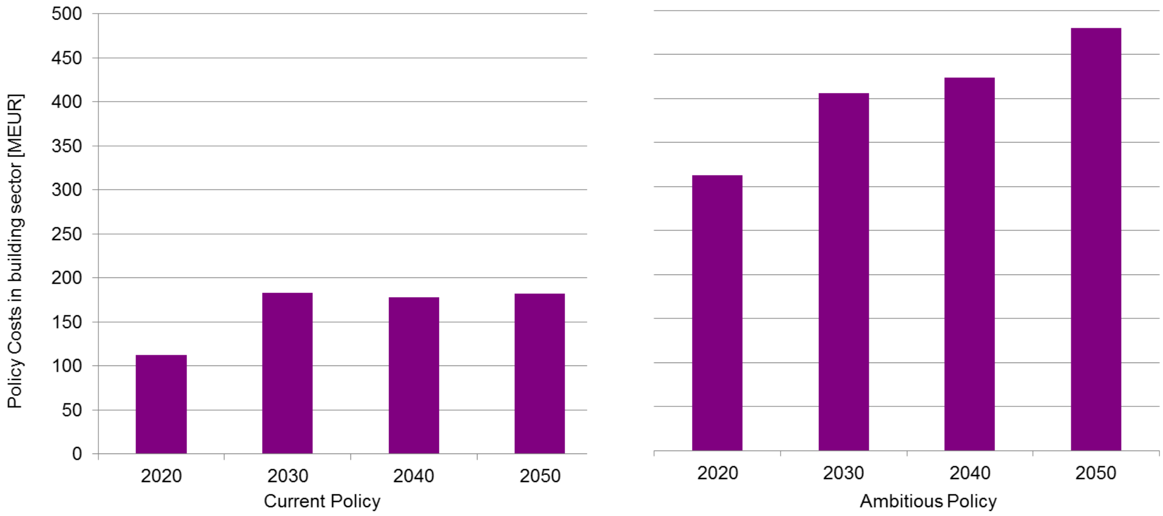

Figure 24: Policy programme costs for the residential and tertiary sector, Czech Republic

2.2.2 Industry

This chapter documents selected indicators for the current and ambitious policy scenario in the Czech industry sector.

- The **current policy scenario** considers policies implemented by 2015 including among others. This includes among others the CO_2 price, EU Ecodesign Standards for energy using products as well as Energy taxes as reported by Eurostat in 2015.

The **ambitious policy scenario** represents a much more ambitious policy mix towards the transformation of the industrial heating and cooling sector. It comprises of the following main elements:

1. Policy package addressing classical non-financial barriers to energy efficiency including the roll-out of energy management systems, energy audits, soft loans, etc.
2. Extension of Ecodesign Minimum standards to additional equipment including steam boilers and industrial furnaces

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3. Increasing investment grants for RES-H technologies including power-to-heat using heat pumps or electric boilers for steam generation
4. RES OPEX support: ~5 Euros/MWh for RES-H including district heating, heat pumps and electric boilers
5. CO_2 price: extending the CO_2 price beyond the ETS (same level) and changing price expectations: Companies now consider the CO_2 price 10 years ahead for their investment appraisal. This is achieved via a transparent and defined tax increase and/or a floor price for the EU ETS
6. Comprehensive support of material efficiency and circular economy: Reduced production of basic materials products due to efficiency improvements along the value chain and shift towards secondary production (e.g. electric steel replacing oxygen steel, more recycled paper, etc.). See table below and Table 9 and Table 10 in the annex for an overview on recycling and secondary production assumptions.

Table 3: Assumptions on use of recycled materials for steel, cement, aluminium and paper in Czech Republic [%]

Indicator		Current policy scenario		Ambitious policy scenario	
	2012	**2030**	**2050**	**2030**	**2050**
Share of electric steel in total crude steel production	7%	7%	7%	35%	73%
Share of clinker in total cement production	67%	62%	61%	57%	55%
Share of secondary aluminium in total aluminium production	100%	100%	100%	100%	100%
Share of recovered fibres in total pulp production	26%	29%	33%	36%	46%

7. Exploitation of industrial excess heat potentials of heat >100°C for use in district heating or, where district heating networks are not nearby, for electricity generation. This can be implemented via financial support but also via regulation (e.g. related to pollution control)
8. Innovation support to speed-up the market introduction of low-carbon production processes for the basic materials industries. This includes various strategies from niche markets via requirements for public procurement, to R&D&I support as grants and soft loans (see e.g. discussion on EU Innovation Fund) a minimum CO_2 price path and more.

Results of the current policy and the ambitious policy scenarios are presented and compared below, beginning with CO_2 emissions, before discussing final energy demand and excess heat potentials. Results are shown for the entire industrial sector including non-H/C applications like mechanical energy. However, non-H/C applications are nearly exclusively found in electricity use, while fuel consumption can be attributed to H/C in 2012.

Total industrial CO_2 emissions in the current policy scenario remain relatively constant at about 25 Mt/year. A reduction in the emissions from other fossil fuels is compensated by an increasing share of natural gas and process related emissions (see Figure 25). The latter are particularly driven by the growing cement production. The ambitious policy scenario shows a different pattern. A continuous and fast decline is observed resulting in a reduction of CO_2 emissions of about 59% by 2050 compared to 2012. Particularly emissions from energy combustion are decreasing, while process related emissions (from cement production) do not change much compared to the current policy scenario. In 2050 main emission sources in the ambitious policy scenario are process emissions, natural gas and coal.

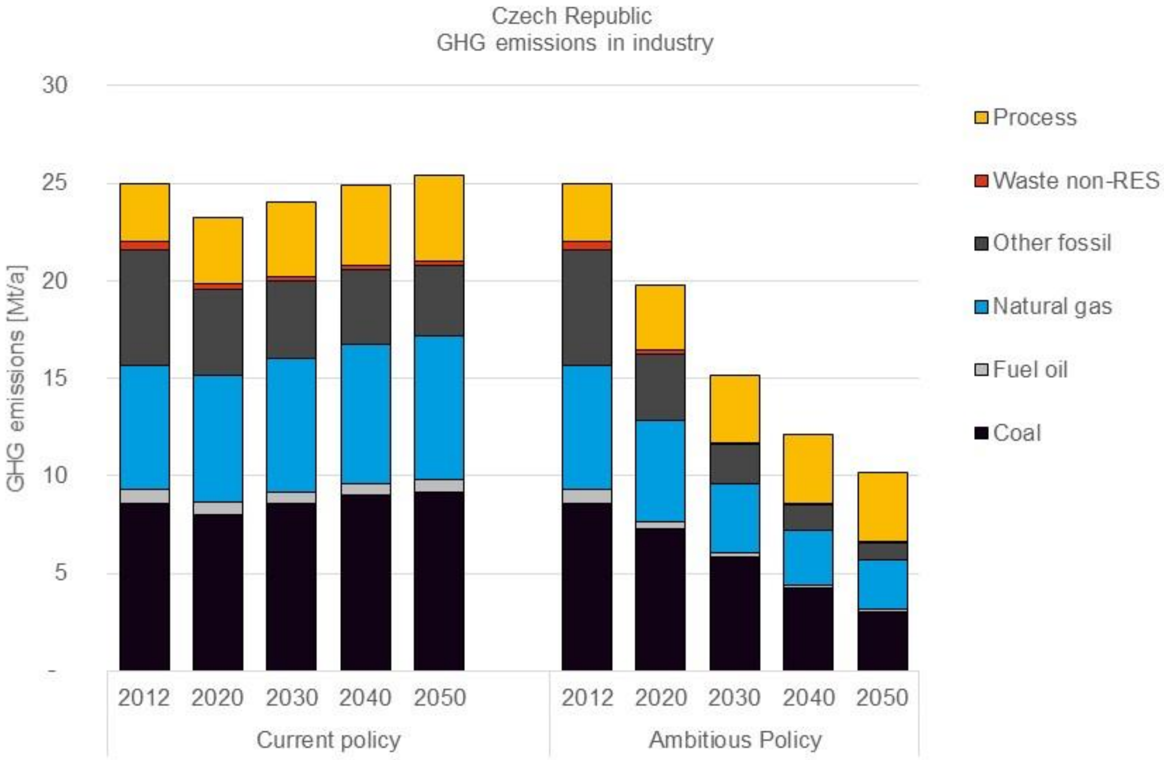

Figure 25: Direct GHG emissions in industry by energy carrier (including process emissions), Czech Republic

In 2012, the sub-sectors non-metallic minerals (mainly cement, but also glass) and even more the iron and steel industry dominated industrial CO_2 emissions in the Czech Republic (Figure 26). While the share of sub-sectors does not change substantially in the current policy scenario, the ambitious policy scenario shows a substantial change. The non-metallic minerals sub-sector is responsible for about half of industrial emissions in 2050 (due to the difficulty to mitigate process related emissions from cement production), while in the other sub-sectors and even in the steel industry substantial emission mitigation is achieved. The change in the steel industry is driven by an ambitious shift from oxygen steel to scrap based electric steel production.

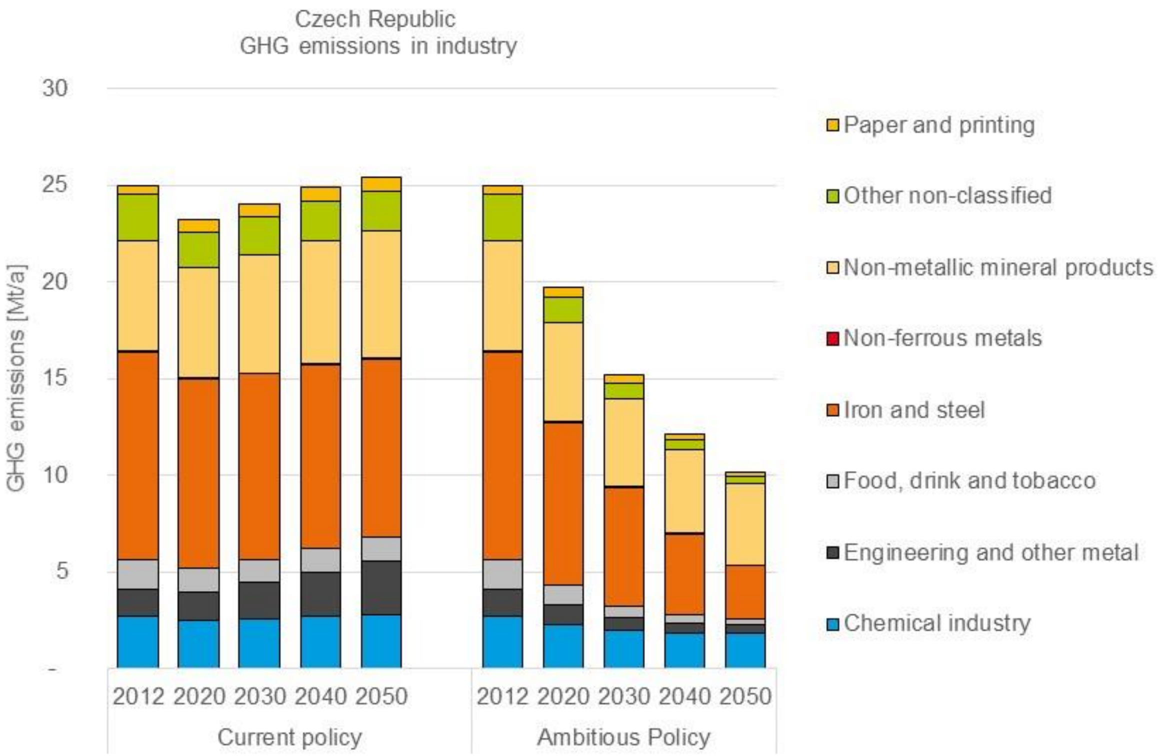

Figure 26: Direct GHG emissions in industry by sub-sector (including process emissions), Czech Republic

The industrial final energy demand by energy carrier is shown in Figure 27. Even the current policy scenario shows an increase in the use of biomass and electricity. Overall the final energy demand increases in the current policy scenario, as fossil fuels are consumed in about the same amount as in 2012. In the ambitious policy scenario, the use of biomass is increasing to nearly 35 TWh resulting in a total share of renewable energy of about 60% in 2050. Coal use is decreasing as oxygen steel is replaced by electric steel and also natural gas is substituted mainly by biomass. The use of ambient heat (via heat pumps) increases, but remains at low shares due to temperature level restrictions.

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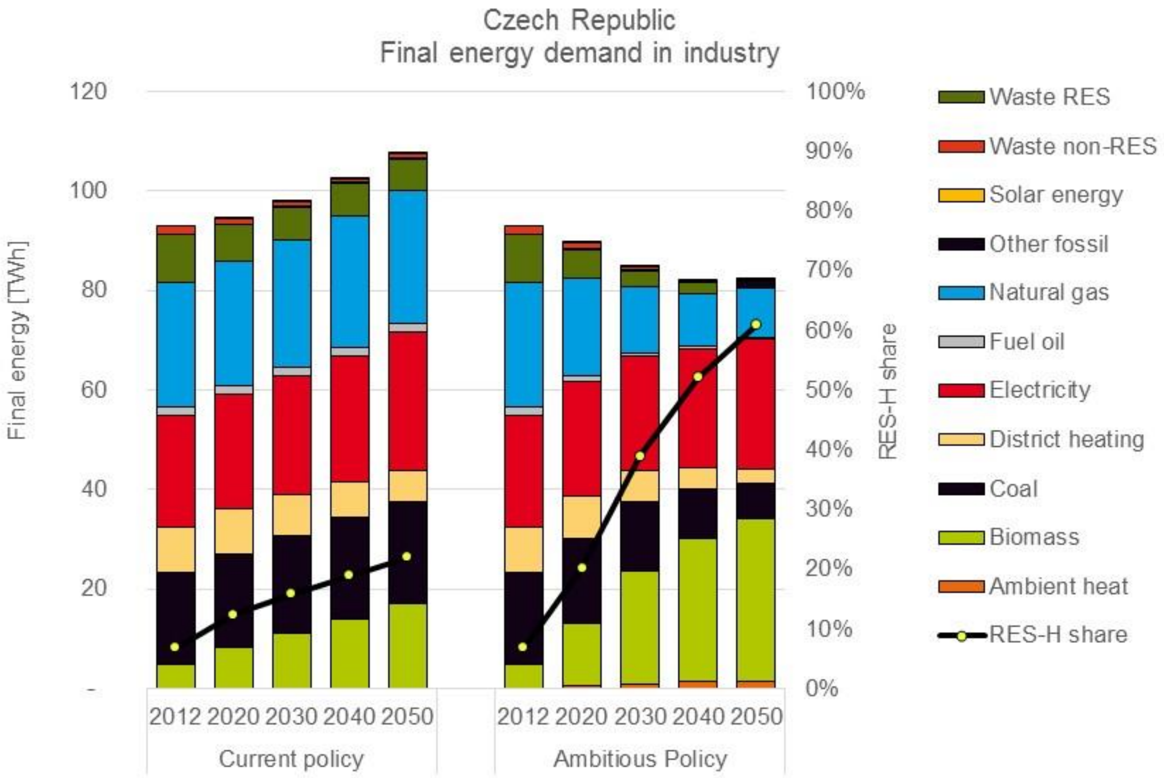

Figure 27: Final energy demand and share of renewables in industry by energy carrier, Czech Republic

Industrial excess heat potentials (flue gas >100°C) in the Czech Republic are available from the steel industry, but also from glass, cement and chemicals production. However, due to the shift from oxygen steel to electric steel in the ambitious policy scenario, the excess heat potentials from sinter, blast furnace and coke ovens are substantially decreasing until 2050.

Note that our assessment of excess heat potentials only considered 30 energy intensive processes/ products and only looked at excess heat from flue gases available at temperatures above 100°C. There is potentially more excess heat available from other sources not covered here and also at lower temperature levels than 100°C.

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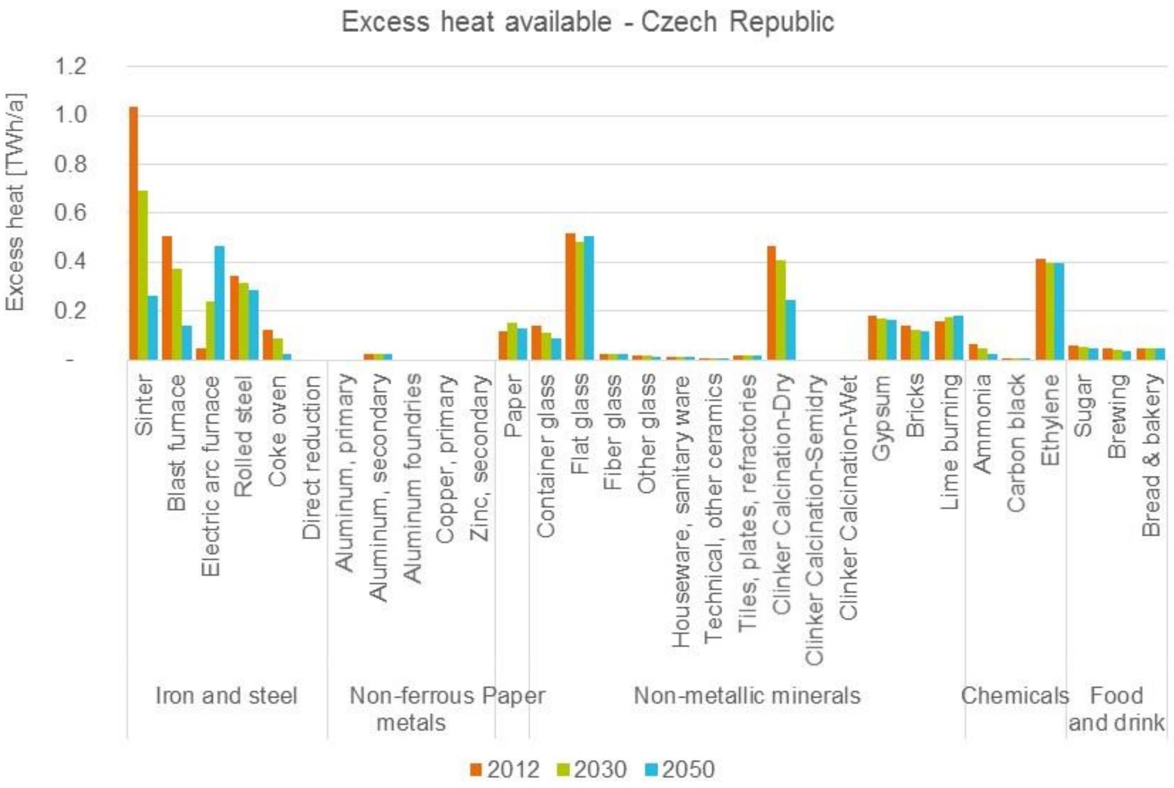

Figure 28: Industrial excess heat potential (>100°C) by process in the ambitious policy scenario, Czech Republic

To better understand the individual impact of the various elements of the policy mix defined for the ambitious policy scenario, Figure 29 shows the impact by type of policy. 6 policy packages are distinguished. From the current policy scenario to the current policy plus 6 (= ambitious policy scenario), the policy mix is extended stepwise. E.g. current policy plus 3 includes financial OPEX support for RES, but also considers all elements included in the scenarios current policy plus 1 and 2.

The figure shows a particularly strong influence from support of OPEX for heat supply based on renewable energy, a substantial impact of the extension of the CO_2 price to companies outside the EU emissions trading scheme (EU ETS) and improvements in (downstream) material efficiency and circular economy.

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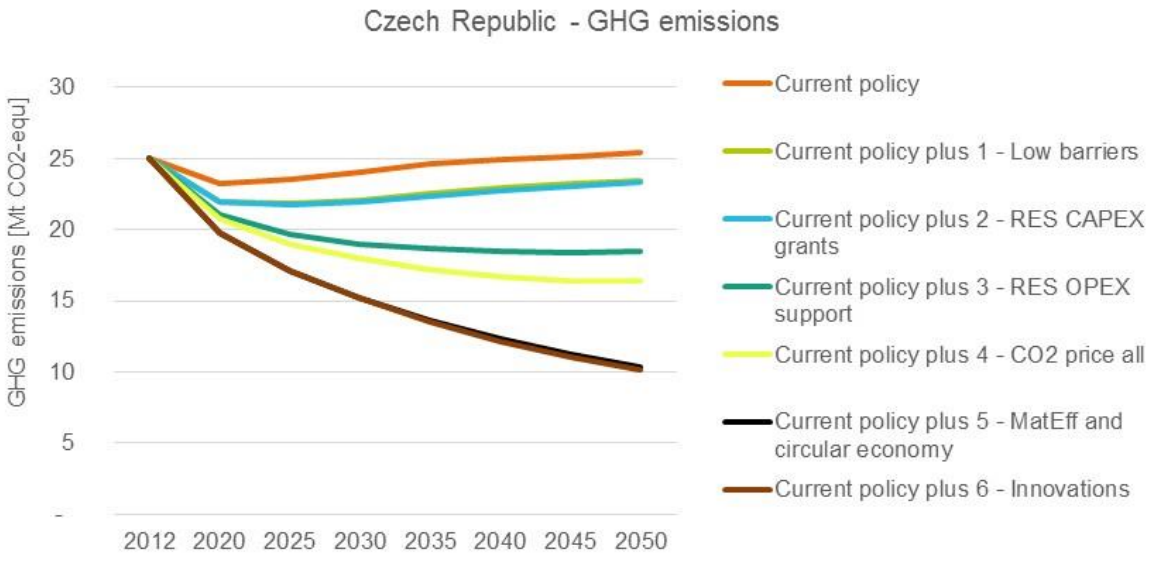

Figure 29: Direct GHG emissions in industry by policy variant, Czech Republic

To summarize, in a current policy scenario, industrial emissions are unlikely to decrease until 2050. An ambitious policy mix with a focus on heating and cooling policies can, however, substantially decrease overall emissions until 2050.

2.2.3 District heating and the power sector

This chapter documents selected indicators for the current and ambitious policy scenario in the Czech district heating (DH) and power sectors. As described in the methodology section, the results are based on an optimisation model (TIMES), which does not necessarily include all relevant and realistic barriers and diffusion constraints. Thus, the results illustrate the cost-optimal investments and operation of the electricity and district heating system, while some non-economic factors (diffusion constraints, social acceptance, political factors, etc.) might not be represented in the results

For the case of the Czech Republic no additional scenario assumptions are added to the scenario assumptions outlined in chapter 1.1.

The projected demand for DH (result from INVERT/EE-Lab and FORECAST-Industry models as documented in the previous chapters) in large DH areas decreases by around 30% until 2050 compared to 2012; a similar trend happens in both ambitious and current policy scenarios. The projected DH demand in small DH areas remains almost the same in 2050 as in 2012 in the current policy scenario. In the ambitious policy scenario the projected DH demand in large DH areas decreases by almost 30% between 2012 and 2050.

The energy demand in large and small DH plants for the two scenarios is presented in Figure 30 and Figure 31 respectively. For the large DH plants, the most considerable difference relates to the

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increase in the share of wood pellets, waste and the decrease of coal in the fuel mix for the ambitious policy scenario. In the current policy scenario, coal consumption reaches the maximum level of 9,61 TWh in 2030, while in the ambitious scenario it decreases by 65% compared to current policy in the same year and reaches 0,12 TWh in 2050 (1% of the total fuel used in large DH). In the ambitious policy scenario wood pellets and waste considerably substitute coal consumption.

The trend for waste consumption in the current policy scenario shows a steady decrease from 2012 (4,5 TWh) and reaches to zero in 2050, while in ambitious policy scenario it increases to the critical amount of 4,96 TWh in 2030 and drops to 4,29 TWh in 2050 (35% of the total fuel used in large DH). Other RES remain low in both policy scenarios in the future. On the other hand, the consumption of natural gas for the supply of DH in large DH areas decreases steadily within the scenario time horizon and between the two policy scenarios, with around 0,31 TWh and less than 0,01 TWh used in 2050 in the current policy and the ambitious policy scenario respectively. Excess heat from industry does not play a role in the supply of DH within the large DH areas in neither scenarios, while 0,4 TWh of excess heat supply small DH areas under the ambitious policy scenario in 2050 (Figure 31). Excess heat is not available in the current policy scenario, as outlined in the section 1.1.

As for the rest of the fuel mix, similar considerations apply to small DH plants, where heat pumps are utilized in the ambitious policy scenario and responsible for 80% of total energy demand (ambient heat plus electricity). Ambient heat has the largest share (36% and 54% in 2050 in the current and ambitious policy scenario respectively). Wood pellets and waste decrease towards 2050 in the two scenarios. Moreover, when comparing the current with the ambitious policy scenario, one can notice an increased energy demand in large DH areas (8,42 TWh vs. 12,23 TWh in 2050), with a consequent decreased demand in small DH areas (19 TWh vs. 11,27 TWh in 2050).

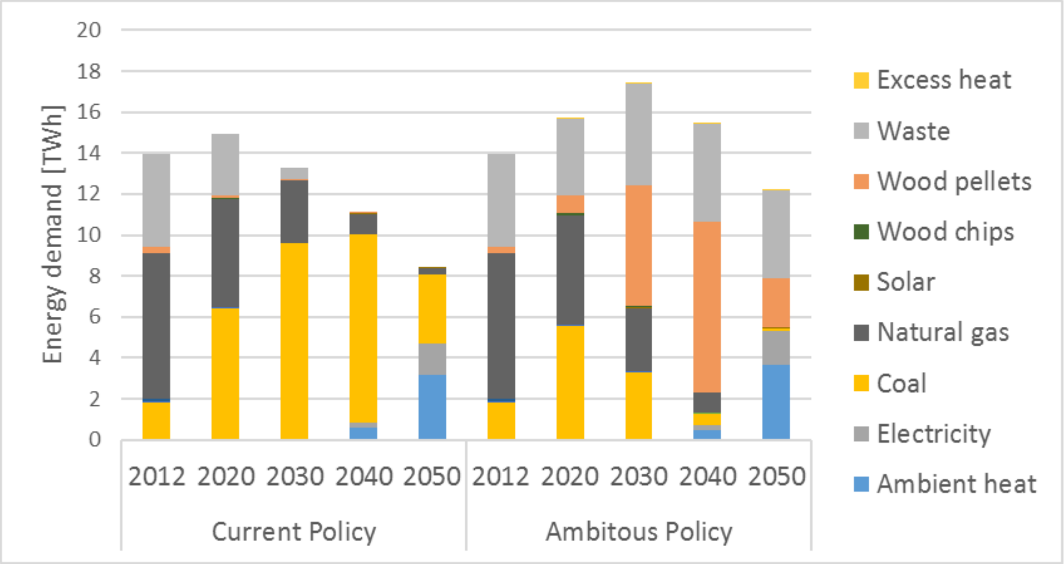

Figure 30: Energy demand in large district heating areas by energy carrier, Czech Republic

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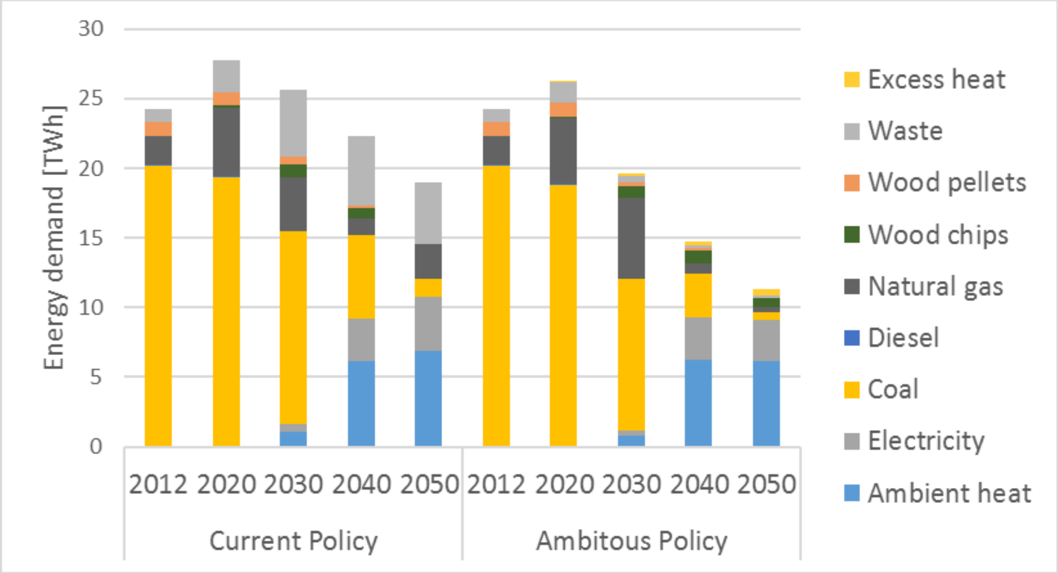

Figure 31: Energy demand in small district heating areas by energy carrier, Czech Republic

The shares of coal and natural gas in the energy demand for electricity generation decrease significantly in both policy scenarios (Figure 32). Coal consumption decreases gradually from 130 TWh in 2012 to 14 TWh and 2 TWh in 2050 in the current policy and the ambitious policy scenarios, respectively. Natural gas consumption decreases from around 7 TWh in 2012 to 3 TWh and 0,4 TWh in 2050 in the current policy and the ambitious policy scenario, respectively. Wood pellets consumption is almost negligible in the current policy scenario, while it reaches 19 TWh in the ambitious policy scenario in 2050 (11% of total energy demand). Wind, solar, hydro and waste almost have a same trend in both policy scenarios. However, the overall energy demand increases in the ambitious policy scenario to around 176 TWh in 2050, compared to 171 TWh in the current policy scenario. The main reason for this difference is the difference in the demand projections.

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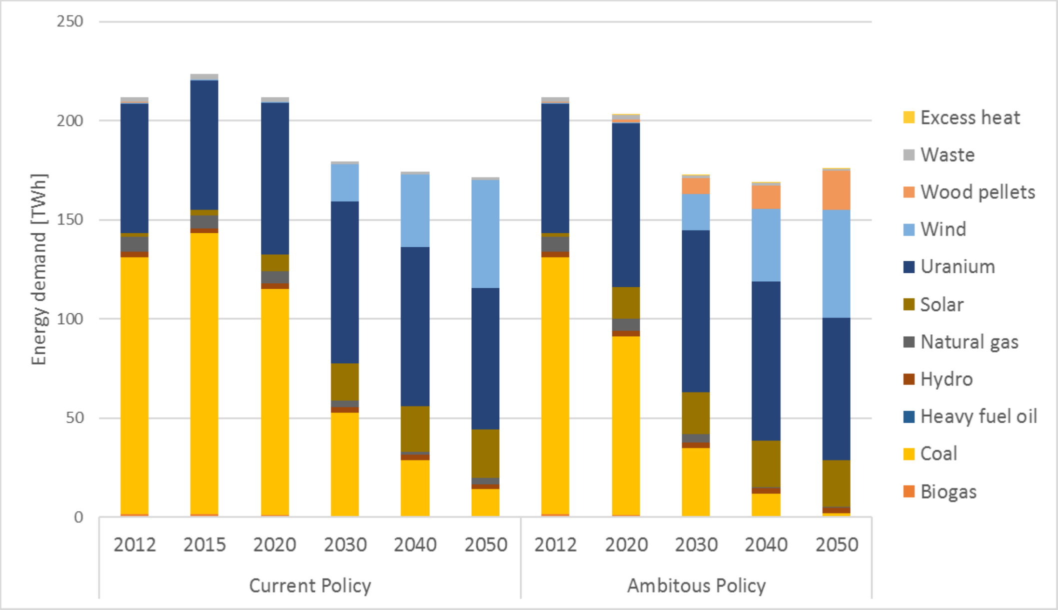

Figure 32: Energy demand for electricity generation by energy carrier, Czech Republic

The annual CO_2 emissions from the generation of electricity and DH are shown in Figure 33 for the analysed scenarios. In both policy scenarios the electricity and DH systems undergo a deep decarbonisation moving from 56,2 Mt in 2012 to 8,2 Mt and 1,8 Mt in 2050 for the current policy and the ambitious policy scenario, respectively. The deep cut in emissions from 2030 is explained by the phase-out of fossil fuels, especially in the electricity only plants, thus replaced by carbon-neutral straw and wood pellets, wind, hydroelectric and solar power.

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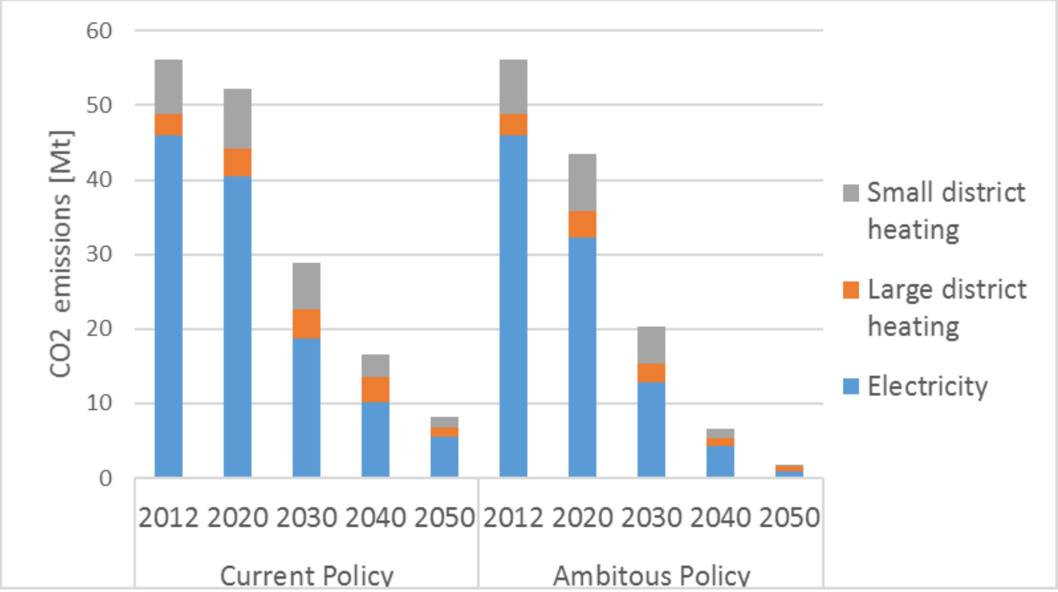

Figure 33: CO$_2$ emissions from generation of district heat and electricity, Czech Republic

The share of RES on the total energy demand for electricity and DH generation increases in both scenarios (Figure 34) until 2050. The growing trend translates from the increase of wind and solar power for electricity only plants and heat pumps in the DH sector, at the expenses of fossil resources. In 2050, the total share of RES reaches 50% and 61% in the current policy and the ambitious policy scenario, respectively. The share of RES in the large DH systems witnesses a faster increase in the ambitious policy scenario (93%) than in the current policy scenario (47%), while the RES share in electricity generation evolves similarly in the current policy (49%) and the ambitious policy scenario (58%) and in small DH systems it also evolves similarly in the current policy (70%) and the ambitious policy scenario (81%). As a result, large DH systems are almost fully based on RES in 2050 (93%), while a lower RES share for electricity only plants (58%) is due to the continued use of fossil fuel up to 2050. While electricity generation contributes a major part to the overall RES share in electricity and DH generation, DH plays a minor role.

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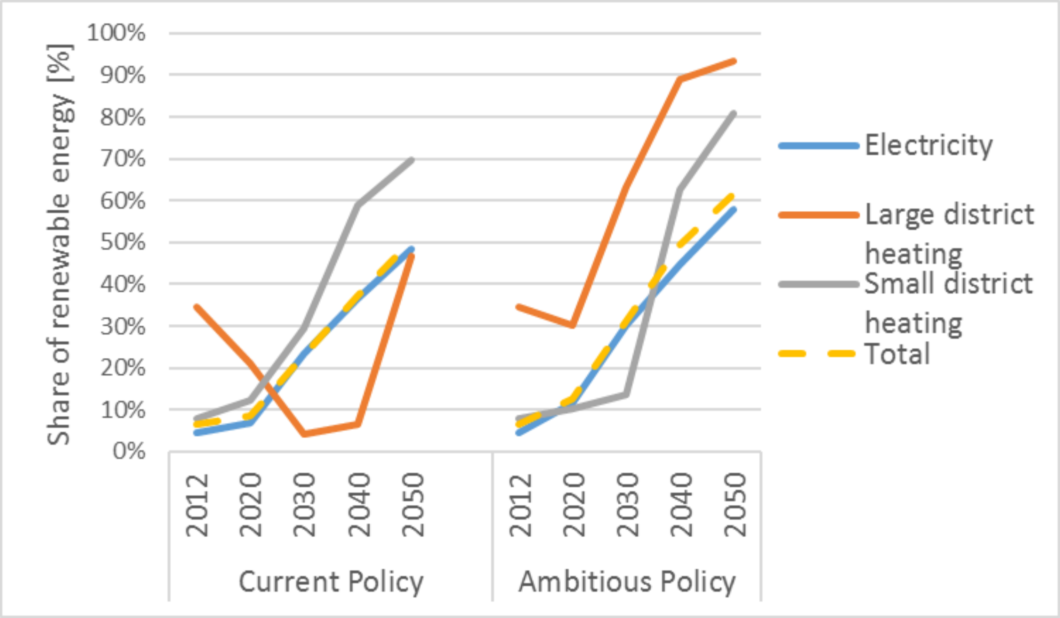

Figure 34: Share of renewable energy in district heat and electricity, Czech Republic

The cost of electricity and DH generation are very similar in the current policy and the ambitious policy scenario. The main reason for this is that the power sector, which is larger than DH sector, follows the same trends in both scenarios. The higher fuel costs in the ambitious policy scenario originate from the switch towards biomass in large DH plants, while the smaller investment costs originate from the favourable financing conditions (0% interest rate for the investments in technologies for using RES).

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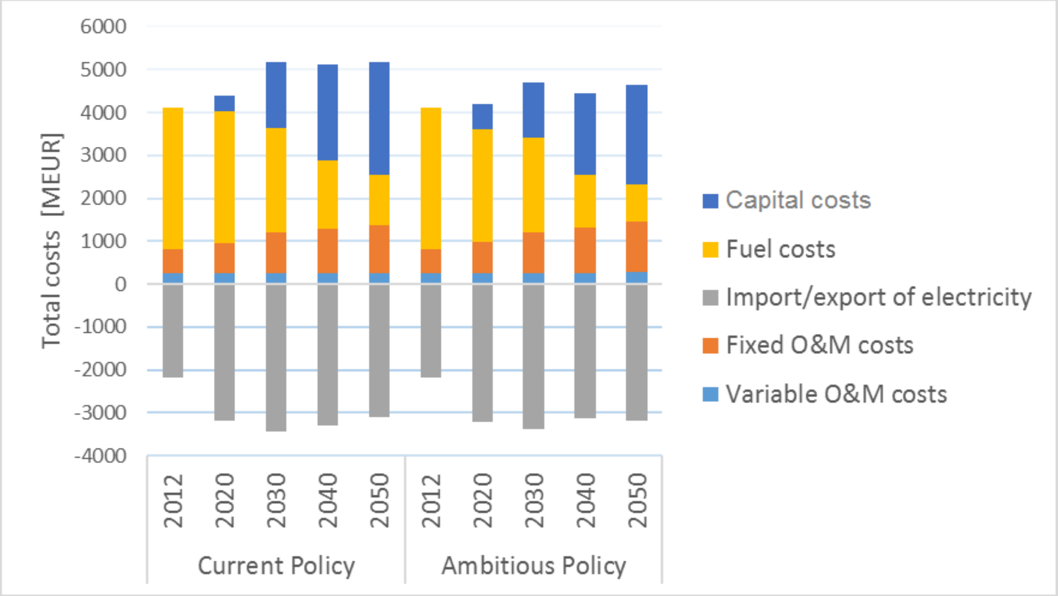

Figure 35: Total costs of district heat and electricity generation, Czech Republic

2.2.4 Overall heating and cooling (H/C) indicators

In this chapter the indicators for countrywide heating and cooling are documented. This comprises the results of the modelling of the buildings, industry, district heating and power sector as documented in the previous chapters, but only taking into account the amounts of emissions, energy and the share of renewable energy related to heating and cooling.

Figure 36 shows the primary energy demand for space heating, hot water, cooling and process heat by energy carrier of all sectors. The overall CO_2 emissions comprise the direct emissions from the buildings and the industry sector, the emissions from the district heating sector and the emissions of the power sector originating from electricity used for heating and cooling. High reductions can be achieved in all sectors in the ambitious policy scenario. The share of the industry sector on the overall emissions increases until 2050. The current policies lead to a CO_2 reduction of 43% while the combined effort of the ambitious policies in all sectors leads to a reduction of 81% in the modelling.

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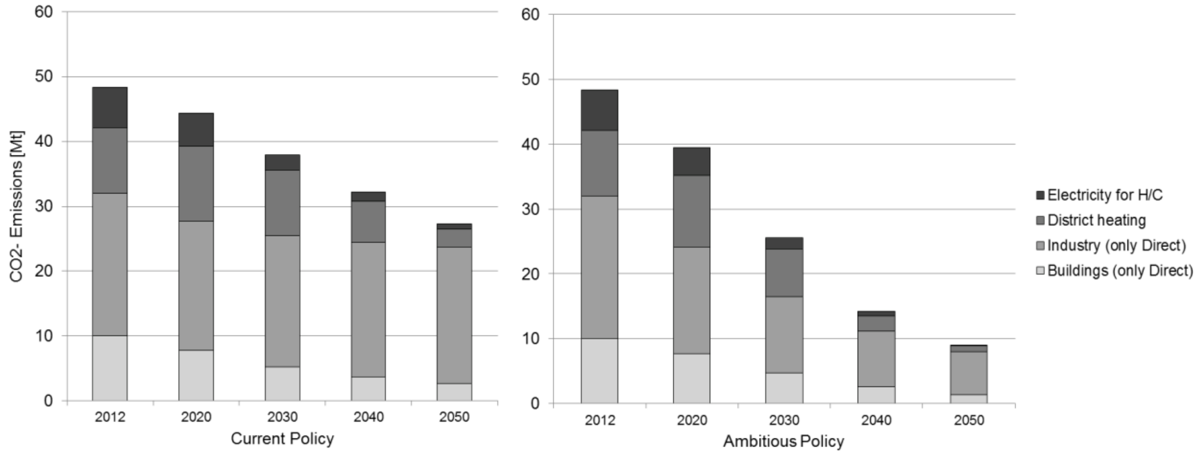

Figure 36: CO$_2$-emissions from heating and cooling by sector, Czech Republic

Figure 37 shows the primary energy demand for heating and cooling by energy carrier of all sectors. The reflected energy demand in this indicator comprises the fuel demand for heating and cooling from the buildings and industry sector (excluding electricity and district heating) plus the primary energy input into the district heating sector plus the primary energy input into the power sector for electricity used for heating and cooling purposes. In the industry sector in the Czech Republic around 78% of the final energy demand is used for heating and cooling purposes. Ambient heat is the ambient part of the heat from heat pumps. Biomass includes wood chips, wood pellets and straw. Other fossils include diesel. Other renewables include biogas, biodiesel, geothermal and wave energy. Solar include solar thermal and solar PV. Waste includes renewable and non-renewable waste.

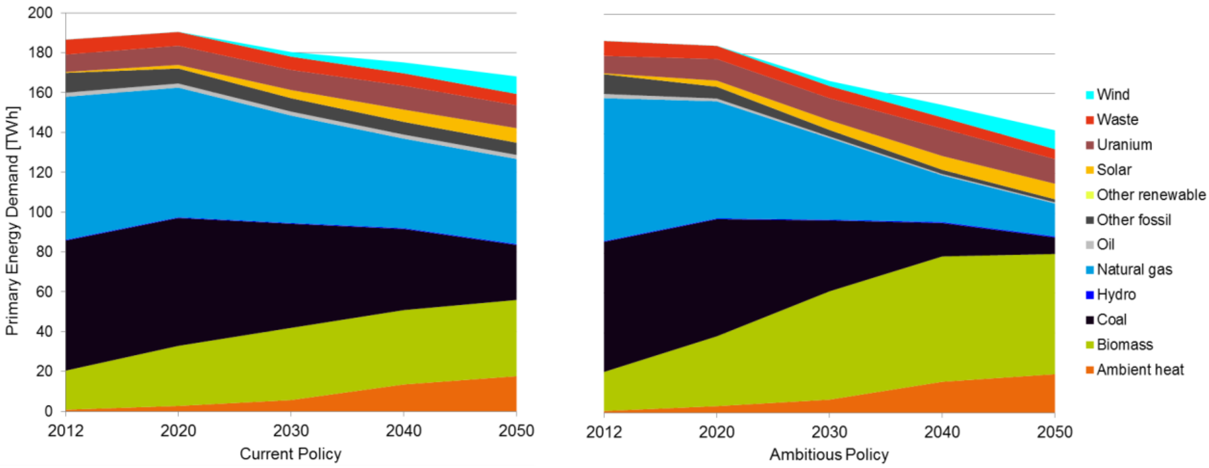

Figure 37: Primary energy demand for heating and cooling by energy carrier, including space heating, hot water, cooling and process heat, Czech Republic

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Figure 38 shows the share of renewable energy used for heating and cooling in the different sectors. For the buildings and industry sector this share is calculated excluding electricity both in the overall demand for heating and cooling and in the amount of renewable energy used to generate electricity. The share of renewable energy in district heating, however, is taken into account in this calculation. Even in the ambitious scenario only in district heating and buildings share of renewable energy above 80% is achieved, while the electricity and the industry sector only achieve around 60%.

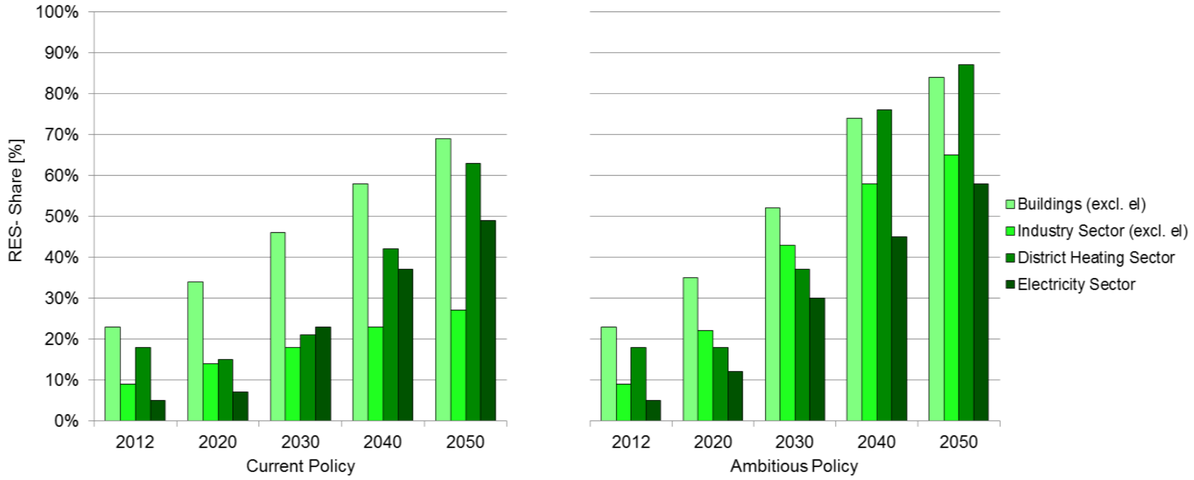

Figure 38: Share of renewables in heating and cooling by sector, Czech Republic

2.2.5 Conclusions and policy recommendations for the Czech Republic

In the previous chapters the results of the quantitative assessment of the influence of two policy scenarios on demand and supply of H/C and related sectors in the Czech Republic are documented. As shown in Figure 36 the CO_2 emissions for H/C are likely to be reduced with currently implemented policies at a low CO_2 price of 7,5 EUR/tCO_2 by 43% until 2050. More ambitious policies in the different sectors together with assuring a continuous increase of the CO_2 price to nearly 90 EUR/tCO_2 in 2050 might lead to a reduction of 81% until 2050. In the following key recommendations for policy making are described that result from the modelling of the national H/C systems within progRESsHEAT. A distinction is made between recommendations for policies targeting buildings, industry and DH and power generation.

The currently implemented and foreseen policies in the Czech Republic targeting **buildings** are likely to reduce direct emissions from H/C in this sector to a large extent (-73%) until 2050, and at the same time remarkably increase the share of RES in this sector (from 23% to 69%). Thus, the current shape of the national building codes and renovation standards, the foreseen RES-H obligation and the available public budgets for subsidising renovation and investments in technologies for RES-H are likely to show remarkable effects until 2050, even with a low price of CO_2. However, these emission reductions will only be achieved with the current policy framework, if a continuous monitoring of the

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compliance with national building codes and renovation standards is installed and non-compliance is penalised. Also, as the connection to DH is counted as an option to fulfil the RES-H obligation, it is important that DH generation is decarbonised in the mid to long term in order not to shift the source of emissions from buildings to DH. In this context it might be interesting to only allow accounting of DH for the compliance with the RES-H obligation, if for the DH system a commissioned decarbonisation roadmap exists.

Although the current policy framework leads to a remarkable decarbonisation of H/C in Czech buildings until 2050, more ambitious policies are needed to meet the emission reduction targets as set out in the Paris Agreement. Thus, faster and deeper decarbonisation of H/C in Czech buildings is needed. An important measure to reach this is an intensified RES-H obligation: on the one hand the obligation should not only apply for buildings that are newly constructed, but also for buildings undergoing a major renovation and in case that the heating system is changed. On the other hand, the share of the heat to be supplied by RES should be increased, so that it becomes less interesting to fulfil the obligation with a combination of fossil fuels and solar thermal systems or paying a penalty instead of compliance. At the same time the public budget for subsidising investments in technologies for RES-H should be increased to additionally trigger the technology shift.

As in many EU countries, the potential for reducing the heat demand in buildings is very high. In order to stimulate the realisation of building retrofit the public budget might be increased, but also could be set mandatory after a certain timeframe. Increased retrofit rates would also help to reduce biomass use for heating in buildings. This is important as on the one hand the amount of sustainable biomass resources might not be sufficient to supply large shares of heat demand in buildings in 2050, and on the other hand will biomass be more essential for the decarbonisation of the industry sector than for buildings. For increasing retrofit rates it is also important to drive standardisation of retrofit activities and awareness raising by implementing energy performance certificates (EPC) of buildings, so that retrofit costs decrease compared to current levels. Finally, information campaigns to increase the awareness of the continuous increase of fuel and emission certificate prices are important, so that this is taken into account in the investment decisions related to building retrofit and heating systems. This, however, is linked to a continuous increase of the CO_2 prices, which can be assured by the application of a CO_2 tax or levy for all sectors at national level, if not achieved by the EU ETS.

In a current policy scenario, CO_2 emissions in **industry** are unlikely to decrease until 2050. An ambitious policy mix with a focus on H/C policies can, however, substantially decrease overall emissions until 2050. This ambitious policy scenario shows an increase in the use of biomass driven by financial (OPEX) support for RES as well as CO_2 prices for non-ETS companies. Thus, if sufficient sustainable biomass resources are available, biomass can contribute substantially to industrial sector decarbonisation. Another key strategy is the support of material efficiency and circular economy. Particularly the replacement of oxygen steel production by (scrap based) electric steel production results in lower coal use and thus lower CO_2 emissions.

The ambitious policy scenario describes a substantial step towards a transition of the industrial sector addressing various levers ranging from energy efficiency, via fuel switch to excess heat use, downstream material efficiency and innovation support. Still, it is not achieving reduction targets for industry that are in line with the Paris goal of a nearly carbon neutral economy. To achieve even

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deeper emission cuts in the long term, more policies are needed that might include a prohibition of using coal where not technically needed, carbon capture and storage/use, more ambitious process innovations in cement, lime, chemicals and steel including the extensive use of synthetic fuels like RES-based methane or RES-H_2 and a more important role of power to heat.

Electricity demand in the Czech Republic is substantially higher than the **district heating** demand. Therefore, the RES share in electricity and DH generation follows the RES share in electricity generation. This can be observed from Figure 39.

Due to the assumption that capacity of nuclear power plants will be linearly decommissioned until 2062, the nuclear power plants existing in 2012 represent part of the capacity until 2050. This capacity is not optimized by the TIMES model. However, the investments in new nuclear capacity are results from the TIMES model. It should be noted that no policy constraints are imposed on investments in nuclear power in the TIMES model for the Czech Republic. The high shares of electricity generation from nuclear plants result in low CO_2 emissions, but not in high RES shares.

Wind and solar are filling the majority of the remaining power generation mix in both scenarios. The main driver for that are the declining investment costs. Coal is almost entirely phased out in the ambitious policy scenario, while in the current policy scenario the share of coal in 2050 reaches 8%. Therefore, it can be observed that the implemented polices in the ambitious policy scenario lead to lower CO_2 emissions and higher RES shares. However, high CO_2 prices don't affect the electricity generation from nuclear power plants. To reach higher RES shares in electricity generation, higher subsidies for RES are needed.

The generation of DH in different areas reach high RES shares in both policy scenarios. This is due to high shares of large heat pumps. The RES share is higher in the ambitious policy scenario, which means that the policies implemented in the ambitious policy scenario give expected effects. On the other hand, the differences between scenarios are not major (RES share of 70% and 81% in the current and ambitious policy scenario, respectively). In larger DH areas, the implemented polices towards 2050 lead to a strong decarbonisation, i.e. the generation is based on waste, wood pellets and large heat pumps. Since the high share of DH is generated from large heat pumps, a larger effect would probably be achieved if stronger polices would be implemented in the electricity generation on the expense of the DH generation.

The modelling of the buildings furthermore shows the importance of DH prices as argument for the consumers to switch to DH. On the one hand can favourable financing conditions for DH infrastructure lower DH consumer prices. On the other hand it can be recommended to implement a stronger planning approach regarding H/C including the definition of DH priority areas in order to increase the connection rates and therefore lower the DH prices for all connected consumers.

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2.3 The case of Germany

2.3.1 Buildings

This chapter documents selected indicators for the current and ambitious policy scenario related to buildings in the residential and tertiary sector.

For buildings the **current policy scenario** includes the following policies that are already in place in Germany:

- New buildings are constructed according to the current national building codes and the foreseen changes until 2021. This includes the national definitions of "Nearly Zero Energy Buildings".
- The building regulation includes a renewable heat obligation: after 2021 a share of 20% of the heat demand in newly constructed buildings has to be covered by heating technologies using renewable energy. After 2035 this also applies in case of a heating system replacement.
- A reasonable public budget of 1 000 to 2 000 MEUR is available for subsidising the retrofit of existing buildings and for subsidising the additional costs of constructing new buildings at heat demands lower than stated in the national building codes.
- For investment subsidies of heating technologies using renewable energy a public budget in the range of 500 MEUR is available.

The **ambitious policy scenario** for the building sector includes additional policies in order to reach a remarkable CO_2 reduction of around 80% in the scenario timeframe. The following policies are implemented for the case of Germany:

1. The Building codes and nZEB-plans will be enhanced in the energy need requirement by 20% compared to the current state.
2. The renewable heat obligation in the building regulation will be intensified: starting with around one third of heat demand that has to be covered by renewable energy after 2020, an increasing share has to be covered by renewables after 2030 and more than two thirds have to be renewable after 2035. This renewable heat obligation applies to new buildings only in the period from 2020 to 2030. Afterwards it also applies in case of a major renovation or a heating system replacement and district heating is counted 100% as an option to reach this share, even if district heating is not 100% supplied by renewable energies.
3. The annual public budget for subsidising the retrofit of existing buildings and for subsidising the additional costs of constructing new buildings at heat demands lower than stated in the national building codes will be slightly increased.
4. The annual public budget for subsidising heating technologies using renewable energy will be slightly increased supporting higher shares of the investment costs.
5. Favourable financing conditions for district heating infrastructure will lead to a decrease of district heating costs by 10%.
6. As stated in the general scenario assumptions in Section 1.1 all sectors have to pay a rising CO_2 price according to the PRIMES projection. This causes higher end consumer energy prices for fossil fuels.

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7. Information campaigns will lead to decision-makers being aware of the continuous increase in energy prices and for CO_2 emission certificates. This causes that rising prices will be taken into account in their investment decisions.
8. It is assumed that by standardisation, awareness rising through EPCs etc. a decrease of building renovation costs can be reached until 2050.

In the following figures key indicators for the current and ambitious policy scenario for buildings in Germany are compared: direct CO_2 emissions, final energy demand, share of renewables (excluding electricity), total annual running and investment costs and the direct costs (of subsidies) for the described policy programmes.

Figure 39 shows the development of the direct CO_2 emissions in the building sector in Germany. As emissions from district heating and electricity are not included in this figure the emissions only result from the use of individual natural gas and oil boiler and very few coal boilers used in Germany. A decrease in CO_2 emissions in the building sector from more than 138 Mt in 2012 to 37,3 Mt (-73%) in 2050 can be achieved in the current policy scenario and to 8,7 Mt (-94%) in 2050 in the ambitious policy scenario. The difference between the two policy scenarios originates to one part from a higher level of heat savings reached with the ambitious policies and to another part from the lower amount of natural gas and coal that will remain in the 2050 heat supply in the ambitious policy scenario.

The considerable GHG-emission reductions already in the current policy scenario are mainly due to currently implemented (or expected) building codes and nZEB standards as well as existing renewable heat obligation and subsidy schemes. Also increasing energy prices contribute to the result. Thus, the result should not be understood in a way that this will happen anyway. First, continuous (and maybe even enhanced) efforts will need to be taken to ensure a proper compliance with existing building codes and regulations. Second, other existing instruments will need to be kept in place and the corresponding public budgets for subsidies will need to be provided. Third, in case of lower energy prices than expected, higher efforts will be required to achieve the result presented here as current policy scenario.

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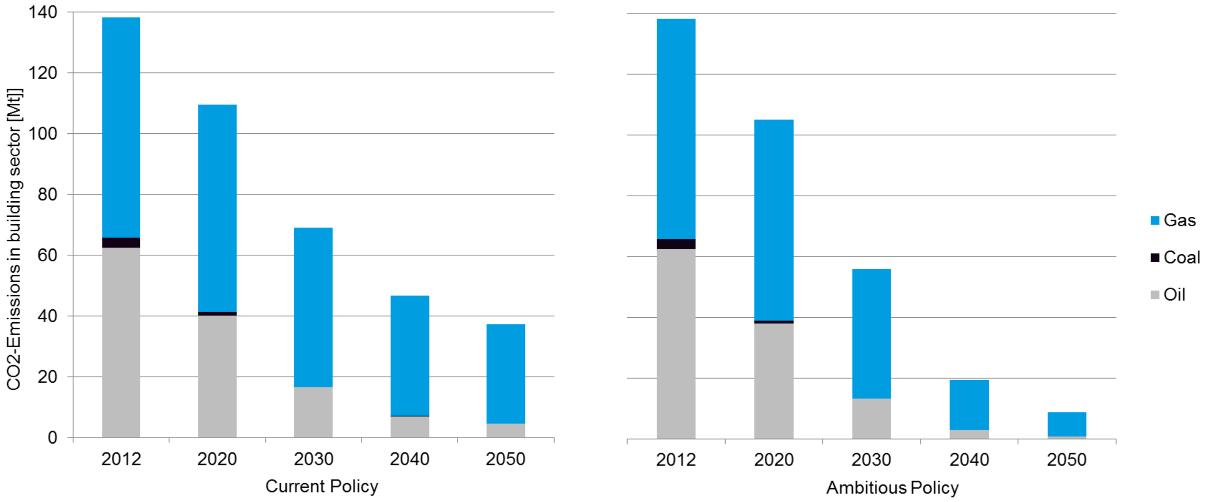

Figure 39: Direct CO_2 emissions for space heating and hot water preparation per energy carrier in the residential and tertiary sector, Germany

Figure 40 shows a decrease in final energy demand for heating and cooling from almost 810 TWh in 2012 to 439 TWh (-46%) until 2050 in the current policy scenario and to 381,5 TWh (-53%) in the ambitious policy scenario. On the secondary axis the figure shows the share of RES in the building sector. For the heat delivered by district heating the respective renewable share of the district heating sector as shown in chapter 2.3.3 is used. Electricity used for H/C is not included in the calculation of this share, but the share of RES in the power sector is also shown in the respective chapter. While with current policies a share of RES of 44% can be achieved in 2050, the share rises even up to 79% with ambitious policies.

At least a part of the remaining gas demand could also be covered by renewable energy sources, which would further reduce CO_2-emissions and increase the share of renewable energy. However, this aspect was not further analysed in this project.

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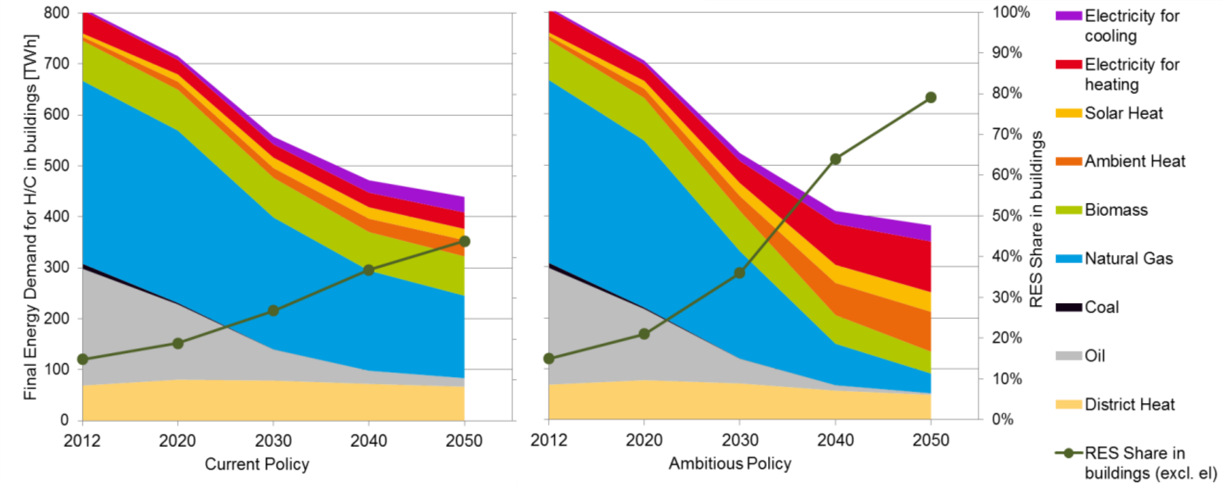

Figure 40: Final energy demand and share of renewables for space heating, hot water preparation and space cooling by energy carrier in the residential and tertiary sector, Germany

Figure 41 shows the development of the annual investment and running costs for all buildings in the residential and tertiary sector for both policy scenarios. The shift from fossil fuelled technologies to technologies using RES results in a shift from running costs to investment costs. The additional subsidies for retrofitting and renewable heating systems generate additional investments leading to the decrease in energy demand and fewer individual natural gas boilers.

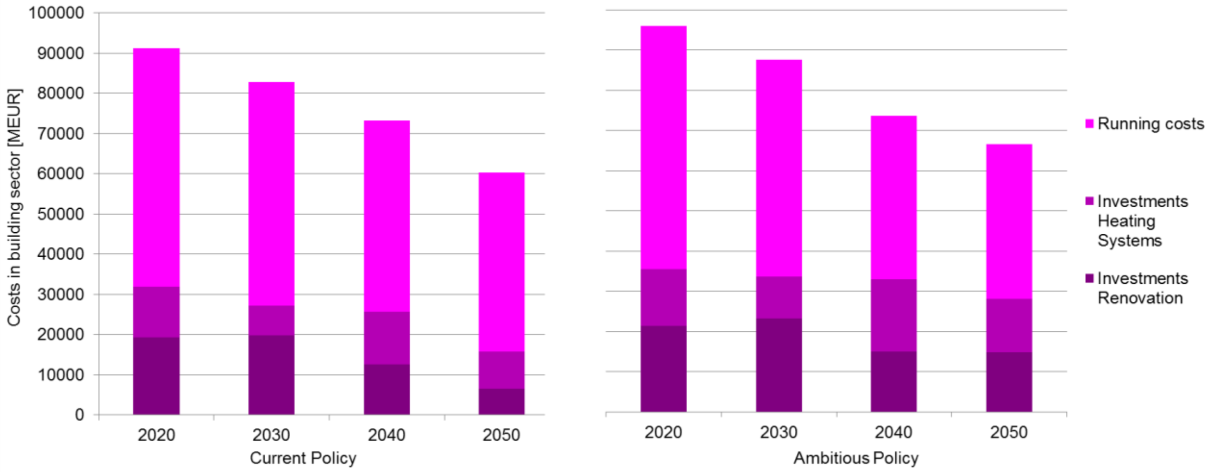

Figure 41: Investments and running costs for building renovation and heating and hot water systems in the residential and tertiary sector, Germany

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Figure 42 shows the policy programme costs for both scenarios. These costs include subsidies for retrofit measures and subsidies for heating technologies using RES, also including solar thermal systems and PV.

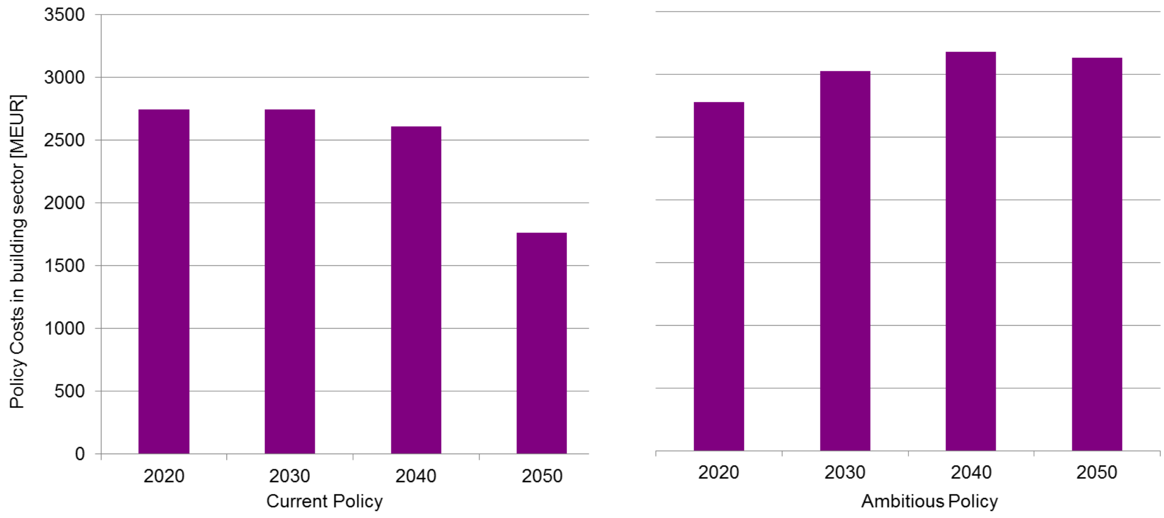

Figure 42: Policy programme costs for the residential and tertiary sector, Germany

2.3.2 Industry

This chapter documents selected indicators for the current and ambitious policy scenario in the German industry sector.

- The **current policy scenario** considers policies implemented by 2015 including among others. This includes among others the CO_2 price, EU Ecodesign Standards for energy using products as well as Energy taxes as reported by Eurostat in 2015.

The **ambitious policy scenario** represents a much more ambitious policy mix towards the transformation of the industrial heating and cooling sector. It comprises of the following main elements:

1. Policy package addressing classical non-financial barriers to energy efficiency including the roll-out of energy management systems, energy audits, soft loans, etc.
2. Extension of Ecodesign Minimum standards to additional equipment including steam boilers and industrial furnaces
3. Increasing investment grants for RES-H technologies including power-to-heat using heat pumps or electric boilers for steam generation
4. RES OPEX support: ~5 Euros/MWh for RES-H including district heating, heat pumps and electric boilers

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5. CO_2 price: extending the CO_2 price beyond the ETS (same level) and changing price expectations: Companies now consider the CO_2 price 10 years ahead for their investment appraisal. This is achieved via a transparent and defined tax increase and/or a floor price for the EU ETS
6. Comprehensive support of material efficiency and circular economy: Reduced production of basic materials products due to efficiency improvements along the value chain and shift towards secondary production (e.g. electric steel replacing oxygen steel, more recycled paper, etc.). See table below and Table 9 and Table 10 in the annex for an overview on recycling and secondary production assumptions.

Table 4: Assumptions on use of recycled materials for steel, cement, aluminium and paper in Germany [%]

Indicator		Current policy scenario		Ambitious policy scenario	
	2012	**2030**	**2050**	**2030**	**2050**
Share of electric steel in total crude steel production	32%	32%	33%	40%	55%
Share of clinker in total cement production	72%	69%	68%	63%	55%
Share of secondary aluminium in total aluminium production	61%	57%	60%	60%	66%
Share of recovered fibres in total pulp production	86%	90%	90%	99%	100%

7. Exploitation of industrial excess heat potentials of heat >100°C for use in district heating or, where district heating networks are not nearby, for electricity generation. This can be implemented via financial support but also via regulation (e.g. related to pollution control)
8. Innovation support to speed-up the market introduction of low-carbon production processes for the basic materials industries. This includes various strategies from niche markets via requirements for public procurement, to R&D&I support as grants and soft loans (see e.g. discussion on EU Innovation Fund) a minimum CO_2 price path and more.

Results of the current policy and the ambitious policy scenarios are presented and compared below, beginning with CO_2 emissions, before discussing final energy demand and excess heat potentials. Results are shown for the entire industrial sector including non-H/C applications like mechanical energy. However, non-H/C applications are nearly exclusively found in electricity use, while fuel consumption can be attributed to H/C in 2012.

As shown in Figure 43, industrial sector GHG emissions are expected to decrease slowly in the current policy scenario until 2050 by about 17% driven by slow fuel switch, energy efficiency and structural changes. The ambitious policy scenario shows a more drastic decrease of about 52% resulting at remaining direct GHG emissions of 84 Mt $CO_{2\text{-equ}}$ in 2050. Dominating emission sources in the ambitious policy scenario are coal, natural gas and process emissions in 2050.

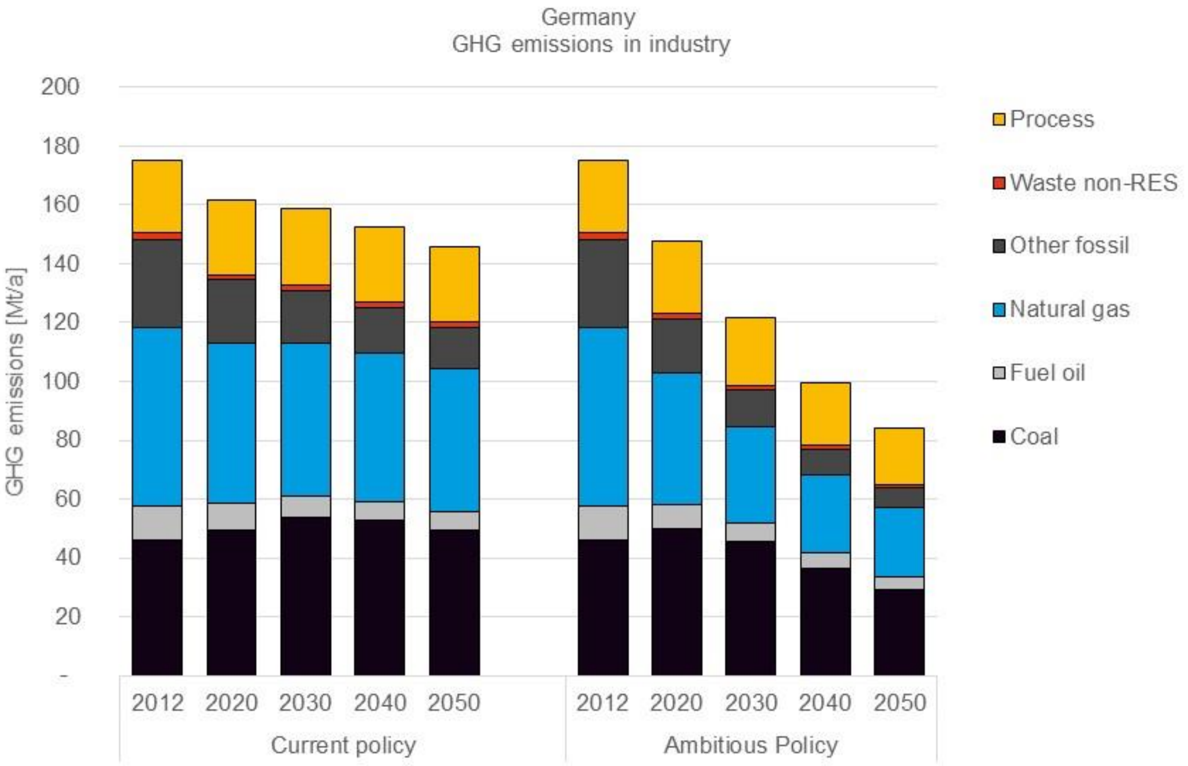

Figure 43: Direct GHG emissions in industry by energy carrier (including process emissions), Germany

In terms of sub-sectors, emissions in 2012 are dominated by the iron and steel industry and the non-metallic minerals (mostly cement) as shown in Figure 44. In 2050 in the ambitious policy scenario remaining emissions are resulting from these two industries and the chemical industry, which gains in share. The change in the steel industry is - among others - driven by a more ambitious shift from oxygen steel to electric steel along the maximum scrap availability potential.

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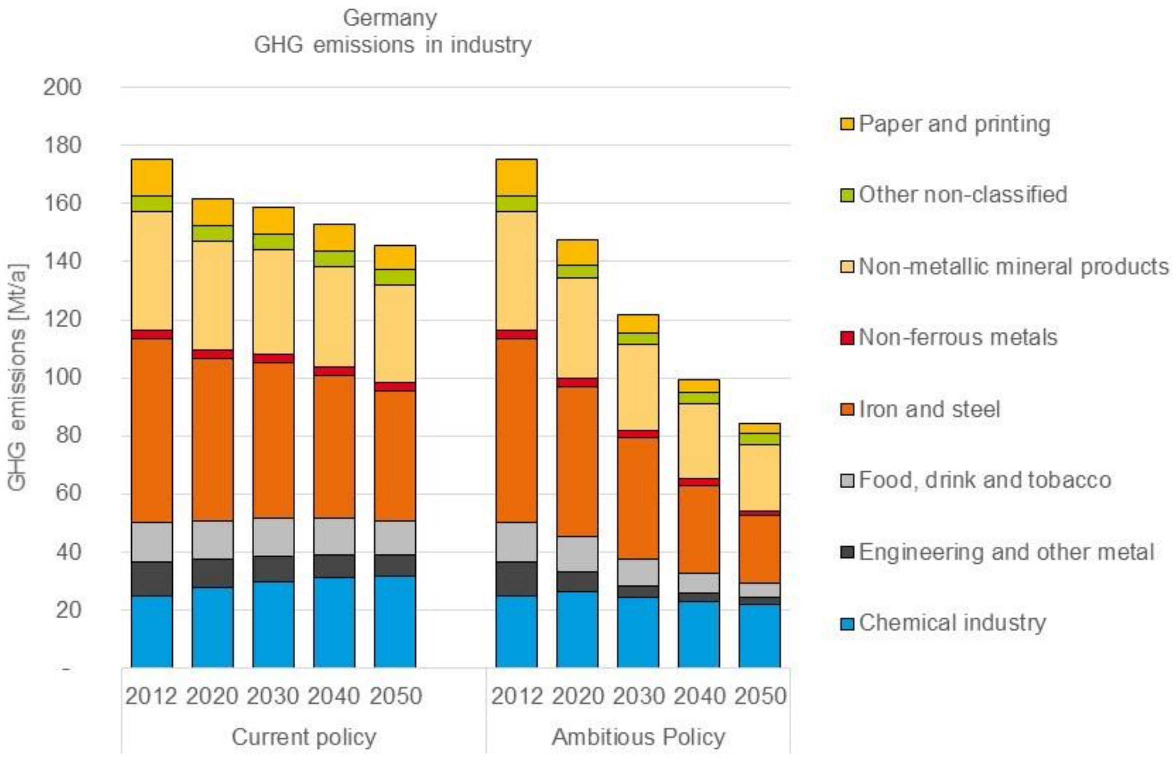

Figure 44: Direct GHG emissions in industry by sub-sector (including process emissions), Germany

The development of final energy demand by energy carrier is shown in Figure 45. The current policy scenario shows only minor changes until 2050, while the ambitious policy scenario describes a first of all a faster reduction of total energy demand reflected by more intensive energy and material efficiency activities. Also an increase in the use of biomass and decreasing coal use are observed. In 2050 relatively high shares of coal and natural gas are remaining in 2050.

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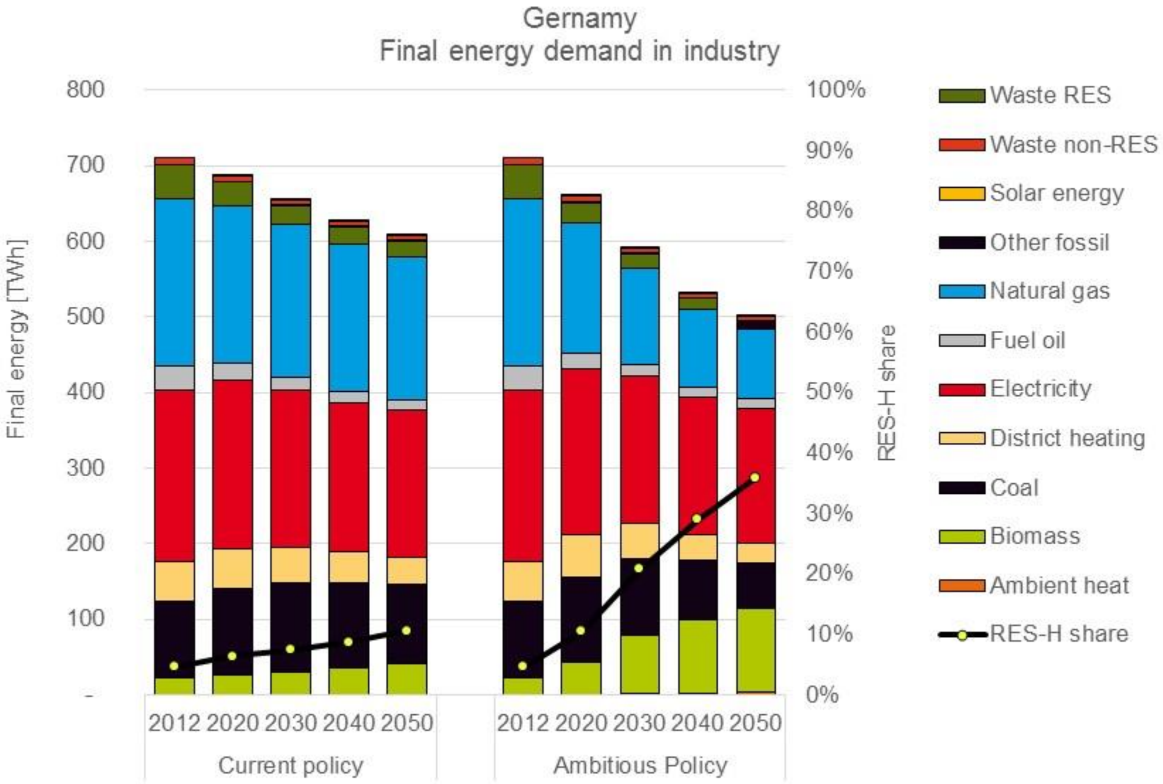

Figure 45: Final energy demand and share of renewables in industry by energy carrier, Germany

Industrial excess heat potentials in Germany available to be used in DH or electricity generation (>100°C and for selected processes) are summarised below for the ambitious policy scenario. Particularly high potentials are available from the chemical industry (steam cracker), but also cement production, pulp and paper and the iron and steel industry. For most processes/products, the available potential decreases towards 2050 as also the final energy demand decreases. In total, a potential of roughly 31 TWh is calculated for 2012 and about 26 TWh for 2050 equivalent to about 7% of the total final energy used for heating and cooling. These figures, however, can be regarded a lower potential as they do only consider heat sources >100°C from selected energy intensive processes. On the other side, possible current use of excess heat is not considered and needs to be subtracted from this potential.

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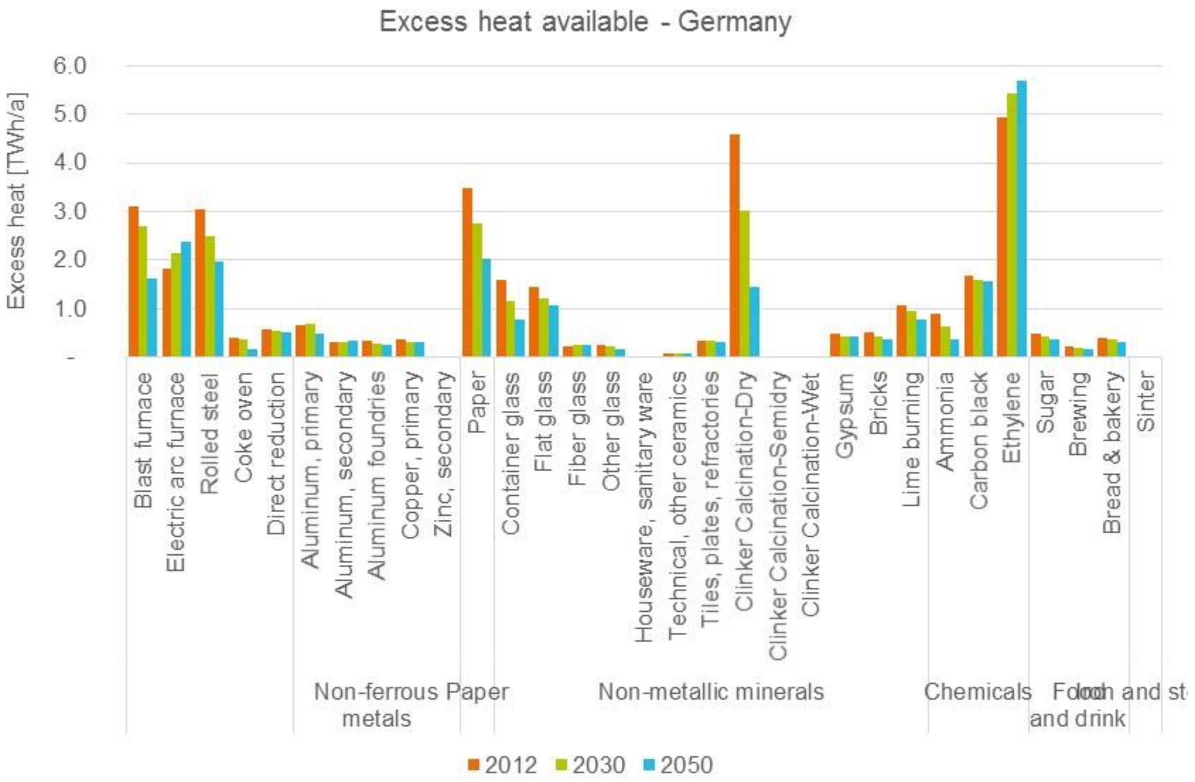

Figure 46: Industrial excess heat potential (>100°C) by process in the ambitious policy scenario, Germany

To better understand the individual impact of the various elements of the policy mix defined for the ambitious policy scenario, Figure 47 shows the impact by type of policy. 6 policy packages are distinguished. From current policy scenario to current policy plus 6 (= ambitious policy scenario), the policy mix is extended stepwise. E.g. current policy plus 3 includes financial OPEX support for RES, but also considers all elements included in the scenarios current policy plus 1 and 2.

The figure shows a particularly strong influence from support of OPEX for RES-based heat supply, a substantial impact of the extension of the CO_2 price to companies outside the EU emissions trading scheme (EU ETS) and improvements in (downstream) material efficiency and circular economy.

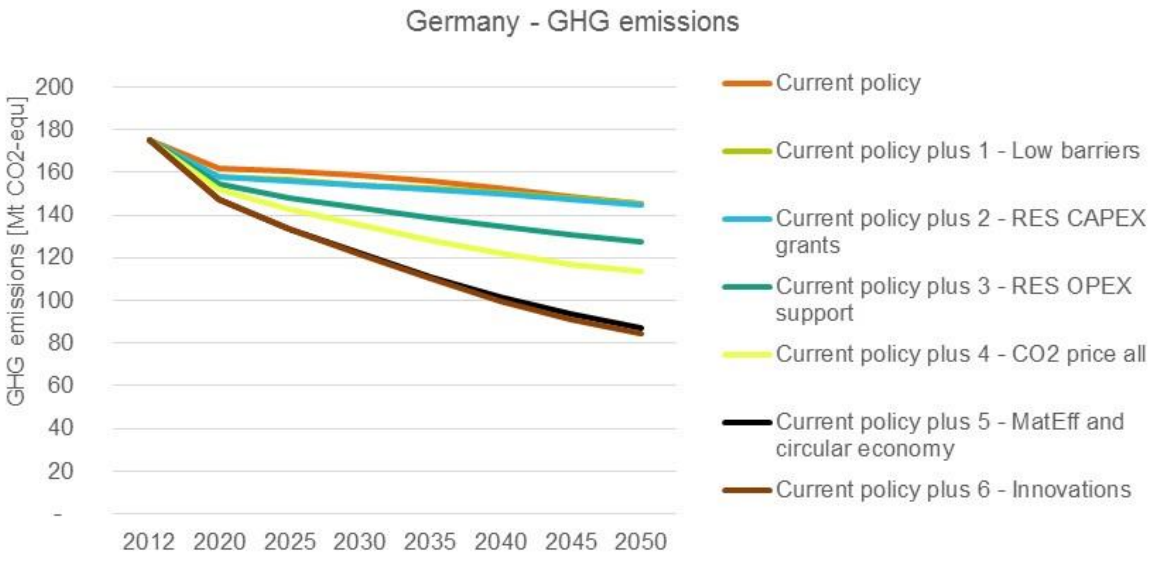

Figure 47: Direct GHG emissions in industry by policy variant, Germany

To summarise, a substantial reduction in final energy demand and a continuous increase in biomass, a shift from oxygen to electric steel, material efficiency in all basic materials industries and innovations in the cement industry result in falling GHG emissions in the ambitious policy scenario compared to the current policy scenario (-52% by 2050 compared to 2012).

2.3.3 District heating and the power sector

This chapter documents selected indicators for the current and ambitious policy scenario in the district heating and power sector. As described in the methodology section, the results are based on an optimisation model (TIMES), which does not necessarily include all relevant and realistic barriers and diffusion constraints. Thus, the results illustrate the cost-optimal investments and operation of the electricity and district heating system, while some non-economic factors (diffusion constraints, social acceptance, political factors, etc.) might not be represented in the results

In addition to the scenario assumptions outlined in the section 1.1, the following assumptions are specific for the case of Germany:

- In both policy scenarios the generation of electricity from nuclear power plants remains at 2012-level until its phase out in 2025 according to the German plans.
- The potential for geothermal heat is limited in both scenarios.
- The capacity of waste incineration plants is kept at the current level.

Due to the developments of demand structures in the buildings and the industry sector in the two policy scenarios, the DH demand in large DH areas is reduced by 15% between 2012 and 2050 in the current policy scenario and by 50% in the ambitious policy scenario. The energy demand of plants in large DH areas is presented for the two policy scenarios in Figure 48. The most considerable

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difference between the two scenarios relates to the decrease of coal and natural gas and the increase of geothermal energy, electricity consumed by heat pumps and the implementation of industrial excess heat in the ambitious policy scenario. Coal demand declines from 48,38 TWh in 2020 to 37,12 TWh in 2050 in the current policy scenario, while in the ambitious policy scenario it decreases to 8,07 TWh in 2050. Natural gas demand also decreases from 56,19 TWh in 2012 to 2,23 TWh in 2050 in the current policy scenario. In the ambitious policy scenario no significant effect on the demand for natural gas can be seen (2,18 TWh in 2050) compared to the current policy scenario. Geothermal energy has a negligible contribution in 2012 in both scenarios, while it increases to 2,31 TWh and 7,87 TWh in 2050 in the current policy and in the ambitious policy scenario, respectively. Heat pumps are not installed in large DH areas in 2012. However, electricity demand for heat pumps in large DH areas increases to 0,33 and 2,97 TWh in 2050 in the calculations of the current policy and ambitious policy scenario, respectively. Excess heat from industrial activity is not available in the current policy scenario, while it reaches a contribution of 1,92 TWh in the ambitious policy scenario in 2050. Diesel and heavy fuel oil demand shows slight fluctuations and phase out in both policy scenarios in 2050. The demand for wood pellets is very small and almost phases out in both policy scenarios. Solar heat does not play a role in large DH areas in 2012 in Germany. However, its contribution increases to 13,79 and 11,3 TWh in 2050 in the current policy and the ambitious policy scenario, respectively. It seems that under the assumptions of the ambitious policy scenario the solar potential will be used for power generation rather than for heat generation. In 2010, 10,82 TWh of waste is used in large DH, however, it decreases to 0,42 TWh in the current policy scenario and disappears in the ambitious policy scenario in 2050. It seems that under the assumptions of the ambitious policy scenario the waste will be used in small DH areas rather than in large DH areas. Moreover, the total energy demand in large DH areas under the assumptions of the current policy scenario is 56,23 TWh, which decreases to 34,34 TWh in the ambitious policy scenario in 2050.

According to the model, results coal would be a cost effective solution in larger district heating areas. However, the strong change in the supply mix from the base year until 2020 of course may not be expected in reality but is due to the cost-optimisation and not included constraints and barriers in the model. Nevertheless, it shows that instruments may be required to make sure that district heating companies do not shift even stronger to coal.

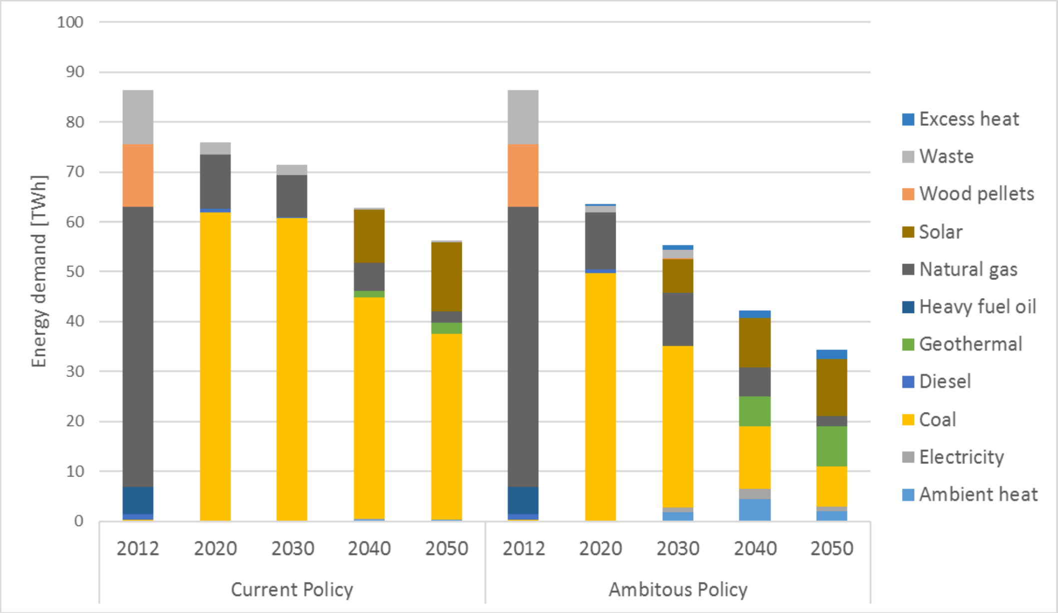

Figure 48: Energy demand in large district heating areas by energy carrier, Germany

The development of the demand for DH in small DH areas is similar in the current policy and ambitious policy scenario. The energy demand of plants in small DH areas is presented for the two policy scenarios in Figure 49. The demand for natural gas and coal for the supply of heat in small DH areas decreases steadily across the time horizon and between the two policy scenarios. In the current policy scenario demand for natural gas is 51,69 TWh in 2012 and decreases to 5,82 TWh in 2050, while in the ambitious policy scenario it decreases to 7,81 TWh in 2050. Coal demand also reduces from 2,79 in 2012 to 1,33 TWh in 2050 in the current policy scenario. Geothermal fluctuates in both scenarios reaching 11,57 TWh in the current policy scenario and has a negligible contribution in the ambitious policy scenario in 2050. There is no contribution of straw and wood chips in the current policy scenario, while in the ambitious policy scenario straw reaches 11,52 TWh in 2050 and wood chips reaches the maximum level of 7,53 TWh in 2030 and finally phases out in 2050. Wood pellet demand is decreasing in both policy scenarios and almost phases out in 2050, while waste demand increases steadily in both policy scenarios from 6,51 TWh in 2012 to 24,2 TWh and 20,31 TWh in 2050 in the current policy and the ambitious policy scenario, respectively. Energy demand for heat pumps (electricity and ambient heat) under the current policy scenario reaches 1,51 TWh in 2050, while in the ambitious policy scenario it reaches 16,39 TWh in 2050. Excess heat from industrial activity is not available in the current policy scenario, while it reaches 1,78 TWh in the ambitious policy scenario in 2050. Diesel and heavy fuel oil fluctuate during the time span and both phase out in the two policy scenarios until 2050. Moreover, the total energy demand in small DH areas under the current policy scenario is 44,44 TWh, which increases to 58,66 TWh in the ambitious policy scenario in 2050.

According to the model results coal would be also a cost effective solution in smaller district heating areas especially in the short term. However, of course the strong change in the supply mix from the

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base year until 2020 may not be expected in reality but is due to the cost-optimisation and not included constraints and barriers in the model. Nevertheless, it shows that instruments may be required to make sure that district heating companies do not shift even stronger to coal.

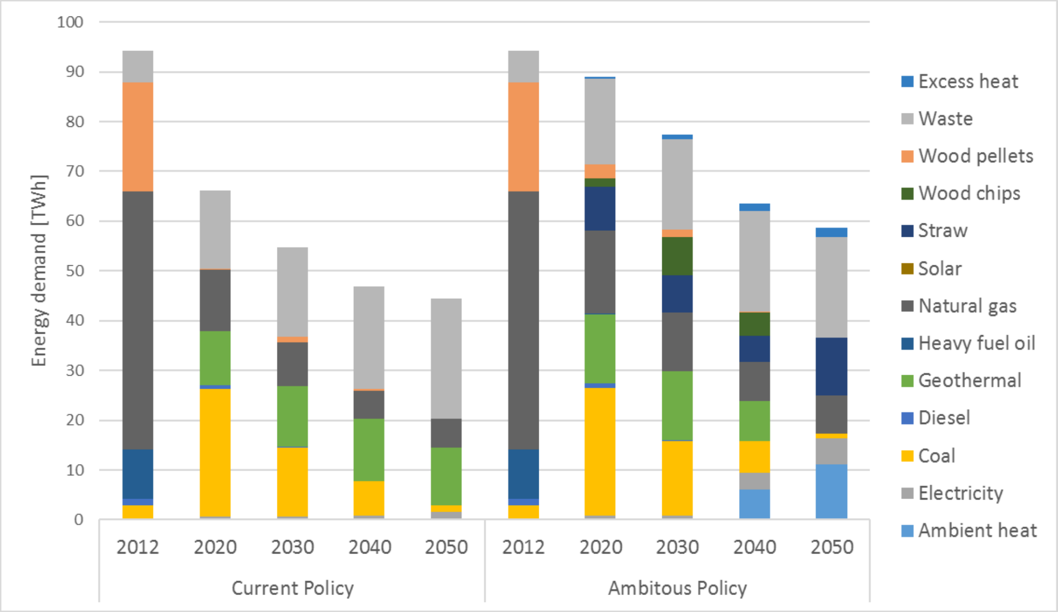

Figure 49: Energy demand in small district heating areas by energy carrier, Germany

The energy demand for electricity generation in the two policy scenarios is depicted in Figure 50. The most significant changes in the electricity generation mix is a decrease of coal, natural gas, heavy fuel oil and an increase of wind and solar. The demand for coal in 2012 is 745 TWh, which decreases to 283 TWh in 2050 in the current policy scenario and experiences a huge decrease in the ambitious policy scenario to the level of 107 TWh in the same year. The demand for natural gas in 2012 is 316 TWh, which decreases to 12 TWh in 2050 in the current policy scenario. In the ambitious policy scenario it decreases to 16 TWh in 2050. Excess heat from industrial activity is available only in the ambitious policy scenario and in this scenario it is used to its full potential of 0,93 TWh. Demand for wood chips is 16 TWh in 2012, which phases out in both policy scenarios. The contribution of wood pellets (16 TWh in 2012) decreases to 0,06 TWh and 0,18 TWh in the current and the ambitious policy scenario in 2050, respectively. The wave technology will be responsible for 3% (17,79 TWh) of total electricity generation in 2050 in the ambitious policy scenario, while it does not play a role in the current policy scenario. Wind and solar power show a steady increase in both policy scenarios. In 2012 solar power accounts for 27 TWh and increases to 41 TWh in 2050 in the current policy scenario and to 180 TWh in the ambitious policy scenario. This is a share of 29% of overall electricity generation. In 2012, wind power contributes with around 52 TWh and increases to 318 TWh in 2050 in the current policy scenario and 260 TWh in the ambitious policy scenario (reaching a share of 42% in the electricity generation mix).

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According to the model results coal will stay cost effective to certain extent in the power sector also in the ambitious policy scenario. As Figure 52 shows the resulting RES shares are not enough to reach the required decarbonisation to comply with the climate targets and stronger measures like a forced phase out of coal may be needed.

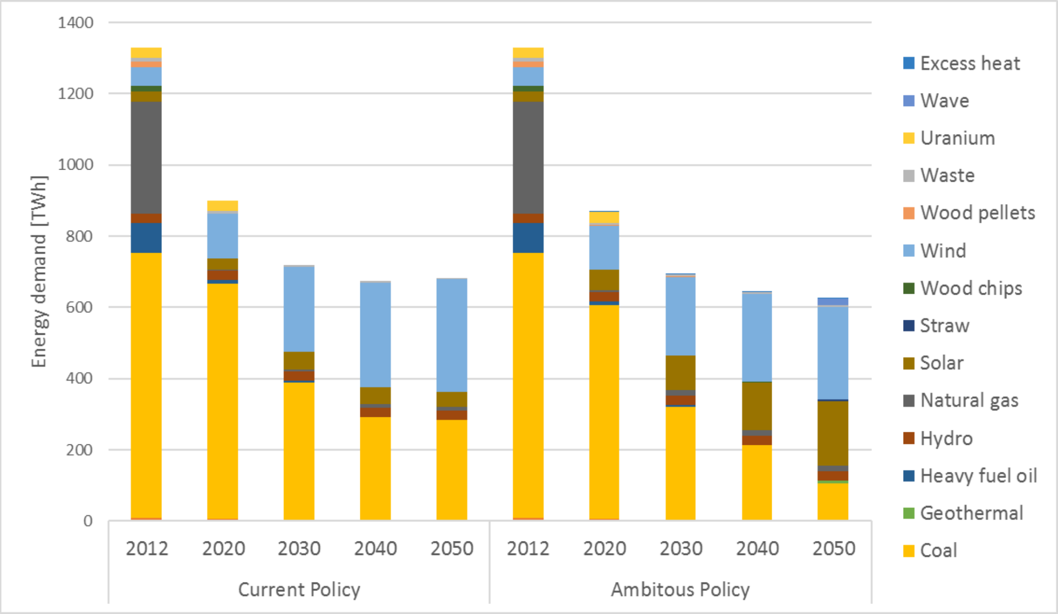

Figure 50: Energy demand for electricity generation by energy carrier, Germany

The annual CO_2 emissions from electricity and DH generation are shown in Figure 51 for the analysed scenarios. In both scenarios, the DH and power systems undergo a strong transition towards decarbonisation decreasing from 372,4 Mt in 2012 to 116,3 Mt and to 47,5 Mt in 2050 for the current and ambitious policy scenario, respectively. This corresponds to a reduction of 85% and 96% from 2012 levels for the two policy scenarios. The cut in emissions is the consequence of the progressive phase-out of fossil fuels, especially in the plants generating electricity only. Plants generating electricity only by burning fossil fuels are replaced by wind and solar power plants.

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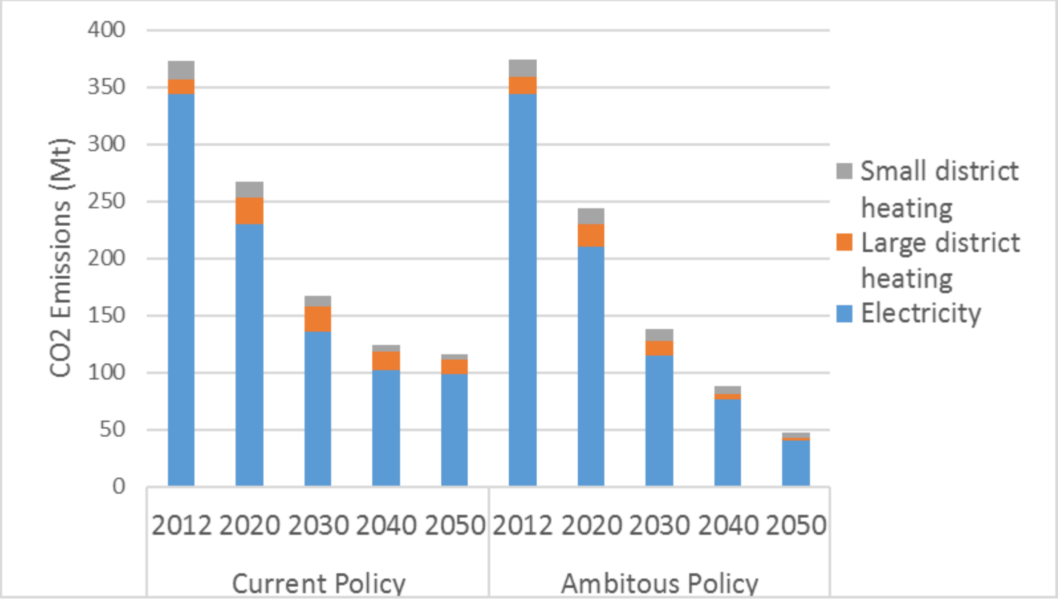

Figure 51: CO_2 emissions from generation of district heat and electricity, Germany

The share of RES on the total energy demand for the generation of electricity and DH is shown in Figure 52. Starting from a RES share of 14% in 2012, a share of 56% and 80% are achieved in 2050 in the current and ambitious policy scenario, respectively. This result is driven mainly by the use of wind and solar power, and marginally wave and geothermal power. As the RES share is calculated as a weighted average of the RES penetration in small and large DH areas as well as electricity generation, it follows the trend of the most relevant element, i.e. electricity, in both scenarios.

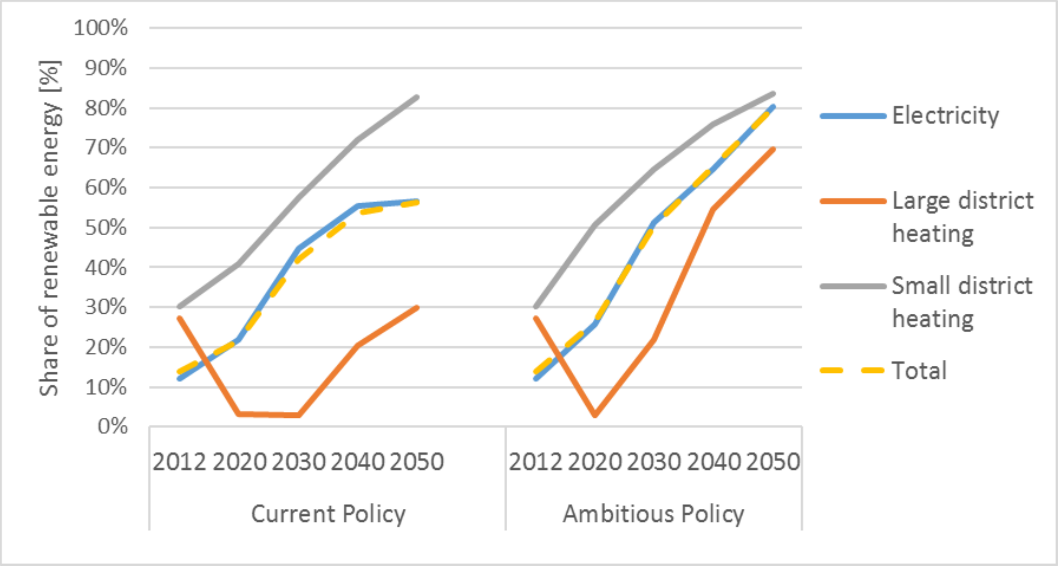

Figure 52: Share of renewable energy in district heat and electricity, Germany

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The electricity demand in Germany is much higher than the demand for DH. Therefore, the main part of the system costs is actually the costs of the electricity system, i.e. the trends of total system costs are determined by the electricity system costs. Figure 53 shows the development of the total system costs for electricity and DH generation for both policy scenarios.

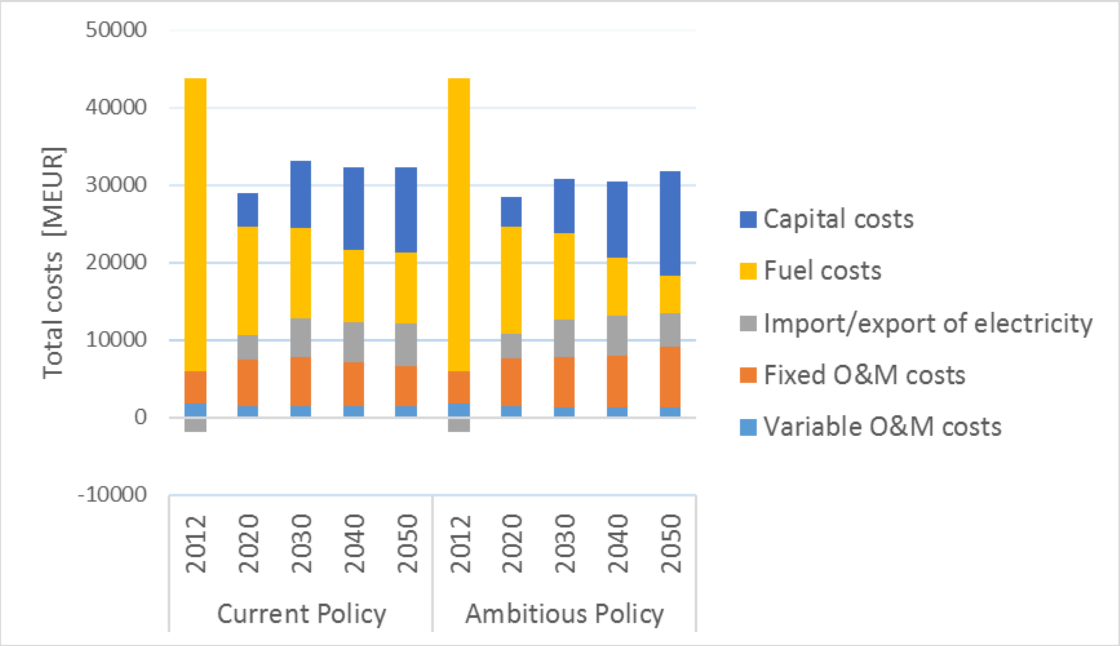

Figure 53: Total costs of district heat and electricity generation, Germany

The main difference between the ambitious and the current policy scenario is the stronger penetration of PV at the expense of coal based power generation in the ambitious policy scenario. As a result of this shift, the investment costs slightly increase in the ambitious policy scenario, while the fuel costs largely decrease in this scenario. The reasons for the slight increase (and not more drastic increase) of investment costs in the ambitious policy scenario are the falling investment costs of PV, as well as the assumption of zero percent interest rate for the investment in technologies using renewable energy sources.

2.3.4 Overall heating and cooling (H/C) indicators

In this chapter the indicators for countrywide heating and cooling are documented. This comprises the results of the modelling of the buildings, industry, district heating and power sector as documented in the previous chapters, but only taking into account the amounts of emissions, energy and the share of renewable energy related to heating and cooling.

Figure 54 shows the CO_2 emissions for H/C purposes from the different sectors. The overall CO_2 emissions comprise the direct emissions from the buildings and the industry sector, the emissions from the DH sector and the emissions of the power sector originating from electricity used for H/C.

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High reductions can be achieved in all sectors in the ambitious policy scenario. The share of the industry sector on the overall emissions increases in both policy scenarios. Furthermore, in the current policy scenario nearly no reduction of industrial CO_2 emissions is achieved. In the current policy scenario a reduction of CO_2 emissions of 47% is achieved, with the assumptions underlying the ambitious policy scenario a reduction of even up to 74% is achieved.

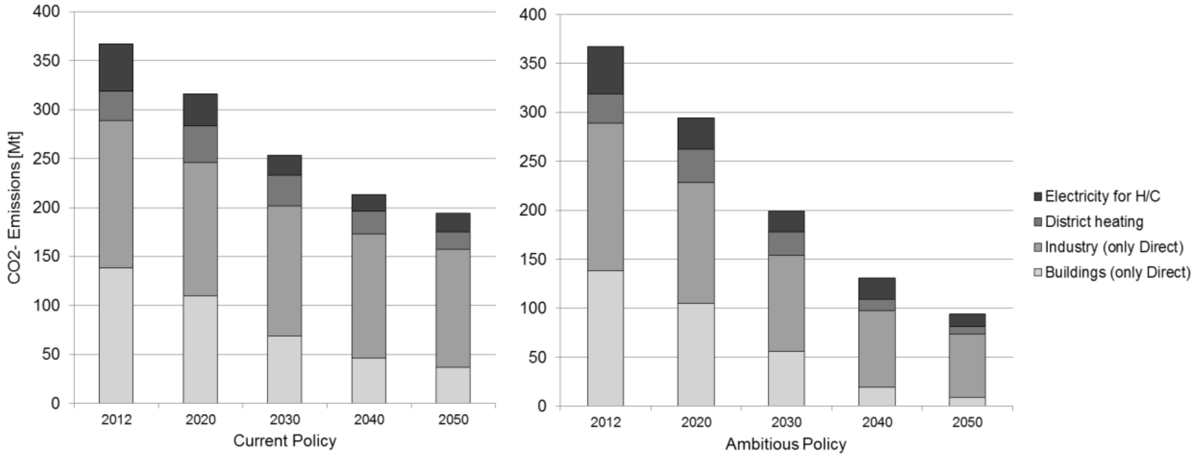

Figure 54: CO_2 emissions from heating and cooling by sector, Germany

Figure 55 shows the primary energy demand for space heating, hot water, cooling and process heat by energy carrier of all sectors. The reflected energy demand in this indicator comprises the fuel demand for H/C from the buildings and industry sector (excluding electricity and district heating) plus the primary energy input into the district heating sector plus the primary energy input into the power sector for electricity used for H/C purposes. In the industry sector in Germany around 73% of the final energy demand is used for H/C purposes. Ambient heat is the ambient part of the heat from heat pumps. Biomass includes wood chips, wood pellets and straw. Other fossils include diesel. Other renewables include biogas, biodiesel, geothermal and wave energy. Solar include solar thermal and solar PV. Waste includes renewable and non-renewable waste.

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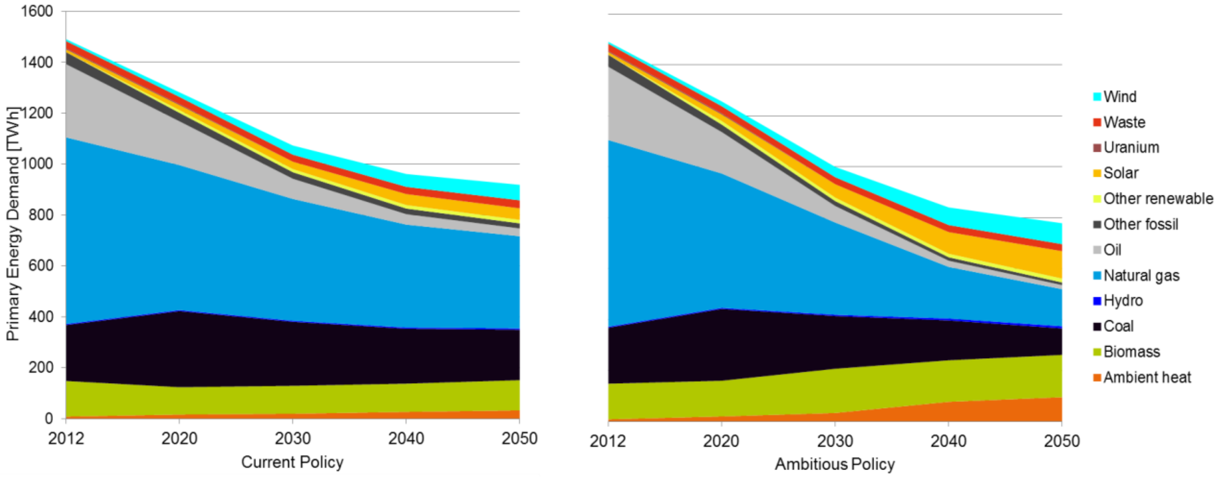

Figure 55: Primary energy demand for heating and cooling by energy carrier, including space heating, hot water, cooling and process heat, Germany

Figure 56 shows the share of energy used for H/C in the different sectors. For the buildings and industry sector this share is calculated excluding electricity both in the overall demand for heating and cooling and in the amount of renewable energy used to generate electricity. The share of renewable energy in district heating, however, is taken into account in this calculation. In the ambitious scenario all sectors but industry can reach around 80% of RES in 2050. The industry sector reaches around 40% of RES only in the ambitious policy scenario.

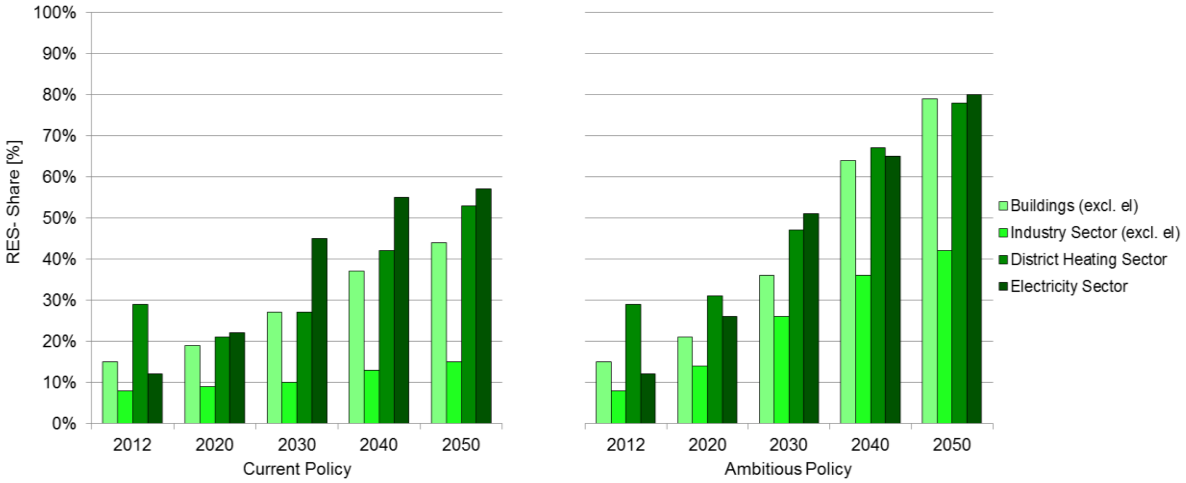

Figure 56: Share of renewables in heating and cooling by sector, Germany

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2.3.5 Conclusions and policy recommendations for Germany

In the previous chapters the results of the quantitative assessment of the influence of two policy scenarios on demand and supply of H/C and related sectors in Germany are documented. As shown in Figure 54 the CO_2 emissions for H/C are likely to be reduced with currently implemented policies at a low CO_2 price of 7,5 EUR/tCO_2 by 47% until 2050. More ambitious policies in the different sectors together with assuring a continuous increase of the CO_2 price to nearly 90 EUR/tCO_2 in 2050 might lead to a reduction of 74% until 2050. In the following key recommendations for policy making are described that result from the modelling of the national H/C systems within progRESsHEAT. A distinction is made between recommendations for policies targeting buildings, industry and DH and power generation.

The currently implemented and foreseen policies in Germany targeting **buildings** are likely to reduce direct emissions from H/C in this sector to a large extent (-73%) until 2050, and at the same time increase the share of RES in this sector from 15% to 43%. Thus, the current shape of the national building codes and renovation standards, the foreseen RES-H obligation and the available public budgets for subsidising renovation and investments in technologies for RES-H are likely to show remarkable effects until 2050, even with a low price of CO_2. However, these emission reductions will only be achieved with the current policy framework, if a continuous monitoring of the compliance with national building codes and renovation standards is installed and non-compliance is penalised. Also, as the connection to DH is counted as an option to fulfil the RES-H obligation, it is important that DH generation is decarbonised in the mid to long term in order not to shift the source of emissions from buildings to DH. In this context it might be interesting to only allow accounting of DH for the compliance with the RES-H obligation, if for the DH system a commissioned decarbonisation roadmap exists.

Although the current policy framework leads to a remarkable decarbonisation of H/C in German buildings until 2050, more ambitious policies are needed to meet the emission reduction targets as set out in the Paris Agreement, especially if the price for CO_2 emission stays at low levels. Thus, a deeper decarbonisation of H/C in German buildings is needed. An important measure to reach this is an intensified RES-H obligation: on the one hand the obligation should not only apply for buildings that are newly constructed or in case of heating system replacement, but also for buildings undergoing a major renovation. On the other hand, the share of the heat to be supplied by RES should be increased, so that it becomes less interesting to fulfil the obligation with a combination of fossil fuels and solar thermal systems or paying a penalty instead of compliance. At the same time the public budget for subsidising investments in technologies for RES-H should be increased to additionally trigger the technology shift. This especially counts for public funding of technologies using RES. In the current policy scenario only a RES share of 43% is reached in 2050. Natural gas keeps playing a major role in the heating of buildings in the current policy scenario, which might be a reasonable tendency, if the price for CO_2 emissions stays at a low level. Therefore, the shift from gas to technologies using RES like heat pumps or solar thermal is a major additional policy target.

As in many EU countries, the potential for reducing the heat demand in buildings is very high. In order to stimulate the realisation of building retrofit the public budget might be increased, but also could be set mandatory after a certain timeframe. Increased retrofit rates would also help to reduce

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biomass use for heating in buildings. This is important as on the one hand the amount of sustainable biomass resources might not be sufficient to supply large shares of heat demand in buildings in 2050, and on the other hand will biomass be more essential for the decarbonisation of the industry sector than for buildings. However, compared to other countries in the EU, in Germany also in the future a lower importance of biomass for heating in buildings might be expected. For increasing retrofit rates it is also important to drive standardisation of retrofit activities and awareness raising by implementing energy performance certificates (EPC) of buildings, so that retrofit costs decrease compared to current levels. Finally, information campaigns to increase the awareness of the continuous increase of fuel and emission certificate prices are important, so that this is taken into account in the investment decisions related to building retrofit and heating systems. This, however, is linked to a continuous increase of the CO_2 prices, which can be assured by the application of a CO_2 tax or levy for all sectors at national level, if not achieved by the EU ETS.

The following conclusions and policy recommendations can be drawn for the **industry** sector in Germany:

- Current policy is not on track towards decarbonisation, though, a slow decrease of industrial CO_2 emissions is expected.
- A decarbonisation strategy for industry needs to focus on the iron and steel, non-metallic minerals and chemicals industries. Even with the policies considered still substantial emissions remain in 2050 in these industries and more radical changes are required.
- Excess heat potentials should be exploited in iron and steel, pulp and paper, cement and chemical industries.
- Biomass is an important RES in industry - if available according to sustainability criteria.
- OPEX support of RES seems more effective than CAPEX support.
- Improved material efficiency and circular economy is a huge mitigation potential - though an effective policy mix is still to be proven and probably contains a bunch of individual measures.
- The current policy mix already includes many policies directed towards overcoming barriers to energy efficiency (e.g. support for energy audits, energy efficiency networks and incentives for energy management schemes). While this is an important pillar of the policy mix, there are probably no more policies needed, rather the enforcement of the existing policies should be ensured.

The ambitious policy scenario describes a substantial step towards a transition of the industrial sector addressing various levers ranging from energy efficiency, via fuel switch to excess heat use, downstream material efficiency and innovation support. Still, it is not achieving reduction targets for industry that are in line with the goal set out in the Paris Agreement at COP 21 of a nearly carbon neutral economy. To achieve even deeper emission cuts in the long term, more policies are needed that might include a prohibition of using coal where not technically needed, carbon capture and storage/use, more ambitious process innovations in cement, lime, chemicals and steel including the extensive use of synthetic fuels like RES-based methane or RES-H_2 and a more important role of power to heat.

Electricity demand in Germany is substantially higher than the **district heating** demand. Therefore, the share of RES in electricity and DH generation follows the share of RES in electricity generation. This can be observed from Figure 52.

The share of RES in electricity generation grows in both policy scenarios and reaches over 50% and over 80% in 2050 in the current and ambitious policy scenario, respectively. This growth is mainly based on electricity generation by wind power plants. However, the growing CO_2 prices are the main driver for a strong growth of solar PV capacity from 2030 onwards in the ambitious policy scenario. The growth of electricity generation by PV is followed by the decrease in generation from coal. Therefore, the assumed policies implemented in the ambitious policy scenario seem to be effective. However they are not strong enough to reach the required decarbonisation to comply with the climate targets and stronger measures like a forced phase out of coal may be needed.

The generation of DH in different DH areas reaches high shares of RES in both policy scenarios. Waste is used in both scenarios. Geothermal plants used for DH generation in the current policy scenario are replaced by a mix of biomass plants and large scale heat pumps in the ambitious policy scenario. Small shares of natural gas are left in the fuel mix in 2050 in both scenarios. Therefore, higher CO_2 prices are probably needed to shift to 100% renewable energy in smaller DH areas.

The policies implemented in the ambitious policy scenario proved to be very efficient in larger DH areas, in which a strong decrease in coal use is followed by the implementation of geothermal and solar heating. Since the policies implemented in the ambitious policy scenario have much higher effect in the smaller DH areas, it could be considered to increase the subsidies for technologies using RES in larger DH areas, while reducing the subsidies in the smaller DH areas.

2.4 The case of Denmark

2.4.1 Buildings

This chapter documents selected indicators for the current and ambitious policy scenario related to buildings in the residential and tertiary sector.

For buildings the **current policy scenario** includes the following policies that are already in place in Denmark:

- New buildings are constructed according to the current national building codes and the foreseen changes until 2021. This includes the national definitions of “Nearly Zero Energy Buildings”.
- No public budget is available for subsidising the retrofit of existing buildings or for subsidising the additional costs of constructing new buildings at heat demands lower than stated in the national building codes.
- For investment subsidies of heating technologies using renewable energy a small public budget of 20 to 30 MEUR is available covering 10-30% of the investment costs of the different technologies using RES.

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The **ambitious policy scenario** for the building sector includes additional policies in order to reach a remarkable CO_2 reduction of around 80% in the scenario timeframe. The following policies are implemented for the case of Denmark:

1. Building codes and nZEB-plans will be kept at current state
2. The renewable heat obligation in the building regulation will be intensified: starting with around one third of heat demand that has to be covered by renewable energy after 2020, an increasing share has to be covered by renewables after 2030 and more than two thirds have to be renewable after 2035. This renewable heat obligation applies to new buildings only in the period from 2020 to 2030. Afterwards it also applies in case of a major renovation or a heating system replacement and district heating is counted 100% as an option to reach this share, even if district heating is not 100% supplied by renewable energies.
3. A public budged of around 70 MEUR for subsidising the retrofit of existing buildings and for subsidising the additional costs of constructing new buildings at heat demands lower than stated in the national building codes will be established
4. The public budget for subsidising investments in heating technologies using renewable energy will be increased by 50% maintaining a share of 10-30% of the investment costs to be covered.
5. Favourable financing conditions for district heating infrastructure will lead to a decrease of district heating costs by 10%
6. As stated in the general scenario assumptions in chapter 1.1 all sectors have to pay a rising CO_2 price according to the PRIMES projection. This causes higher end consumer energy prices for fossil fuels.
7. Information campaigns will lead to decision-makers being aware of the continuous increase in prices for fuels and CO_2 emission certificates. This causes that rising prices will be taken into account in their investment decisions.
8. It is assumed that by standardisation, awareness rising through EPCs etc. a decrease of building renovation costs by almost 15% can be reached until 2050

In the following figures key indicators for the current and ambitious policy scenario for buildings in Denmark are compared: direct CO_2 emissions, final energy demand, share of renewables (excluding electricity), total annual running and investment costs and the direct costs (of subsidies) for the described policy programmes.

Figure 57 shows the development of the direct CO_2 emissions from the building sector in Denmark. As emissions from district heating and electricity are not included in this figure the emissions only result from the use of individual natural gas and oil boilers used in Denmark. A decrease in CO_2 emissions in the building sector from 3,2 Mt in 2012 to 0,71 Mt (-78%) in 2050 can be achieved in the current policy scenario and to 0,57 Mt (-82%) in 2050 in the ambitious policy scenario. This difference between the two policy scenarios originates to one part from a higher level of heat savings and to another part from the lower amount of natural gas that will remain in the 2050 heat supply in the ambitious policy scenario.

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At least a part of the remaining gas demand could also be covered by renewable energy sources, which would further reduce CO_2-emissions and increase the share of renewable energy. However, this aspect was not further analysed in this project.

The considerable GHG-emission reductions already in the current policy scenario are mainly due to currently implemented (or expected) building codes and nZEB standards as well as existing renewable heat obligation and subsidy schemes. Also increasing energy prices contribute to the result. Thus, the result should not be understood in a way that this will happen anyway. First, continuous (and maybe even enhanced) efforts will need to be taken to ensure a proper compliance with existing building codes and regulations. Second, other existing instruments will need to be kept in place and the corresponding public budgets for subsidies will need to be provided. Third, in case of lower energy prices than expected, higher efforts will be required to achieve the result presented here as current policy scenario.

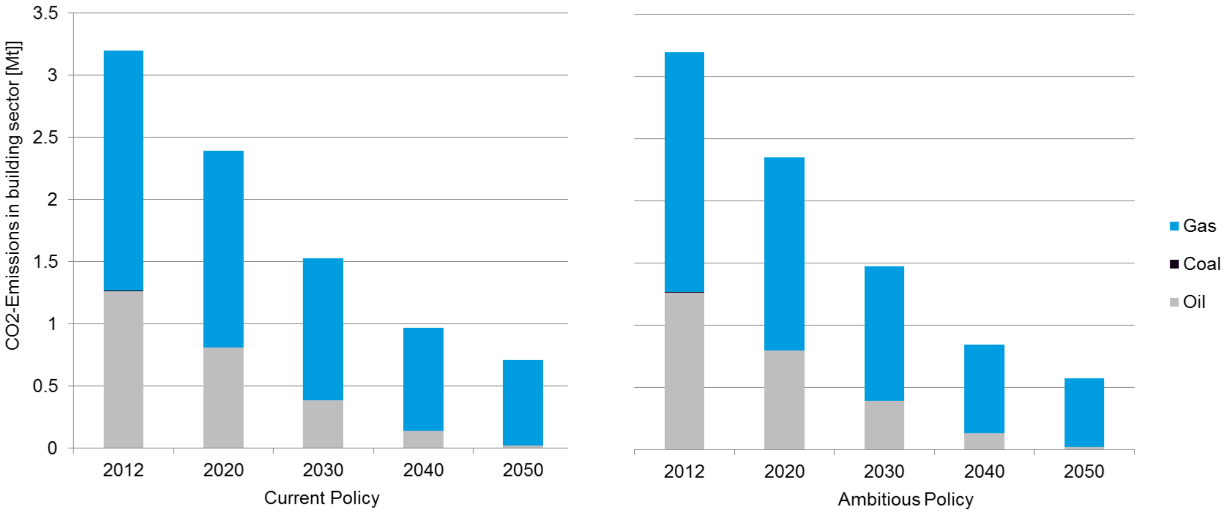

Figure 57: Direct CO_2 emissions for space heating and hot water preparation per energy carrier in the residential and tertiary sector, Denmark

Figure 58 shows a decrease in final energy demand for heating and cooling from 58,4 TWh in 2012 to 42,3 TWh (-28%) until 2050 in the current policy scenario and to 41,2 TWh (-29%) in the ambitious policy scenario. On the secondary axis the figure shows the share of RES in the building sector. For the heat delivered by district heating the respective renewable share of the district heating sector as shown in chapter 2.4.3 is used. Electricity used for heating and cooling is not included in the calculation of this share. The share of renewable energy in the power sector, however, is also shown in chapter 2.4.3. The resulting share of RES accounts for more than 90% in 2050 in both scenarios and the demand for natural gas can be reduced by additionally 20% in the ambitious policy scenario compared to the current policy scenario. Due to the high share of district heating in Denmark the decarbonisation of district heating is even more important than policies for individual heating systems.

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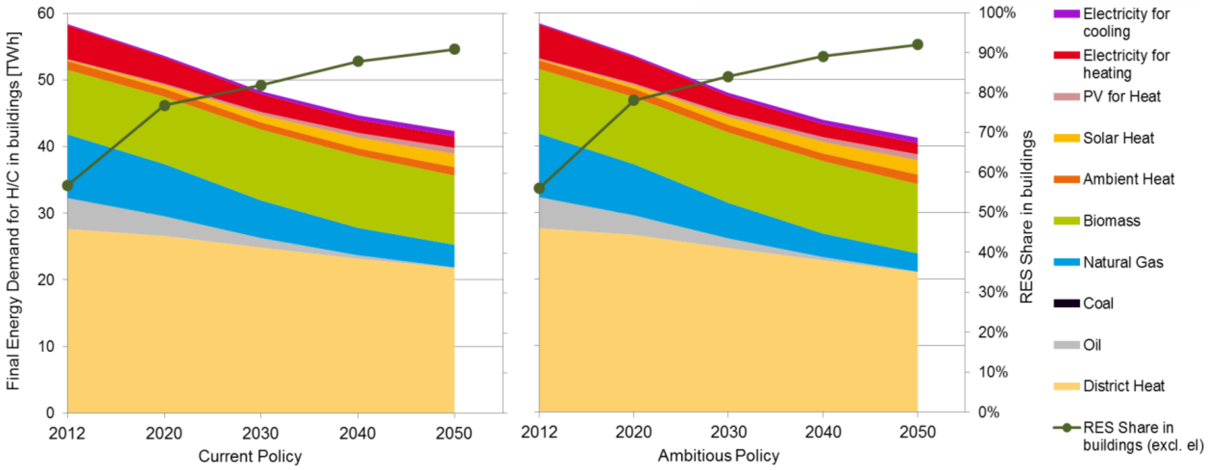

Figure 58: Final energy demand and share of renewables for space heating, hot water preparation and space cooling by energy carrier in the residential and tertiary sector, Denmark

Figure 59 shows the development of the annual total investment and running costs for both scenarios in Denmark. Running costs of heating and cooling systems in buildings can be reduced in the current and ambitious policy scenario by only 15 and 19%, respectively. This reduction is lower than in many other countries, which is mainly due to the high share of district heating in the Denmark. While running costs caused by fossil fuels reduce by more than 80% in the ambitious policy scenario, the running costs from district heating increase by 15% in this scenario. This is as well due to a higher share of district heating in the country.

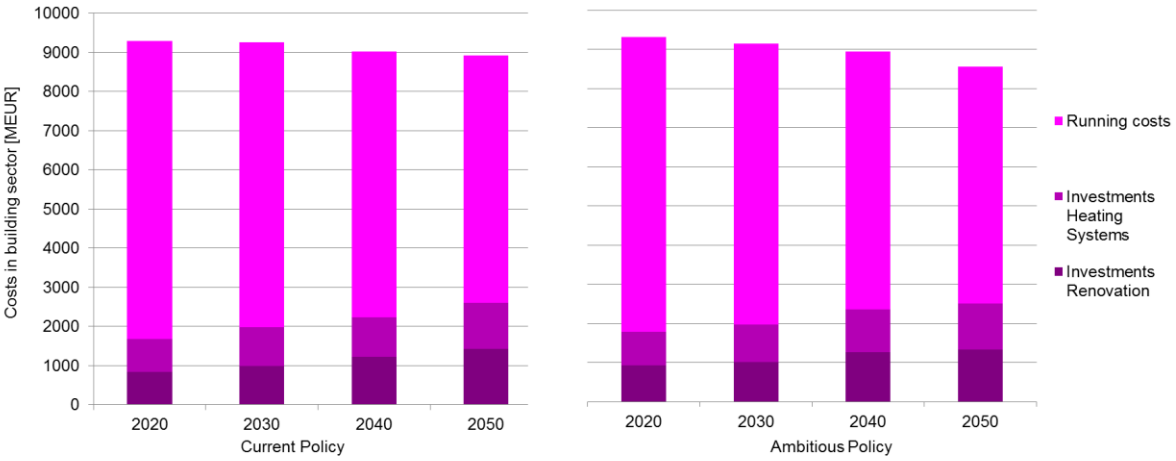

Figure 59: Investments and running costs for building renovation and heating and hot water systems in the residential and tertiary sector, Denmark

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Figure 60 shows the increasing policy programme costs for the ambitious policy scenario compared to the current policy scenario. These costs include subsidies for renovation measures and subsidies for heating technologies using renewable energies, also including solar thermal systems.

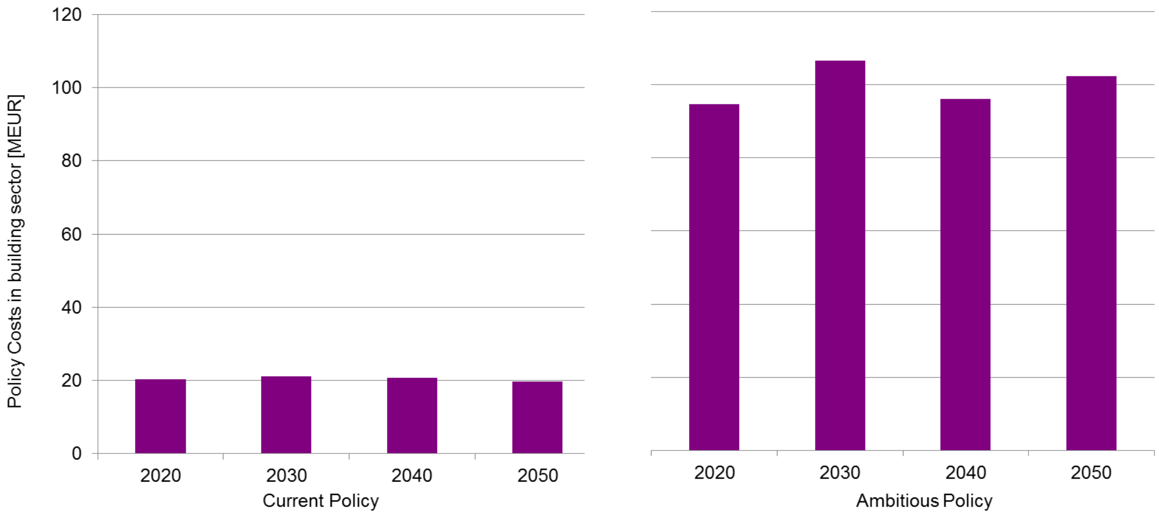

Figure 60: Policy programme costs for the residential and tertiary sector, Denmark

2.4.2 Industry

This chapter documents selected indicators for the current and ambitious policy scenario in the Danish industry sector.

- The **current policy scenario** considers policies implemented by 2015 including among others. This includes among others the CO_2 price, EU Ecodesign Standards for energy using products as well as Energy taxes as reported by Eurostat in 2015.

The **ambitious policy scenario** represents a much more ambitious policy mix towards the transformation of the industrial heating and cooling sector. It comprises of the following main elements:

1. Policy package addressing classical non-financial barriers to energy efficiency including the roll-out of energy management systems, energy audits, soft loans, etc.
2. Extension of Ecodesign Minimum standards to additional equipment including steam boilers and industrial furnaces
3. Increasing investment grants for RES-H technologies including power-to-heat using heat pumps or electric boilers for steam generation
4. RES OPEX support: ~5 Euros/MWh for RES-H including district heating, heat pumps and electric boilers

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5. CO_2 price: extending the CO_2 price beyond the ETS (same level) and changing price expectations: Companies now consider the CO_2 price 10 years ahead for their investment appraisal. This is achieved via a transparent and defined tax increase and/or a floor price for the EU ETS
6. Comprehensive support of material efficiency and circular economy: Reduced production of basic materials products due to efficiency improvements along the value chain and shift towards secondary production (e.g. electric steel replacing oxygen steel, more recycled paper, etc.). See table below and Table 9 and Table 10 in the annex for an overview on recycling and secondary production assumptions.

Table 5: Assumptions on use of recycled materials for steel, cement, aluminium and paper in Denmark [%]

Indicator		Current policy scenario		Ambitious policy scenario	
	2012	2030	2050	2030	2050
Share of electric steel in total crude steel production					
Share of clinker in total cement production	77%	42%	22%	57%	57%
Share of secondary aluminium in total aluminium production	100%	100%	100%	100%	100%
Share of recovered fibres in total pulp production	100%	100%	100%	100%	100%

7. Exploitation of industrial excess heat potentials of heat >100°C for use in district heating or, where district heating networks are not nearby, for electricity generation. This can be implemented via financial support but also via regulation (e.g. related to pollution control)
8. Innovation support to speed-up the market introduction of low-carbon production processes for the basic materials industries. This includes various strategies from niche markets via requirements for public procurement, to R&D&I support as grants and soft loans (see e.g. discussion on EU Innovation Fund) a minimum CO_2 price path and more.

Results of the current policy and the ambitious policy scenarios are presented and compared below, beginning with CO_2 emissions, before discussing final energy demand and excess heat potentials. Results are shown for the entire industrial sector including non-H/C applications like mechanical energy. However, non-H/C applications are nearly exclusively found in electricity use, while fuel consumption can be attributed to H/C in 2012.

Compared to other EU countries, Denmark has a relatively low share of heavy industry and as a consequence, the importance of industrial CO_2 emissions compared to other sectors is a little lower. Still, industry was responsible for about 6,3 Mt CO_2 emissions in 2012 as shown in Figure 61. While the major share of these emissions is energy related, the Danish industry also has a substantial amount of process-related emissions mainly from cement production accounting to about 1 Mt in 2012.

In the current policy scenario, CO_2 emissions from industry are slightly increasing, mainly due to a shift to coal and an increase in total final energy demand driven by economic growth. The increase in coal demand reflects the underlying energy price projection (see assumptions in chapter 1.1 and the figures of the price projection in the annex). The ambitious policy scenario on the other hand experiences a constant decrease of industrial CO_2 emissions of about 30% until 2050 compared to 2012. A major share of the reduction comes from reductions in fuel oil, natural gas and other fossil fuels. While the increase in coal use is slowed down compared to the current policy scenario, the assumed policy-mix is not strong enough to mitigate the drastic increase until 2030, where CO_2-prices are not yet high enough to make biomass more competitive.

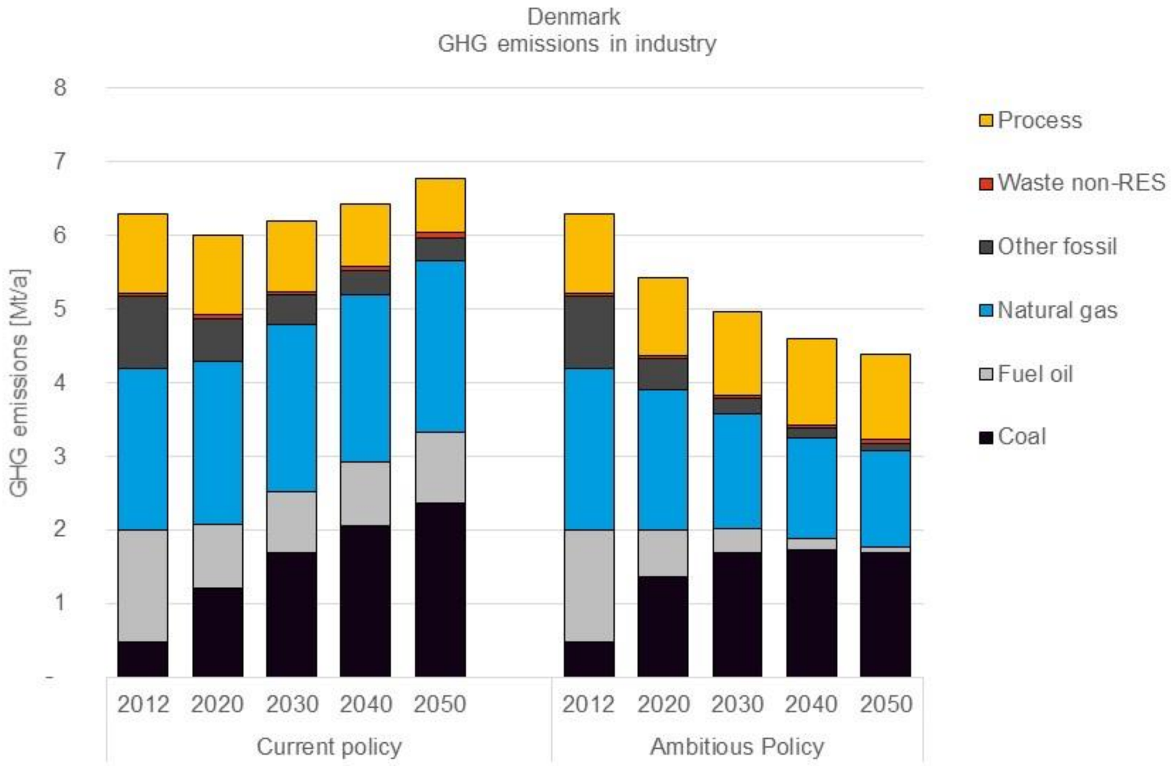

Figure 61: Direct GHG emissions in industry by energy carrier (including process emissions), Denmark

In terms of sub-sectors, the major emitters of CO_2 in the Danish industry are the non-metallic minerals industry (mainly cement production) and the food industry. Compared to other countries, emissions from iron and steel, chemicals, non-metallic minerals and pulp and paper are very low, due to the low importance of these industries in Denmark (see Figure 62). On the other side, the food industry is comparably important. In the ambitious policy scenario, the relative importance of the non-metallic minerals sub-sector even increases until 2050. This is due to the high share of process related emissions in this sub-sector, which are more difficult to mitigate, especially without carbon capture and storage (CCS), which is not included in the analysis.

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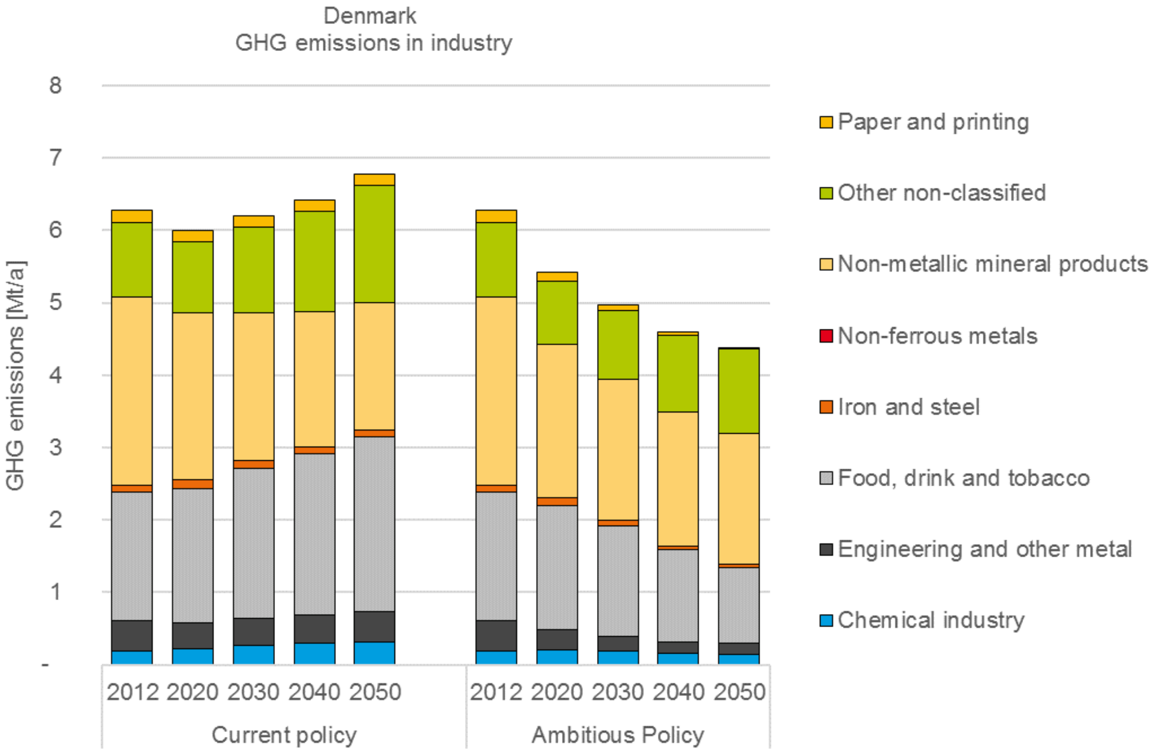

Figure 62: Direct GHG emissions in industry by sub-sector (including process emissions), Denmark

The development of final energy demand by energy carrier is shown in Figure 63. The increase of final energy demand as observed in the current policy scenario is mitigated in the ambitious policy scenario as a result of energy efficiency and material efficiency improvement. The ambitious policy scenario also sees a substantial increase in biomass from about 2 TWh in 2012 to 7 TWh in 2050, replacing natural gas and fuel oil. As a result, the share of RES in industrial H/C energy supply increases from about 10% to 47% in 2050 (note that electricity is not considered in the calculation of the RES-H share). In 2050, biomass and electricity are the most important energy carriers.

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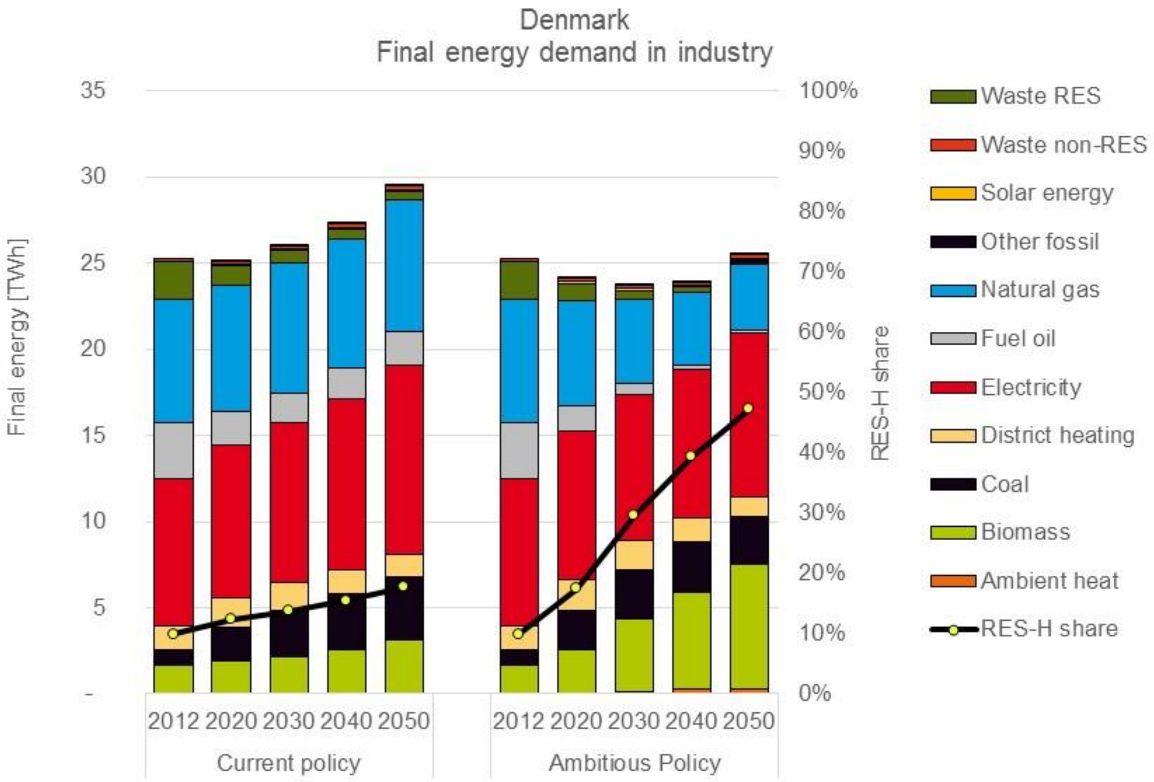

Figure 63: Final energy demand and share of renewables in industry by energy carrier, Denmark

Industrial excess heat potentials (flue gas >100°C) available from energy-intensive plants in Denmark are also strongly influenced by the industrial structure. Accordingly, the major source of industrial excess heat can be found in cement production as shown in Figure 64. This, however, goes back to one large plant in the North of Denmark close to the city of Aalborg, which already uses part of the excess heat in the district heating network of the city. More potential seems to be available at that location.

Note that our assessment of excess heat potentials only considered 30 energy intensive processes/ products and only looked at excess heat available >100°C from flue gases. Including more processes, particularly from the food industry or data centres and looking at lower temperature heat sources will certainly increase the available potential.

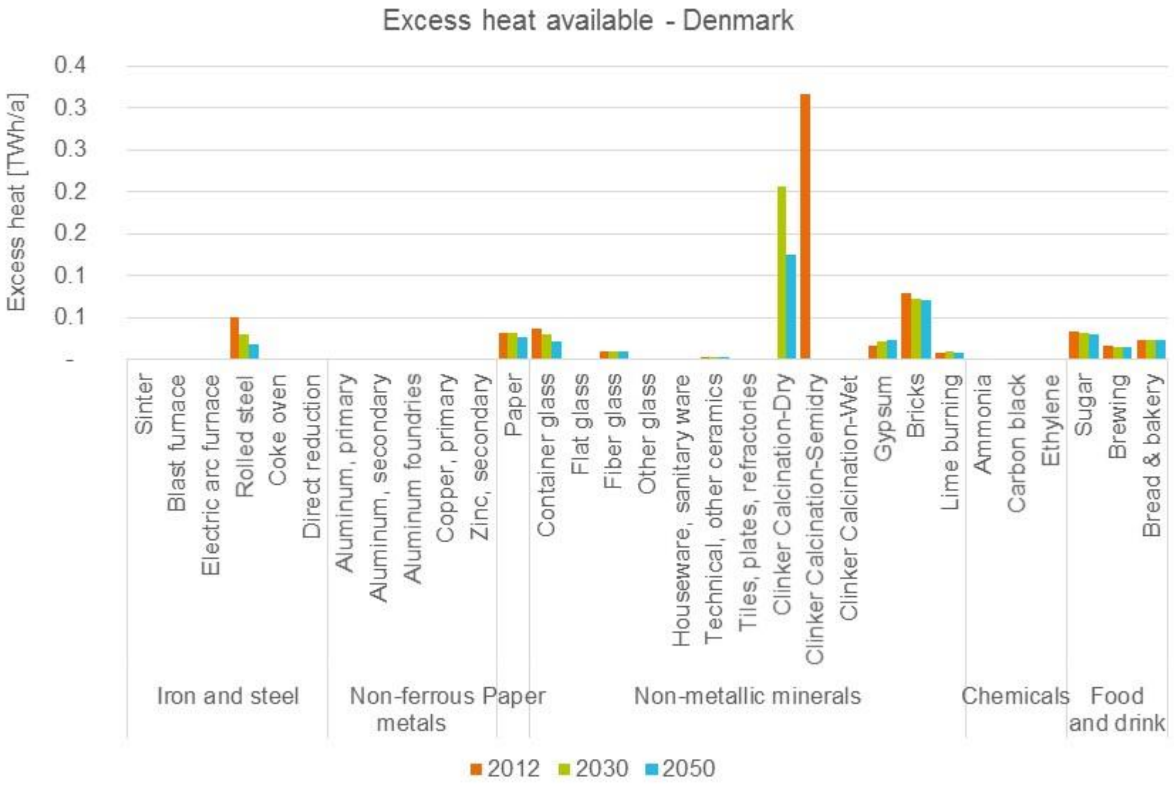

Figure 64: Industrial excess heat potential (>100°C) by process in the ambitious policy scenario, Denmark

To summarise, the Danish industry consists of relatively few plants from the basic materials industries (main exception is a large cement plant). On the other side, the food industry is more important than in other countries. This structure also affects the results of both policy scenarios. The ambitious policy scenario only observes a reduction of industrial GHG emissions of about 30% by 2050 compared to 2012. Mainly responsible is a high share of process related emissions remaining in 2050 from the cement production and an increase in coal use driven by low coal prices. A development in line with the Paris Agreement certainly requires a more ambitious reduction, possibly increasing the role of power to heat to replace remaining natural gas and coal demand, but also investigating the possible use of CCS for the cement industry.

2.4.3 District heating and the power sector

This chapter documents selected indicators for the current and ambitious policy scenario in the Danish district heating (DH) and power sectors calculated by the TIMES-DK model without using the demand input from the building sector and industry sector models.

As described in the methodology section, the results are based on an optimisation model (TIMES), which does not necessarily include all relevant and realistic barriers and diffusion constraints. Thus, the results illustrate the cost-optimal investments and operation of the electricity and district heating system, while some non-economic factors (diffusion constraints, social acceptance, political factors, etc.) might not been represented in the results.

The energy demand in large and small DH areas is presented in Figure 65 and Figure 66 for the two policy scenarios. The most notable effect in both scenarios is the phase-out of fossil fuels and bio fuels until 2050. Furthermore, solar heat becomes the important energy carrier in large DH areas in the ambitious policy scenario. While DH demands in increases in the current policy scenario until 2050, it remains at the same level as in 2012 in the ambitious policy scenario. In general, this could the result of heat savings, construction of new and demolition of old buildings in the residential sector, development of district heating demands in the industrial and service sector and expansion of existing district heating networks. In the present case, district heating is expanded to supply higher share of residential demand in both scenarios, while the difference happens in the ambitious policy scenario; industrial sector demands less DH in the ambitious scenario.

Between the current and the ambitious policy scenario primarily the fuel mix is influenced. Large DH systems in the ambitious policy scenario experience an earlier implementation of waste and solar DH, at the expense of solid biofuels. However, in the year 2050 the amount of waste in large DH areas is the same in both scenarios. This is due to the implemented constraint that all non-recycled waste needs to be incinerated, i.e. used for electricity and / or DH generation. As it cheaper to use other sources for electricity generation, waste has to be used for DH generation in both scenarios, thus decreasing the share of large-scale heat pumps (in the ambitious policy scenario) and solar heating (in the current policy scenario) in the DH generation.

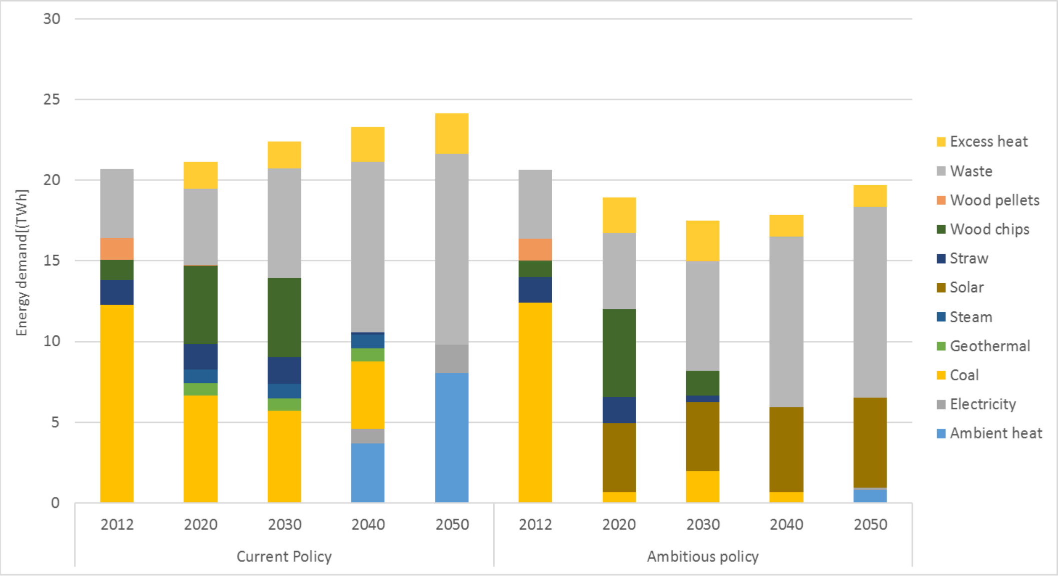

Figure 65: Energy demand in large district heating areas by energy carrier, Denmark

Small DH areas experience an earlier implementation of geothermal district heating and solar heating in the ambitious policy scenario than in the current policy scenario. This goes at the expense of both

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solid bio fuels and later implementation of large-scale heat pumps. This leads to a slightly lower energy demand and an almost identical supply mix as in the current policy scenario in 2050.

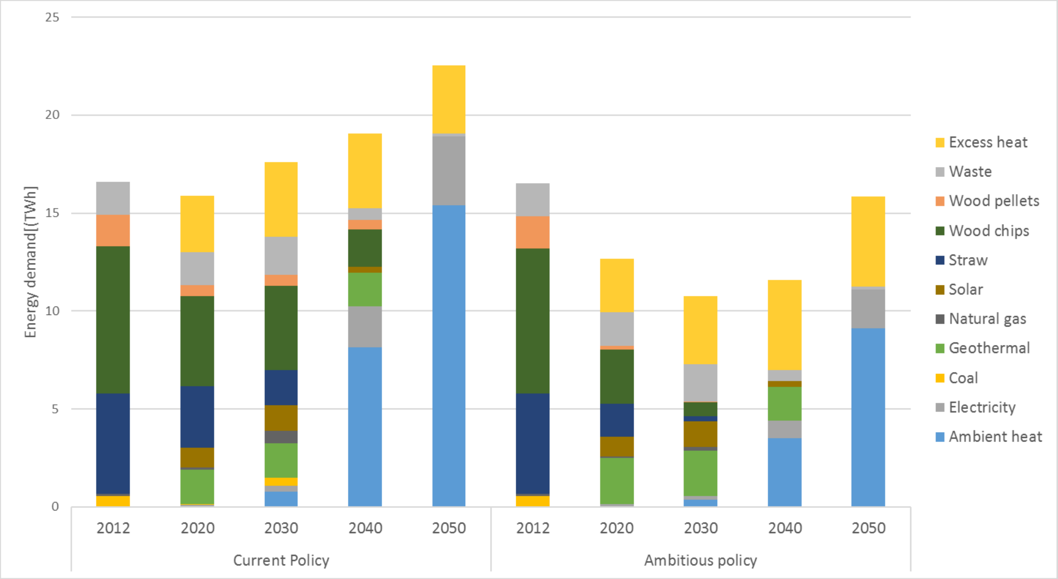

Figure 66: Energy demand in small district heating areas by energy carrier, Denmark

The Danish power sector is expected to increase in the coming years, reaching almost 70 TWh of electricity generation in the current policy scenario and almost 80 TWh in the ambitious policy scenario. Common for both policy scenarios is a base generation of coal CHP in the transition period and a similar amount of solar PV in 2050(limited to a maximum of 9 GW in 2050 due to land use change). The growth of PVs is faster in the ambitious policy scenario. However, while the current policy scenario shows a decrease in coal demand in the years 2012-2040 and finally abandoning of coal for electricity production in 2050; the ambitious policy scenario shows even stronger decrease in coal use after 2020 resulting in no coal in electricity production from 2040 onwards. Furthermore, wind power increases heavily towards 2050 in both scenarios. In the ambitious policy scenario the increase of wind power is even stronger.

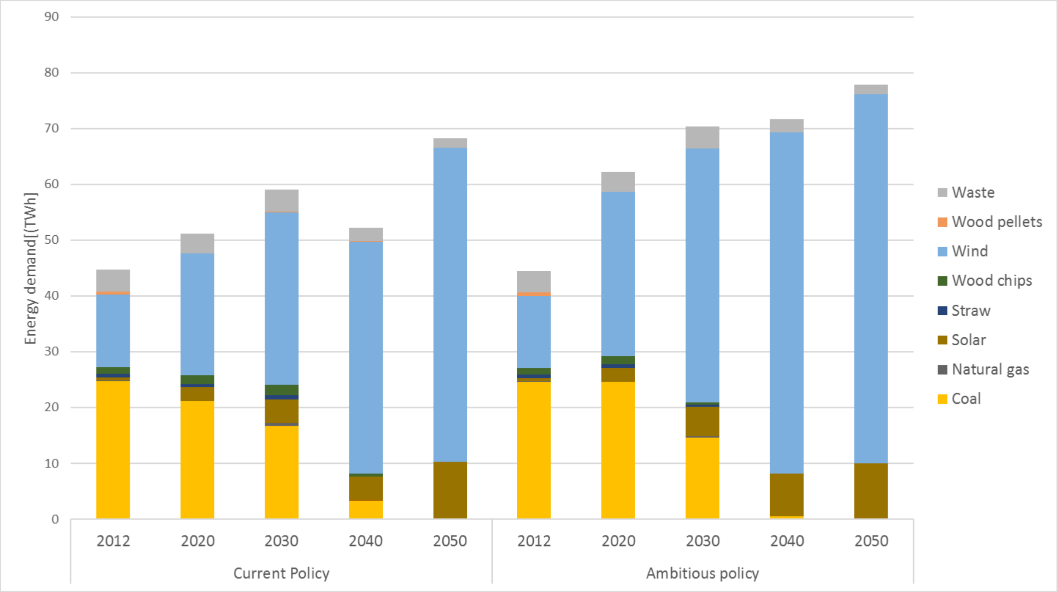

Figure 67: Energy demand for electricity generation by energy carrier, Denmark

The CO_2 emissions from the generation of electricity and DH are expected to decrease in the current and ambitious policy scenario from currently 14 Mt to below 2 Mt in 2050.

The strong decrease in the CO_2 emissions is a result of high investments in wind power and solar for electricity production and solar heating, large-scale heat pumps and excess heat from industries in DH production. The faster reduction of CO_2 emissions in the ambitious scenario is due to investments in solar DH in large DH areas, geothermal heat in Small DH areas as well as du to more ambitious investments in wind power and solar PV for electricity production. All of these investments are happening at the expense of coal-based production. The only emissions in 2050 are from DH production in large DH areas.

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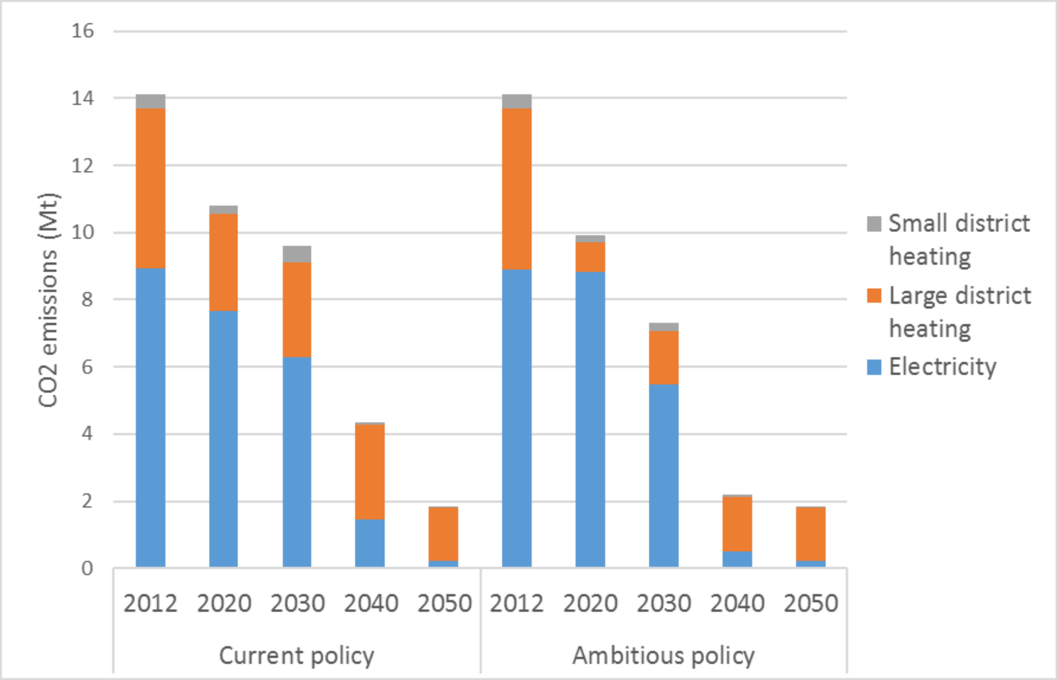

Figure 68: CO_2 emissions from generation of district heat and electricity, Denmark

As shown in the figures of energy demand for electricity and DH generation, the penetration of RES is expected to be high and fast in both policy scenarios. This increase in the use of RES for both electricity and DH generation is even higher and faster in the ambitious than in the current policy scenario.

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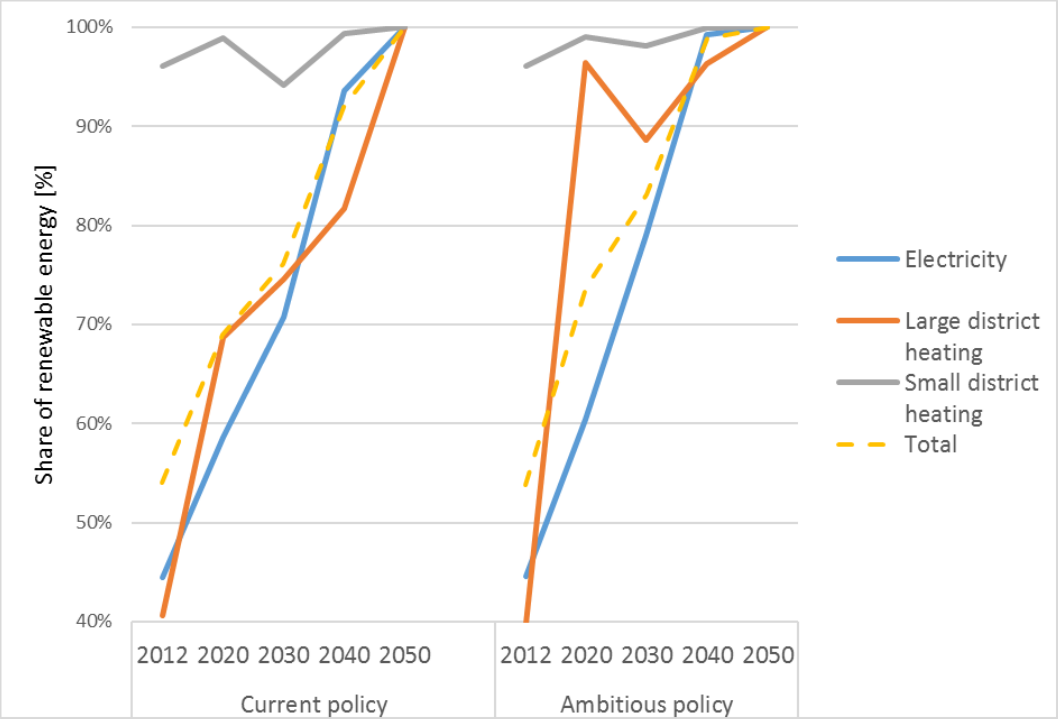

Figure 69: Share of renewable energy in district heat and electricity, Denmark

The total costs of electricity and DH generation system in the two scenarios appears to be similar until 2020. In 2030, the reduced use of coal in the ambitious scenario results in lower fuel costs. The influence of the fuel costs after 2030 is minor because of the high RES shares in both scenarios.

The investment costs have major influence on the total costs. Despite higher investments after 2020 (mainly in wind power) in the ambitious scenario the investment costs are lower. This is because the investments in wind power (and other renewable energy technologies) are effectively cheaper in the ambitious scenario. This is due to 0% discount rate for investments in renewable energy technologies. As a result, there are more investments in renewable technologies. The additional benefit from more investments in renewable technologies is the increased export of electricity and consecutively earnings from electricity exports. Therefore, the electricity and heating sector would benefit from policies implemented in the ambitious policy scenario.

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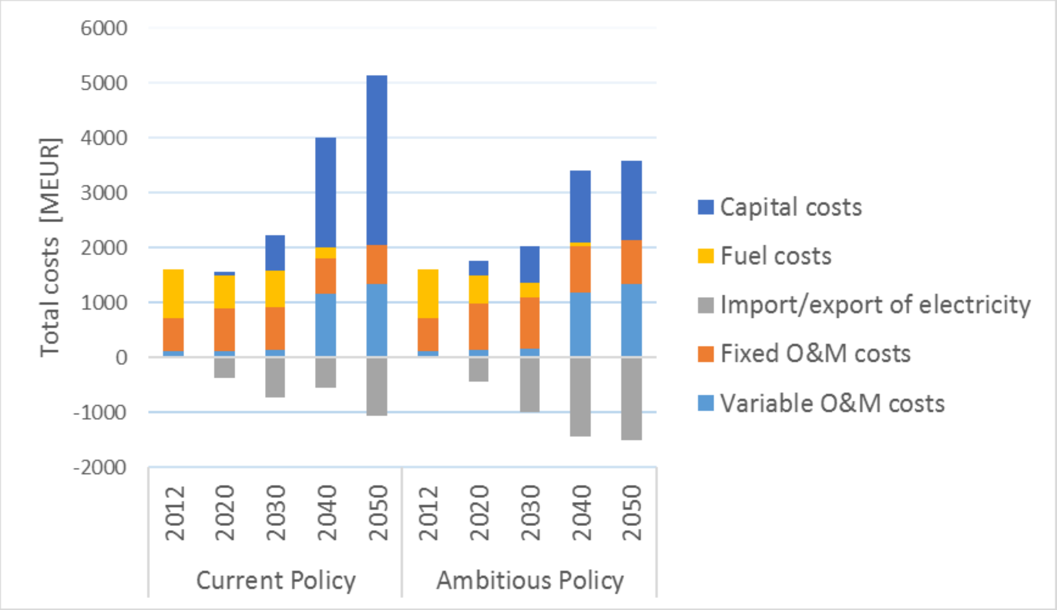

Figure 70: Total costs of district heat and electricity generation, Denmark

2.4.4 Overall heating and cooling (H/C) indicators

In this chapter the indicators for countrywide heating and cooling are documented. This comprises the results of the modelling of the buildings, industry, district heating and power sector as documented in the previous chapters, but only taking into account the amounts of emissions, energy and the share of renewable energy related to heating and cooling.

Figure 71 shows the CO_2 emissions for H/C purposes from the different sectors. The overall CO_2 emissions comprise the direct emissions from the buildings and the industry sector, the emissions from the district heating sector and the emissions of the power sector originating from electricity used for H/C. Remarkable reductions can be achieved in both policy scenarios. However, in the current policy scenario industrial CO2 emissions even increase due to increased production. The share of the industry sector on the overall emissions increases in both scenarios until 2050, due to the higher difficulty of emission mitigation in this sector. In the current policy scenario reductions of CO_2 emissions of 43% can be achieved until 2050. In the ambitious policy scenario reductions of up to 63% are achieved.

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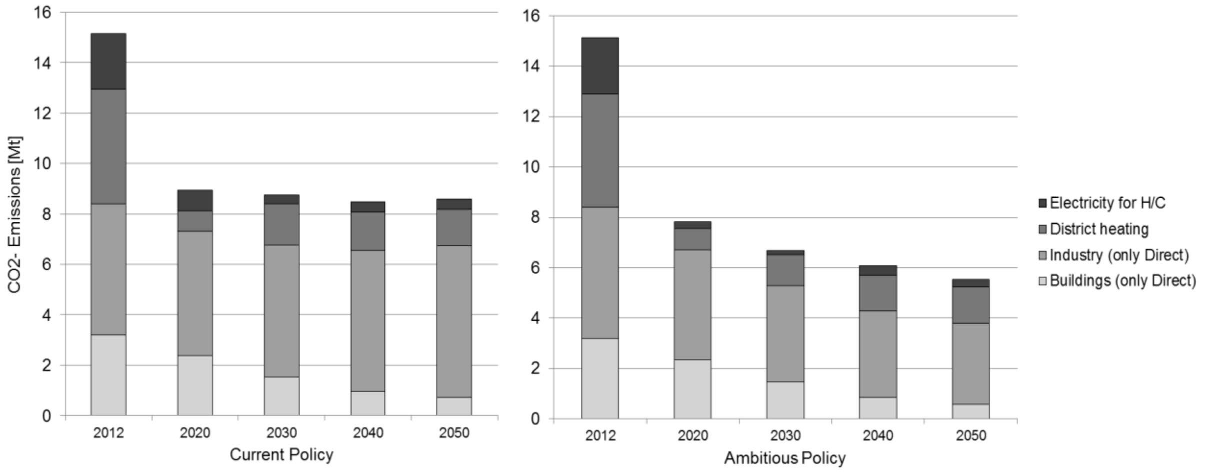

Figure 71: CO$_2$ emissions from heating and cooling by sector, Denmark

Figure 72 shows the primary energy demand for space heating, hot water, cooling and process heat by energy carrier of all sectors. The reflected energy demand in this indicator comprises the fuel demand for heating and cooling from the buildings and industry sector (excluding electricity and district heating) plus the primary energy input into the district heating sector plus the primary energy input into the power sector for electricity used for H/C purposes. In the industry sector in Denmark around 73% of the final energy demand is used for H/C purposes. Ambient heat is the ambient part of the heat from heat pumps. Biomass includes wood chips, wood pellets and straw. Other fossils include diesel. Other renewables include biogas, biodiesel, geothermal and wave energy. Solar include solar thermal and solar PV. Waste includes renewable and non-renewable waste.

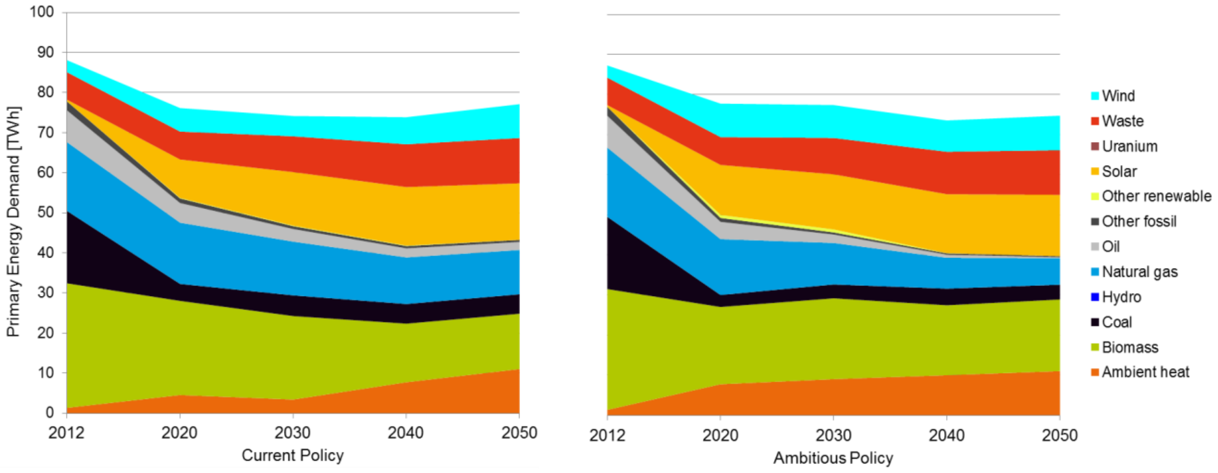

Figure 72: Primary energy demand for heating and cooling by energy carrier, including space heating, hot water, cooling and process heat, Denmark

Figure 73 shows the share of renewable energy used for heating and cooling in the different sectors. For the buildings and industry sector this share is calculated excluding electricity both in the overall demand for heating and cooling and in the amount of renewable energy used to generate electricity. The share of renewable energy in district heating, however, is taken into account in this calculation. In both scenarios all sectors but industry will reach 90 - 100% share of RES in 2050 topping 80% already in 2030. The industry sector needs ambitious policies to reach 54% compared to only 25% in the current policy scenario.

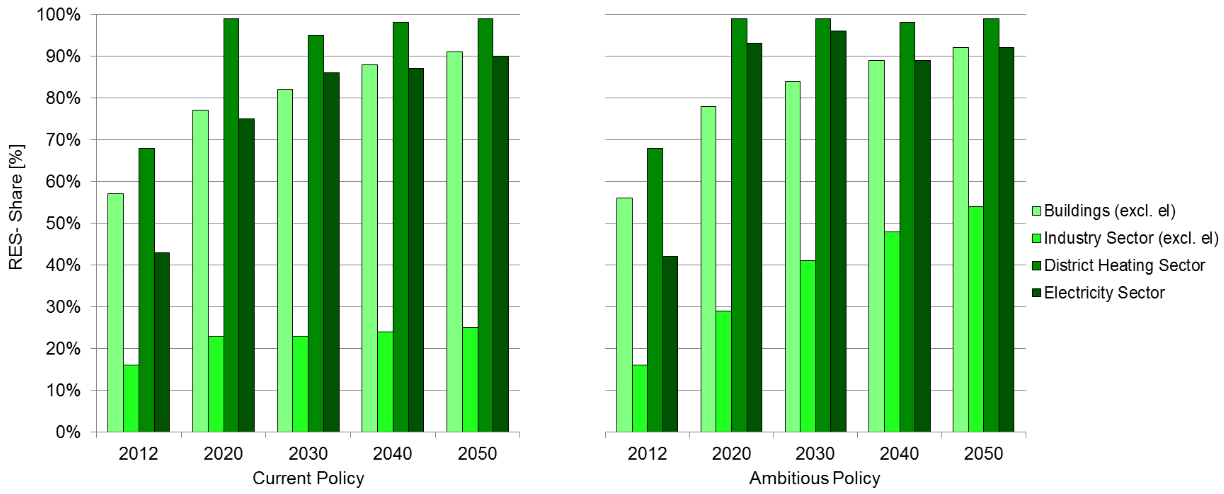

Figure 73: Share of renewables in heating and cooling by sector, Denmark

2.4.5 Conclusions and policy recommendations for Denmark

In the previous chapters the results of the quantitative assessment of the influence of two policy scenarios on demand and supply of H/C and related sectors in Denmark are documented. As shown in Figure 71 the CO_2 emissions for H/C are likely to be reduced with currently implemented policies at a low CO_2 price of 7,5 EUR/tCO_2 by 43% until 2050. More ambitious policies in the different sectors together with assuring a continuous increase of the CO_2 price to nearly 90 EUR/tCO_2 in 2050 might lead to a reduction of 63% until 2050. In the following key recommendations for policy making are described that result from the modelling of the national H/C systems within progRESsHEAT. A distinction is made between recommendations for policies targeting buildings, industry and DH and power generation.

The currently implemented and foreseen policies in Denmark targeting **buildings** are likely to reduce direct emissions from H/C in this sector to a large extent (-78%) until 2050, and at the same time remarkably increase the share of RES in this sector (from 55% to 91%). Thus, the current shape of the national building codes and renovation standards, the foreseen RES-H obligation and the available public budgets for subsidising investments in technologies for RES-H are likely to show remarkable

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effects until 2050, even with a low price of CO_2. However, these emission reductions will only be achieved with the current policy framework, if a continuous monitoring of the compliance with national building codes and renovation standards is installed and non-compliance is penalised. Also, as the connection to DH is counted as an option to fulfil the RES-H obligation, it is important that DH generation is decarbonised in the mid to long term in order not to shift the source of emissions from buildings to DH. In this context it might be interesting to only allow accounting of DH for the compliance with the RES-H obligation, if for the DH system a commissioned decarbonisation roadmap exists.

The current policy framework leads to a remarkable decarbonisation of H/C in Danish buildings until 2050. If looking solely on the buildings, Denmark is probably nearly on track for reaching the emission reduction targets as set out in the Paris Agreement. However, as emission reduction in buildings is cheaper and more easily achievable than in industry, more ambitious policies will be needed also in the building sector. An important measure to further reduce emissions is an intensified RES-H obligation: on the one hand the obligation should not only apply for buildings that are newly constructed, but also for buildings undergoing a major renovation and in case that the heating system is changed. On the other hand, the share of the heat to be supplied by RES should be increased, so that it becomes less interesting to fulfil the obligation with a combination of fossil fuels and solar thermal systems or paying a penalty instead of compliance. At the same time the public budget for subsidising investments in technologies for RES-H should be increased to additionally trigger the technology shift.

As in many EU countries, the potential for reducing the heat demand in buildings is very high in Denmark. In order to stimulate the realisation of building retrofit funding for such measures should be established, and also could be set mandatory after a certain timeframe. Increased retrofit rates would also help to reduce biomass use for heating in buildings. This is important as on the one hand the amount of sustainable biomass resources might not be sufficient to supply large shares of heat demand in buildings in 2050, and on the other hand will biomass be more essential for the decarbonisation of the industry sector than for buildings. For increasing retrofit rates it is also important to drive standardisation of retrofit activities and awareness raising by implementing energy performance certificates (EPC) of buildings, so that retrofit costs decrease compared to current levels. Finally, information campaigns to increase the awareness of the continuous increase of fuel and emission certificate prices are important, so that this is taken into account in the investment decisions related to building retrofit and heating systems. This, however, is linked to a continuous increase of the CO_2 prices, which can be assured by the application of a CO_2 tax or levy for all sectors at national level, if not achieved by the EU ETS.

The following conclusions and policy recommendations can be drawn for the **industry** sector in Denmark:

- Neither the current policy nor the ambitious policy scenario is on track towards deep decarbonisation.

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- A decarbonisation strategy for industry needs to find a solution for the high process related emissions from cement production, which accounts for about 25% of remaining CO_2 emissions in 2050 in the ambitious policy scenario. An option can be the use of CCS.
- Excess heat potentials should be exploited in the cement industry. An identification of additional excess heat potentials in less energy intensive industries and from other sources is needed. Studies going into this direction are already available (Bühler et al. 2017).
- Biomass is an important RES for industry - if available according to sustainability criteria. However, the food industry requires process heat also on lower temperature levels often below 100°C, which provides opportunities for the use of solar thermal heating and heat pumps as well.
- Despite high financial support for RES and increasing CO_2 prices, coal is still cost competitive in the ambitious policy scenario. Regulative instruments are proposed to phase out the use of coal.
- OPEX support of RES seems more effective than CAPEX support.

The current policy mix already includes many policies directed towards overcoming barriers to energy efficiency (e.g. support for energy audits, energy efficiency networks and incentives for energy management schemes). While this is an important pillar of the policy mix, there are probably no more policies needed, rather the enforcement of the existing policies should be ensured.

Unlike in the other analysed countries, **electricity** demand in Denmark in 2012 is comparable to the **district heating** demand. Denmark also currently (in 2012) has a high share of RES of 52% in the generation of DH and electricity. This is characterized by a high use of biomass and waste in DH generation and a large share of wind in the electricity generation. The situation in 2012 gives a very good starting point to reach high shares of RES in electricity and DH generation until 2050.

Electricity generation reaches 100% RES in 2050 in both policy scenarios. The generation in both scenarios is based mainly on wind. Therefore, the assumption of declining costs of wind and solar power are enough to decarbonize the electricity generation in Denmark. Therefore, under the assumptions in the model, the policies implemented in the ambitious policy scenario are not needed to reach 100% renewable electricity production in 2050, i.e. the implemented polices can be used to reach the goal faster. The subsidies for investments in renewable energy technologies and the rising CO_2 costs can be transferred to other sectors of the energy system, such as industry, transportation, etc. and thus help decarbonisation of these sectors.

High shares of RES in both scenarios characterize the generation of district heat in small and large DH areas. Taxes on fossil fuels and declining costs of technologies for RES seem to be enough to completely shift to renewable energy. Consecutively, the implemented polices in the ambitious policy scenario do not seem to be necessary.

2.5 The case of Portugal

2.5.1 Buildings

This chapter documents selected indicators for the current and ambitious policy scenario related to buildings in the residential and tertiary sector.

For buildings the **current policy scenario** includes the following policies that are already in place in Portugal:

- New buildings are constructed according to the current national building codes and the foreseen changes until 2021. This includes the national definitions of "Nearly Zero Energy Buildings".
- The building regulation includes a renewable heat obligation: after 2021 a small share of the final heat demand in newly constructed buildings has to be covered by heating technologies using renewable energy. Solar gains through glazings are not included but solar systems for heating or hot water in combination with a fossil boiler can reach the required share
- No subsidies are available for subsidising the retrofit of existing buildings or for subsidising the additional costs of constructing new buildings at heat demands lower than stated in the national building codes.
- No subsidies are available for heating technologies using renewable energy.

The **ambitious policy scenario** for the building sector includes additional policies in order to reach a remarkable CO_2 reduction of around 80% in the scenario timeframe. Alongside with some reduction in the emissions from heating this includes mainly measures to reduce the growth of the space cooling demand. The following policies are implemented for the case of Portugal:

1. Building codes and nZEB-plans would be kept at current state but additional shading and passive measures will be integrated reducing cooling loads for all buildings.
2. The renewable heat obligation in the building regulation would be intensified: starting with less than one third of heat demand that has to be covered by renewable energy after 2020, an increasing share has to be covered by renewables after 2030 and more than two thirds have to be renewable after 2035. This renewable heat obligation applies to new buildings only in the period from 2020 to 2030. Afterwards it also applies in case of a major renovation or a heating system replacement and district heating is counted 100% as an option to reach this share, even if district heating is not 100% supplied by renewable energies.
3. A public budget of around 60 MEUR per year for subsidising the retrofit of existing buildings and for subsidising the additional costs of constructing new buildings at heat demands lower than stated in the national building codes would be established.
4. A public budget of around 15 MEUR per year for subsidising heating technologies using renewable energy would be established supporting 15-20% of the investment costs.
5. Favourable financing conditions for district heating infrastructure would lead to a decrease of district heating costs by 10%.
6. As stated in the general scenario assumptions in chapter 1.1 all sectors have to pay a rising CO_2 price according to the PRIMES projection. This would cause higher energy end consumer prices for fossil fuels.

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7. Information campaigns would lead to decision-makers being aware of the continuous increase in prices for fuels and CO_2 emission certificates. This causes that rising fuel prices will be taken into account in their investment decisions.
8. It is assumed that by standardisation, awareness rising through EPCs etc. a decrease of building renovation costs by almost 18% can be reached until 2050.

In the following figures key indicators for the current and ambitious policy scenario for buildings in Portugal are compared: direct CO_2 emissions, final energy demand, share of renewables (excluding electricity), total annual running and investment costs and the direct costs (of subsidies) for the described policy programmes.

Figure 74 shows the development of the direct CO_2 emissions from the building sector. Emissions from district heating and electricity are not included in this figure but they are considered in the respective sector chapter and in the overall heating and cooling chapter. In this chapter the emissions of the building sector only result from the use of individual natural gas and oil boilers. A decrease in CO_2 emissions in the building sector from 2,2 Mt in 2012 to 0,27 Mt (-88%) in 2050 can be achieved in the current policy scenario and to 0,23 Mt (-89%) in 2050 in the ambitious policy scenario. There is only a small difference between the two scenarios because the heating sector in Portugal would be widely based on renewables in both scenarios in 2050 and the ambitious policies are targeting mostly the space cooling demand, which is supplied mainly by electricity.

The considerable GHG-emission reductions already in the current policy scenario are mainly due to currently implemented (or expected) building codes and nZEB standards as well as existing renewable heat obligation. Also increasing energy prices contribute to the result. Thus, the result should not be understood in a way that this will happen anyway. First, continuous (and maybe even enhanced) efforts will need to be taken to ensure a proper compliance with existing building codes and regulations. And second, in case of lower energy prices than expected, higher efforts will be required to achieve the result presented here as current policy scenario.

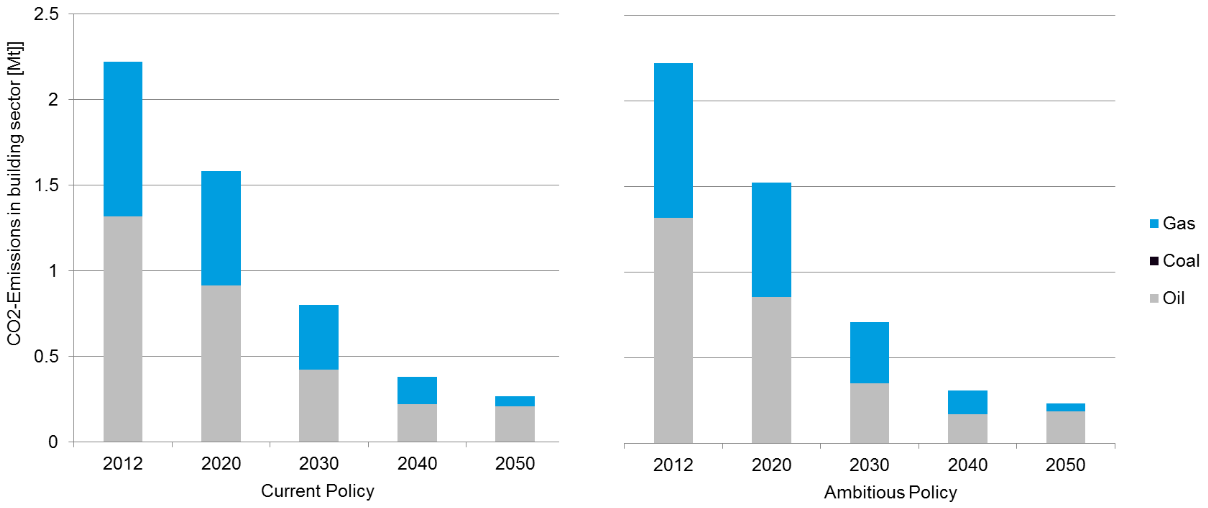

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Figure 74: Direct CO_2 emissions for space heating and hot water preparation per energy carrier in the residential and tertiary sector, Portugal

Figure 75 shows the development in final energy demand for heating and cooling in Portugal. In the current policy scenario the demand decreases from almost 20,6 TWh in 2012 to 18,9 TWh in 2030 and then increase to 20,3 TWh (-46%) until 2050 due to increasing electricity demand for space cooling. While the demand for heating can be decreased by 30% until 2050, the demand for space cooling more than triples within this period and the share of energy demand used for cooling rises from 11% in 2012 to almost 38% in 2050 in the current policy scenario. In the ambitious policy scenario the total demand can be kept almost constant at 19 TWh after 2030 resulting in an overall demand reduction of 7% compared to 2012. On the secondary axis the figure shows the share of renewable energy in the building sector. For the heat delivered by district heating the respective renewable share of the district heating sector as shown in chapter 2.5.3 is used. Electricity used for heating and cooling is not included in the calculation of this share but the renewable share of the power sector is also shown in in chapter 2.5.3. Electricity and therefore also the cooling demand is not included in the calculation of this share leading to a similar renewable share of 91% in both scenarios for the heating demand.

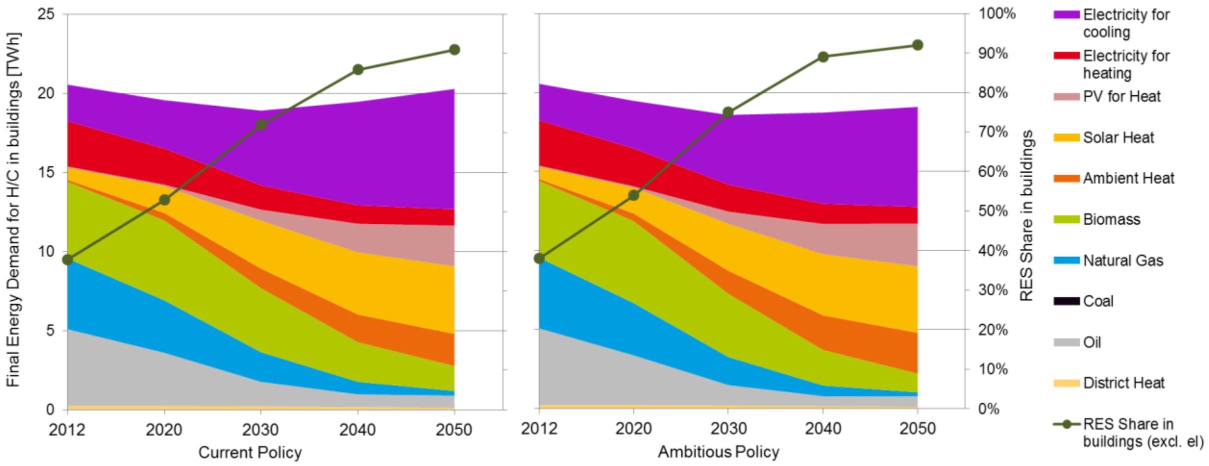

Figure 75: Final energy demand and share of renewables for space heating, hot water preparation and space cooling by energy carrier in the residential and tertiary sector, Portugal

Figure 76 shows the development of the annual total investment and running costs for both policy scenarios for Portugal. In 2012 around 19% of the running costs are caused by cooling equipment rising to more than 67% of the running costs in the current policy scenario in 2050. This why the running cost in the current policy scenario only decline a little, despite the high share of renewables for heating. Investment costs indicated here are almost the same in both scenarios because costs of cooling equipment and for shading measures are not included in the figure.

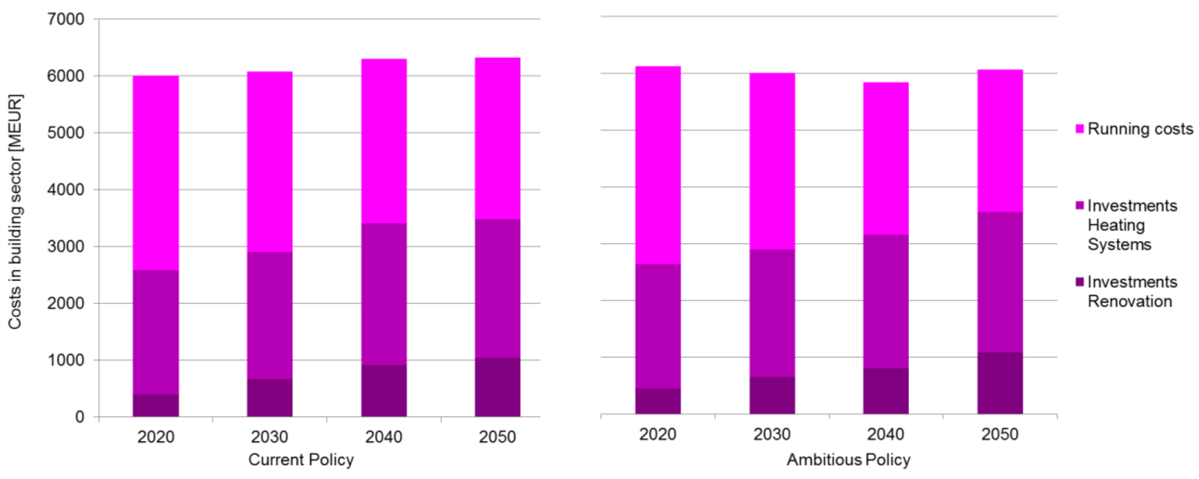

Figure 76: Investments and running costs for building renovation and heating and hot water systems in the residential and tertiary sector, Portugal

Figure 77 shows the policy programme costs for both scenarios. These costs include subsidies for buildings retrofit and subsidies for heating technologies using renewable energy, also including solar thermal systems. In the current policy scenario no subsidies are available neither for retrofitting measures, which include shading and passive measures, nor for heating systems using renewable energy. In the ambitious policy scenario such programmes are established in the range between 60 and 70 MEUR per year.

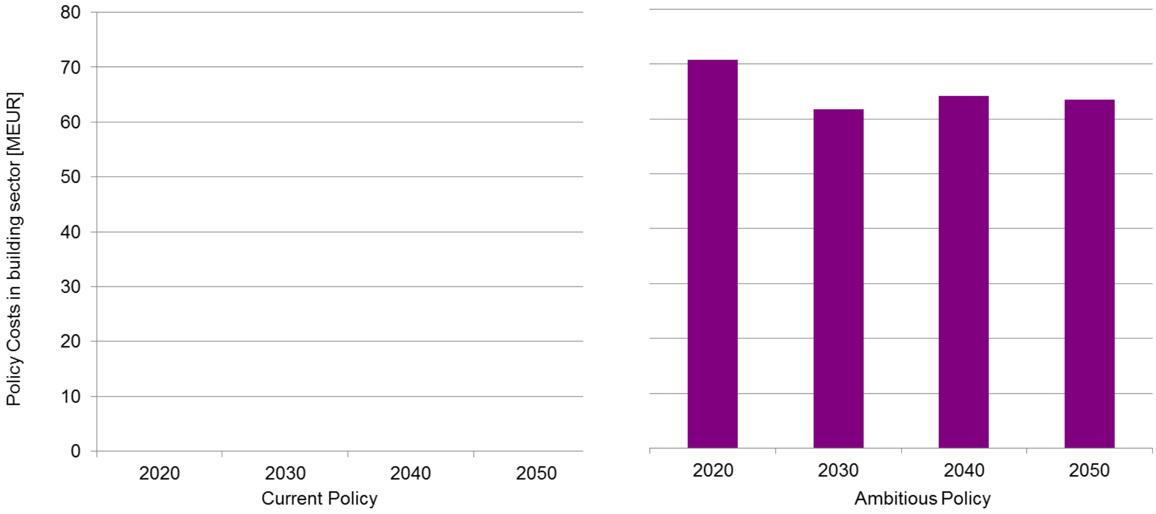

Figure 77: Policy programme costs for the residential and tertiary sector, Portugal

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2.5.2 Industry

This chapter documents selected indicators for the current and ambitious policy scenario in the Portuguese industry sector.

- The **current policy scenario** considers policies implemented by 2015 including among others. This includes among others the CO_2 price, EU Ecodesign Standards for energy using products as well as Energy taxes as reported by Eurostat in 2015.

The **ambitious policy scenario** represents a much more ambitious policy mix towards the transformation of the industrial heating and cooling sector. It comprises of the following main elements:

1. Policy package addressing classical non-financial barriers to energy efficiency including the roll-out of energy management systems, energy audits, soft loans, etc.
2. Extension of Ecodesign Minimum standards to additional equipment including steam boilers and industrial furnaces
3. Increasing investment grants for RES-H technologies including power-to-heat using heat pumps or electric boilers for steam generation
4. RES OPEX support: ~5 Euros/MWh for RES-H including district heating, heat pumps and electric boilers
5. CO_2 price: extending the CO_2 price beyond the ETS (same level) and changing price expectations: Companies now consider the CO_2 price 10 years ahead for their investment appraisal. This is achieved via a transparent and defined tax increase and/or a floor price for the EU ETS
6. Comprehensive support of material efficiency and circular economy: Reduced production of basic materials products due to efficiency improvements along the value chain and shift towards secondary production (e.g. electric steel replacing oxygen steel, more recycled paper, etc.). See table below and Table 9 and Table 10 in the annex for an overview on recycling and secondary production assumptions.

Table 6: Assumptions on use of recycled materials for steel, cement, aluminium and paper in Portugal [%]

Indicator		Current policy scenario		Ambitious policy scenario	
	2012	2030	2050	2030	2050
Share of electric steel in total crude steel production	100%	100%	100%	100%	100%
Share of clinker in total cement production	96%	90%	88%	82%	71%
Share of secondary aluminium in total aluminium production	100%	100%	100%	100%	100%
Share of recovered fibres in total pulp production	13%	14%	15%	20%	26%

7. Exploitation of industrial excess heat potentials of heat >100°C for use in district heating or, where district heating networks are not nearby, for electricity generation. This can be implemented via financial support but also via regulation (e.g. related to pollution control)

8. Innovation support to speed-up the market introduction of low-carbon production processes for the basic materials industries. This includes various strategies from niche markets via requirements for public procurement, to R&D&I support as grants and soft loans (see e.g. discussion on EU Innovation Fund) a minimum CO_2 price path and more.

Results of the current and the ambitious policy scenarios are presented and compared below, beginning with CO_2 emissions, before discussing final energy demand and excess heat potentials from industrial activity. Results are shown for the entire industrial sector including non-H/C applications like mechanical energy. However, non-H/C applications are nearly exclusively found in electricity use, while fuel consumption can be attributed to H/C in 2012.

Industrial CO_2 emissions in 2012 were completely dominated by the non-metallic minerals industry, which means mainly cement production (see Figure 79). This is also the reason for the high share of process related emissions in Portugal (chemical processes in the production of cement, see Figure 78) and posing the major challenge for the long-term decarbonisation. While fuel switch and energy efficiency together drive emissions in the ambitious policy scenario down by 51%, additional reductions require mitigation of process related emissions from cement production. Carbon capture and storage might be needed, if alternative innovative low-carbon cement types will not make it on the market early enough.

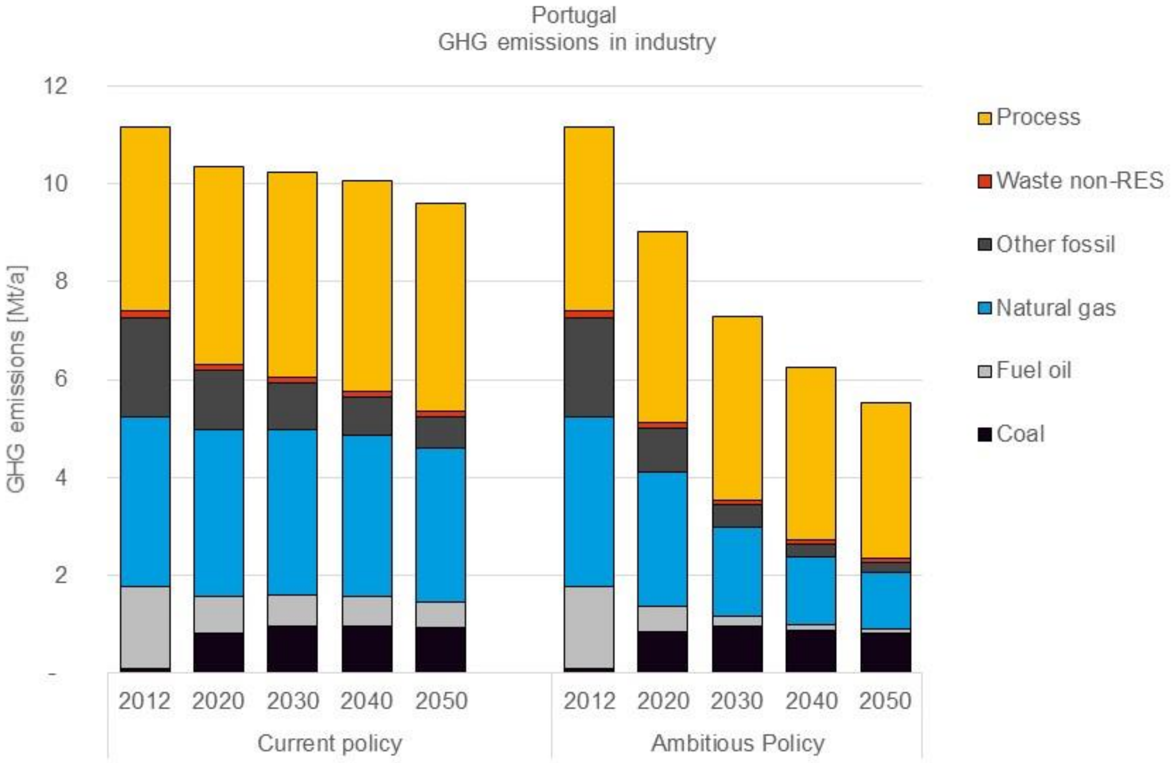

Figure 78: Direct GHG emissions in industry by energy carrier (including process emissions), Portugal

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As mentioned, in terms of sub-sector shares, the non-metallic minerals industry (mainly cement production) is dominating total industrial emissions with a share of 75% in 2012 (note that according to the definition of final energy demand, the petrochemical/refinery industry is not part of the industrial sector and not included in this analysis). While fuel switch and material efficiency substantially reduce emissions also from the cement industry in the ambitious policy scenario, there is a remaining socket from process related emissions in 2050 (see Figure 79).

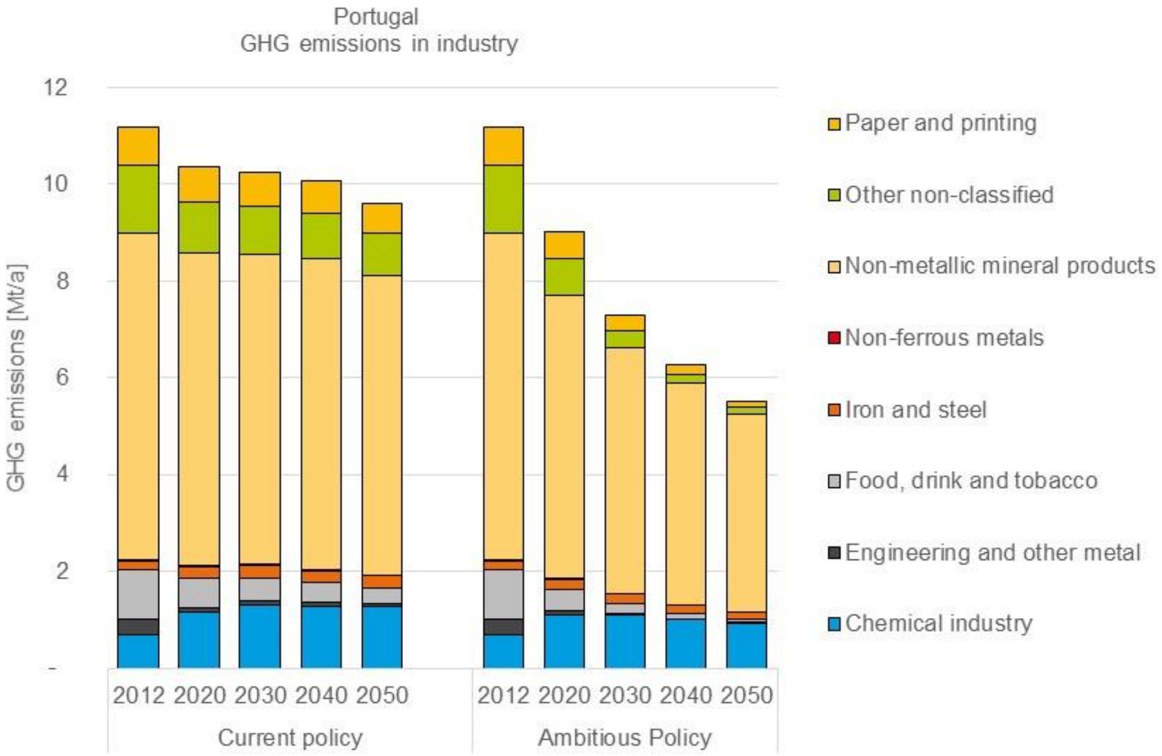

Figure 79: Direct GHG emissions in industry by sub-sector (including process emissions), Portugal

Final energy demand decreases in the current and the ambitious policy scenario by 11% and 28% until 2050 compared to 2012, respectively (see Figure 80). In the ambitious policy scenario also a substantial increase of renewable energy used for heating is observed. The share of renewable energy increases from an already high level of 30% in 2012 to 64% in 2050. Note that electricity is not included in the calculation of this share, because it is mostly used to generate mechanical energy.

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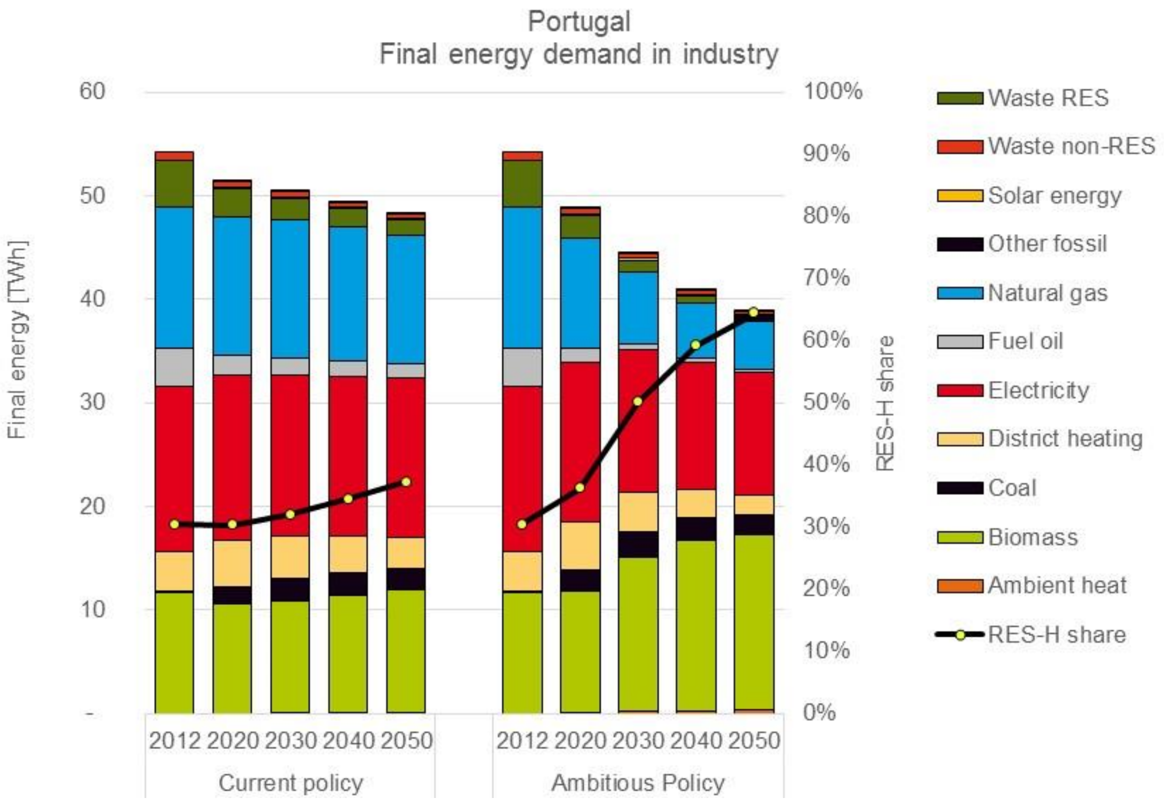

Figure 80: Final energy demand and share of renewables in industry by energy carrier, Portugal

The available excess heat potentials are also dominated by cement (clinker) production as shown in Figure 81. Other processes from which potentials are available are the production of electric steel, the paper production and steam crackers in ethylene production.

Note that our assessment of excess heat potentials only considered 30 energy intensive processes/ products and only looked at excess heat from flue gases available at temperatures above 100°C. There is potentially more excess heat available from other sources not covered here and also at lower temperature levels than 100°C.

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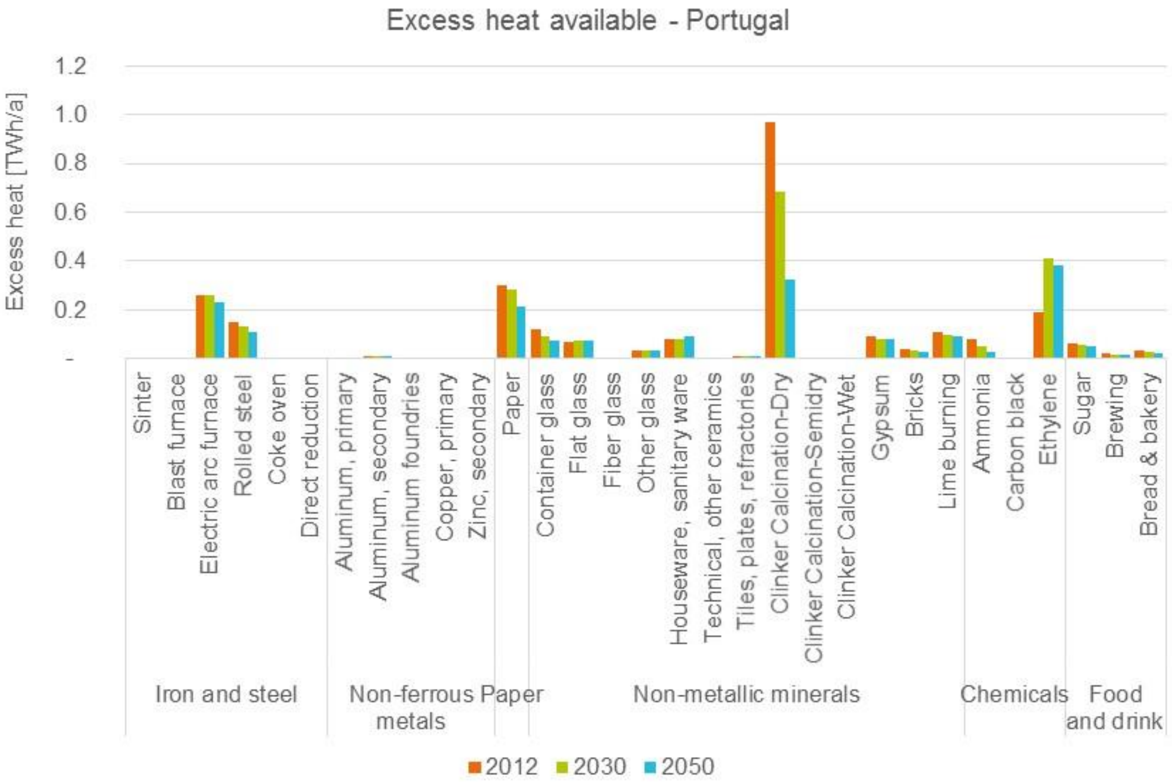

Figure 81: Industrial excess heat potential (>100°C) by process in the ambitious policy scenario, Portugal

The policy impact modelling (Figure 82) shows a strong impact for energy efficiency policies, RES OPEX support and material efficiency. Establishing a CO_2 price beyond the EU emissions trading scheme (ETS) does not have a high impact, most likely also due to the high importance of the cement industry, which is already covered in the EU ETS.

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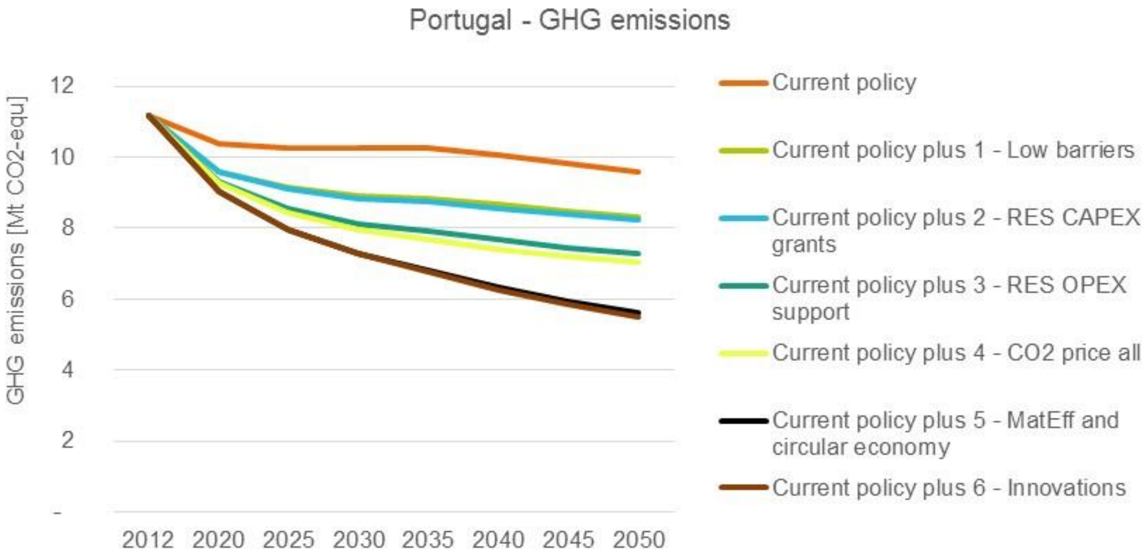

Figure 82: Direct GHG emissions in industry by policy variant, Portugal

To conclude, decarbonising the industry sector in Portugal is mainly a question of decarbonising cement production, as the non-metallic minerals sector was responsible for 75% of industrial CO_2 emissions in 2012.

2.5.3 District heating and the power sector

This chapter documents selected indicators for the current and ambitious policy scenario in the Portuguese district heating (DH) and power sectors. As described in the methodology section, the results are based on an optimisation model (TIMES), which does not necessarily include all relevant and realistic barriers and diffusion constraints. Thus, the results illustrate the cost-optimal investments and operation of the electricity and district heating system, while some non-economic factors (diffusion constraints, social acceptance, political factors, etc.) might not be represented in the results.

In addition to the scenario assumptions outlined in chapter 1.1, the following assumptions are specific for the case of Portugal:

- The annual increase of new renewable technologies like wave power and geothermal heat for power generation is limited
- Capacities of waste incineration plants are limited due to limitation of waste as energy carrier

Due to the warmer climate in Portugal compared to countries such as Austria, Germany and Denmark, DH is much less important than electricity generation. This can be seen in Figure 86.

The models INVERT/EE-Lab and FORECAST-Industry provide the projections of DH demands in large and small DH areas from buildings (see Figure 75) and industry (see Figure 80). When DH demands in

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2050 are compared to DH demands in 2012 it can be observed that they decrease by around 20% and 50% in the current and ambitious policy scenario, respectively. This trend is the same for large and small DH areas.

Figure 83 presents the energy demand in large DH areas in Portugal. The major drop in fuel input cannot be explained by the falling demand. The reason for the major drop in fuels used for the generation of DH in large DH areas is the following. The cheapest way to generate electricity in the starting years of the analysed period is natural gas CHPs. The heat generation in the gas-CHPs is used to feed large DH areas. Due to the much lower DH demand in large DH areas than heat generated in the gas-CHPs large parts of the heat generated in the gas-CHPs is wasted. However, the energy demand for gas used for heat generation in the CHPs is still counted in the energy demand for large DH areas.

The large share of generated DH is wasted, while the remaining share is used to supply the projected demand in large DH areas.

The energy demand of plants in large DH areas follows a similar evolution in both policy scenarios moving towards 2050: from natural gas fired plants to a combination of heat pumps and waste incineration plants. Moreover, in the ambitious policy scenario small amounts of solar heating, wood pellet-fired plants and excess heat from industry are utilized. Coal is still used in large DH areas in 2050, corresponding to 42% and 7% of the total energy demand in the current and ambitious policy scenario, respectively.

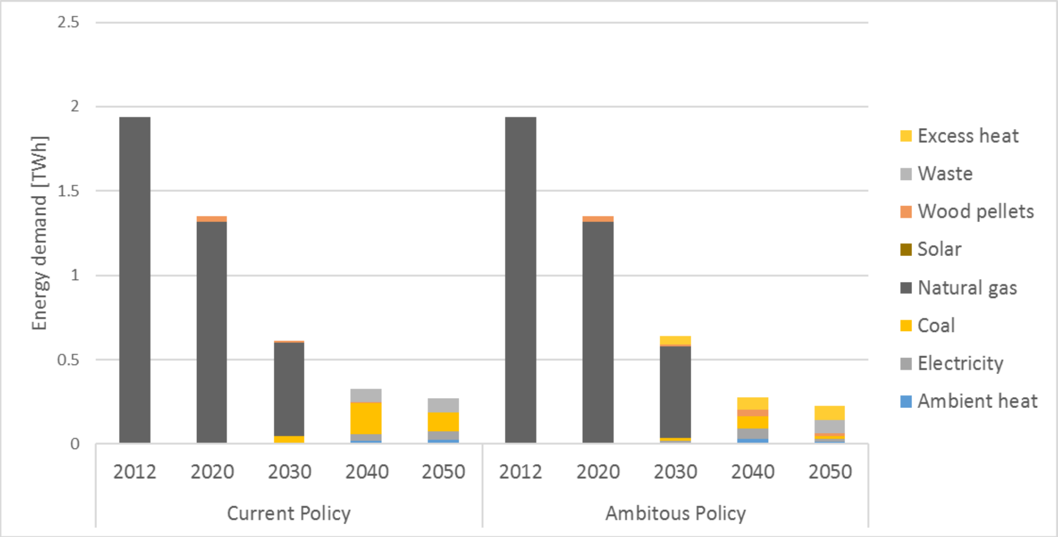

Figure 83: Energy demand in large district heating areas by energy carrier, Portugal

In 2012, the energy demand for DH generation in small DH areas in Portugal is above 5 TWh including heavy fuel oil, natural gas, wood pellets and waste (Figure 84). Under the current policy scenario the fuel consumption reduces by 10%, while it decreases by 28% in the ambitious policy scenario. This decrease is mainly driven by the assumed decrease in DH demand in those areas. Similarly to the trend in large DH areas, in both scenarios the fossil fuels, i.e. natural gas and heavy fuel oil, and biomass fuels (i.e. straw and wood pellets) are progressively replaced by other RES (i.e. geothermal until 2040, waste, heat pumps and excess heat). As a result, waste becomes an important resource for small DH systems in 2050. The share of waste corresponds to 68% and 85% of the total energy demand in those systems in the current and ambitious policy scenario, respectively.

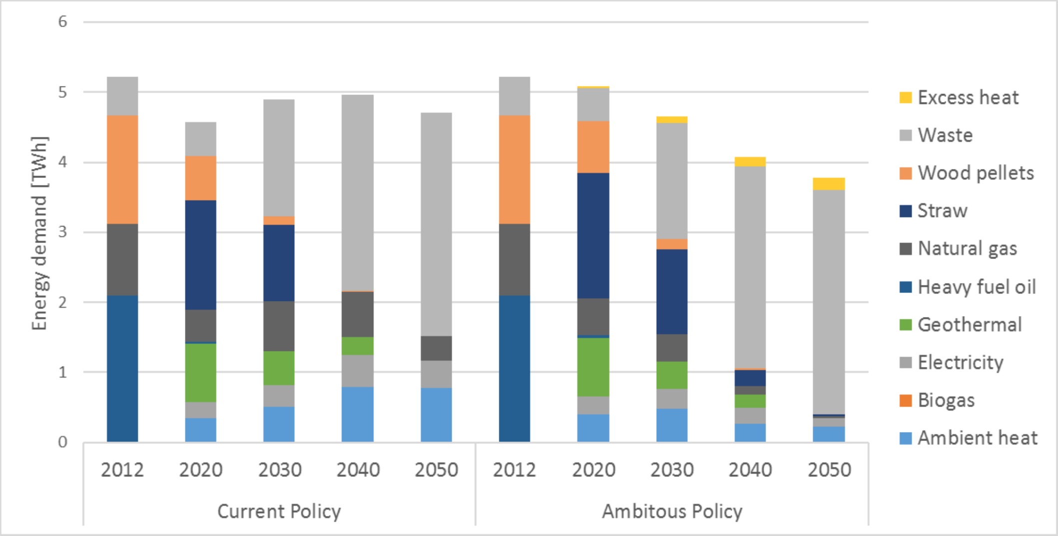

Figure 84: Energy demand in small district heating areas by energy carrier, Portugal

The energy demand for electricity generation in Portugal equals 77,8 TWh in 2012 (Figure 85). The energy demand slightly decreases towards 2050 in both the current and ambitious policy scenario, except for an increase in the demand in the year 2020. This is due to reduced and then increased exports to neighbouring Spain. The exports stay high (around 7 TWh per year) until 2050 in both policy scenarios.

While the fuel mix does not change radically in the current policy scenario, except for increased diffusion of solar and wind power at the expense of natural gas and coal, the power sector undergoes deeper modifications under the ambitious policy scenario. The hydroelectric power remains approximately constant over the time horizon with around 12,2 TWh in 2050. The reason for the fixed production is the constant hydro capacity (constraint described in the chapter 1.1). Fossil fuels, i.e. natural gas and coal, rapidly reduce their contribution to the electricity generation with the uptake of wind, wood pellets-fired plants, solar power and wave power. This is due to the combined effects of 0% interest rate for investment in technologies for RES and high CO_2 prices. In the ambitious policy scenario, the energy demand for electricity generation corresponds to 37% of wind power, 18% of hydropower, 16% of solar power, 14% of wood pellets, 8% of wave power and the remaining 7% of coal, geothermal and woodchips.

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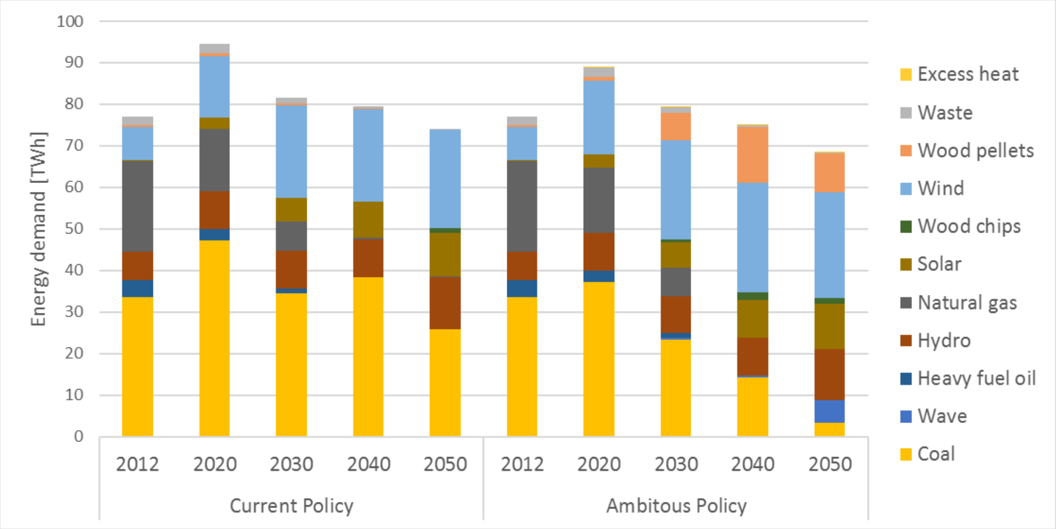

Figure 85: Energy demand for electricity generation by energy carrier, Portugal

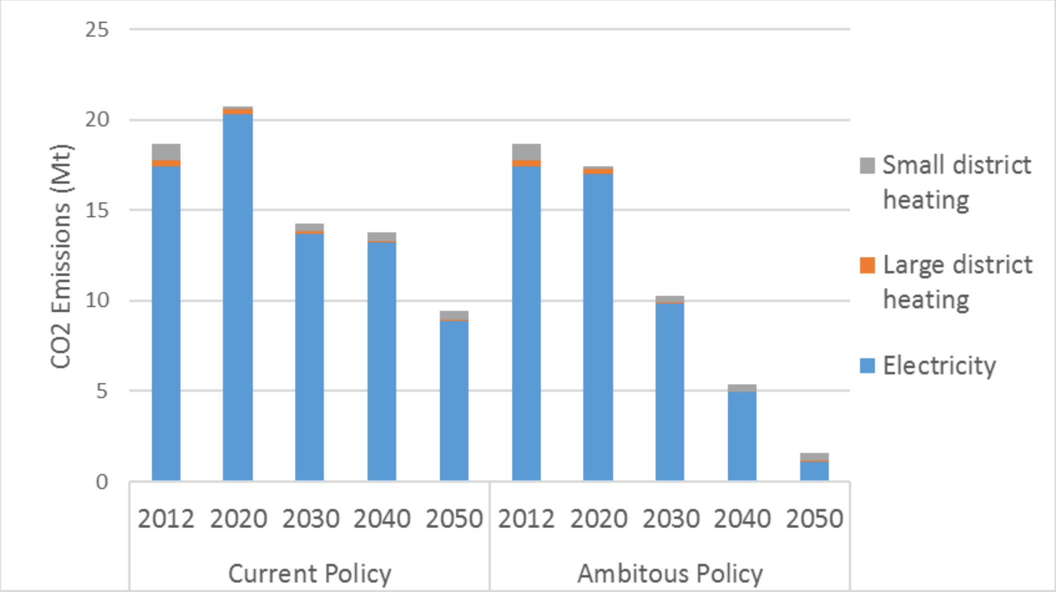

Figure 86: CO_2 emissions from generation of district heat and electricity, Portugal

The annual CO_2 emissions from the generation of DH and electricity are shown in Figure 86 for the two analysed policy scenarios. In both scenarios the DH and electricity systems undergo a deep decarbonisation moving from 18,7 Mt in 2012 to 9,5 Mt and 1,5 Mt in 2050, corresponding to a 49% and 92% reduction from 2012 levels, for the current and ambitious policy scenario, respectively.

In the current policy scenario CO_2 emissions rise to 19,3 Mt in 2020 due to the increased utilization of coal (and more generally due to the higher fuel consumption) in electricity generation. The higher fuel consumption results in higher electricity generation to cover reduced imports and increased exports of electricity to Spain. The cut in emissions from 2025 onwards is explained by the

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progressive phase-out of fossil fuels, especially in the electricity only plants, thus replaced by wind, solar and wave power. As expected, in both scenarios most of the emissions derive from electricity generation as the DH system does not have a high coverage in Portugal.

The share of RES in the generation of electricity and DH is presented in Figure 87. The RES shares in small and large DH areas and in electricity generation are presented separately for both policy scenarios. Starting from an overall RES share of 24% in 2012, in the current and ambitious policy scenario a share of 66% and 95% is achieved in 2050, respectively. Especially solar PV and wind power play a major role in Portugal, wave and geothermal power have marginal shares in the overall generation of DH and electricity from RES. The total share of RES in DH and electricity generation in Portugal follows the development of the RES share in the electricity generation, as DH plays a minor role in the country. In small DH areas a high share of RES is already reached in 2020 in both policy scenarios due to the rapid phase-out of natural gas in these areas. A slow increase of the RES share can be observed in large DH areas until 2030, with a fast uptake of RES after 2030.

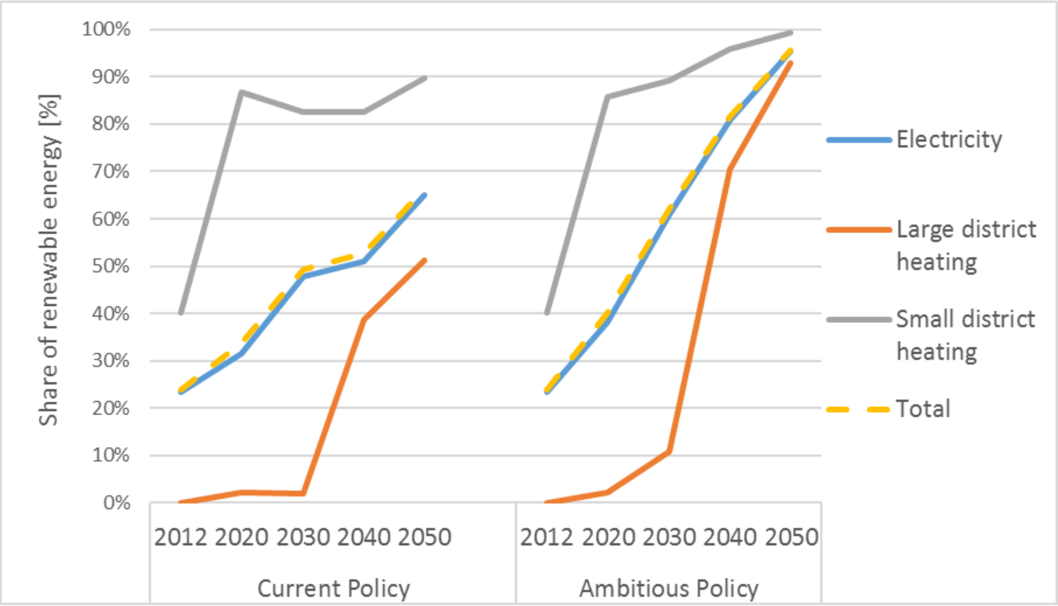

Figure 87: Share of renewable energy in district heat and electricity, Portugal

The composition of the total system costs is similar in both policy scenarios, as presented in Figure 88. As expected, in the ambitious policy scenario the total system costs show a lower share of fuel costs and a higher share of investment costs in the years close to 2050. The earnings from export of electricity to Spain are higher in the ambitious policy scenario.

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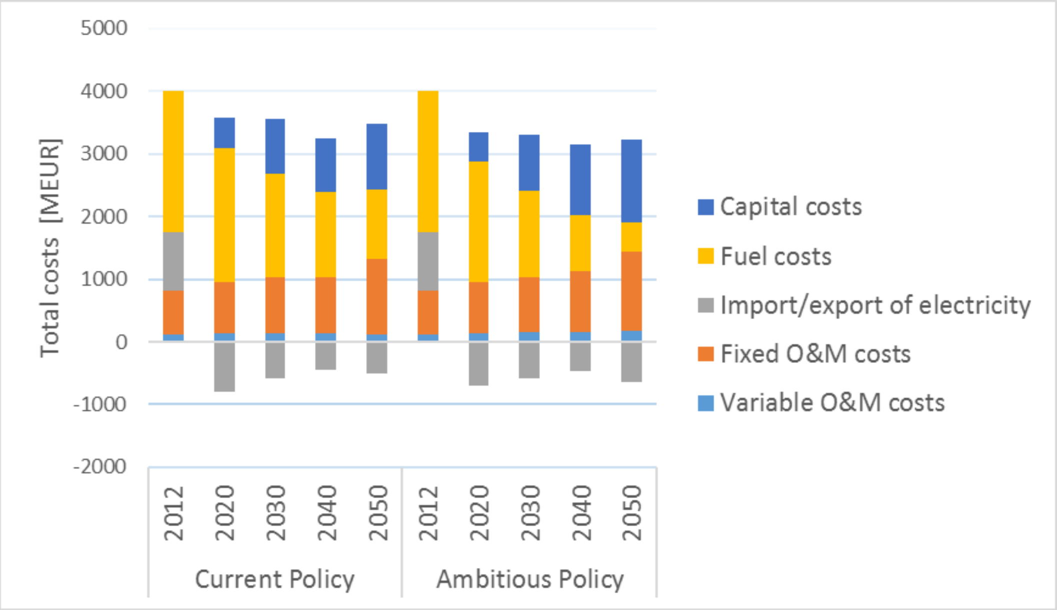

Figure 88: Total costs of district heat and electricity generation, Portugal

2.5.4 Overall heating and cooling (H/C) indicators

In this chapter the indicators for countrywide heating and cooling are documented. This comprises the results of the modelling of the buildings, industry, district heating and power sector as documented in the previous chapters, but only taking into account the amounts of emissions, energy and the share of renewable energy related to heating and cooling.

Figure 89 shows the CO_2 emissions for heating and cooling purposes from the different sectors. The overall CO_2 emissions comprise the direct emissions from the buildings and the industry sector, the emissions from the district heating sector and the emissions of the power sector originating from electricity used for heating and cooling. High reductions can be achieved in all sectors in the ambitious policy scenario. The share of the industry sector on the overall emissions increases until 2050. The current policies lead to a CO_2 reduction of 43%, while the combined effort of the ambitious policies in all sectors can lead to a reduction of 77% regarding to the modelling.

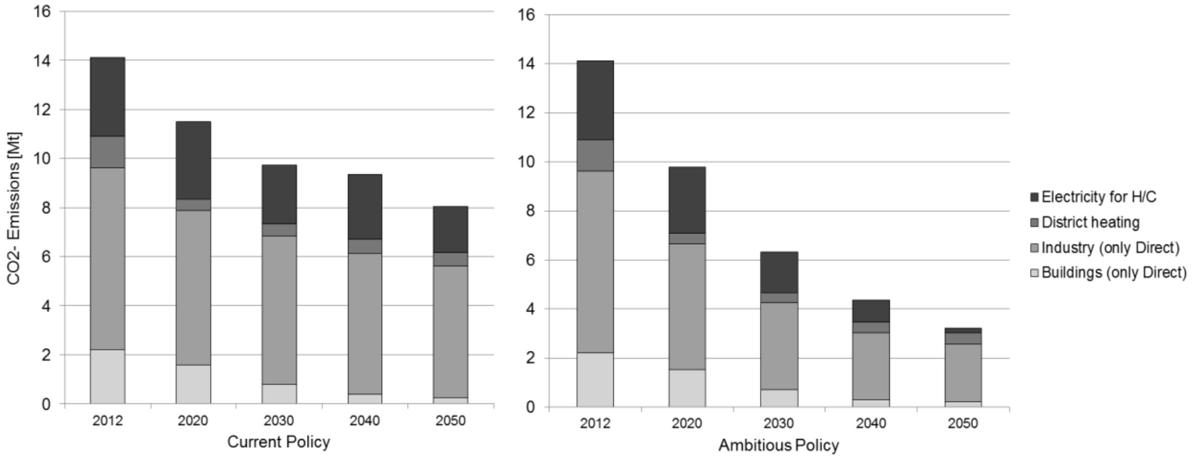

Figure 89: CO$_2$ emissions from heating and cooling by sector, Portugal

Figure 90 shows the primary energy demand for heating and cooling by energy carrier of all sectors. The reflected energy demand in this indicator comprises the fuel demand for heating and cooling from the buildings and industry sector (excluding electricity and district heating) plus the primary energy input into the district heating sector plus the primary energy input into the power sector for electricity used for heating and cooling purposes. In the industry sector in Portugal around 77% of the final energy demand is used for heating and cooling purposes. Ambient heat is the ambient part of the heat from heat pumps. Biomass includes wood chips, wood pellets and straw. Other fossils include diesel. Other renewables include biogas, biodiesel, geothermal and wave energy. Solar include solar thermal and solar PV. Waste includes renewable and non-renewable waste.

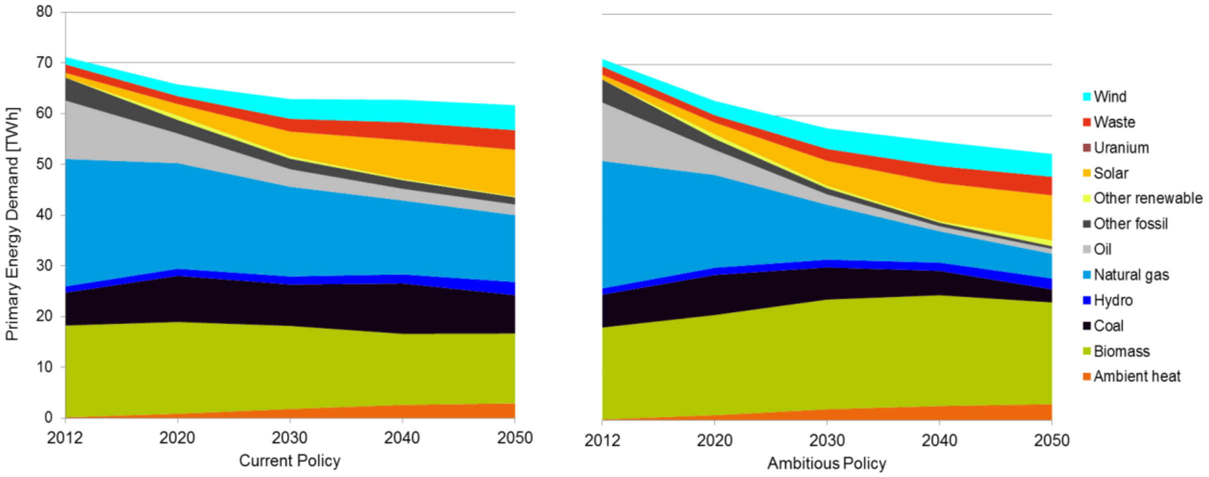

Figure 90: Primary energy demand for heating and cooling by energy carrier, including space heating, hot water, cooling and process heat, Portugal

Figure 91 shows the share of renewable energy used for heating and cooling in the different sectors. For the buildings and industry sector this share is calculated excluding electricity both in the overall demand for heating and cooling and in the amount of renewable energy used to generate electricity. The share of renewable energy in district heating, however, is taken into account in this calculation. In the ambitious policy scenario all sectors except the industry can reach more than 90% of renewable energy in heating and cooling in 2050. The industry sector reaches a share of around 70% in the ambitious policy scenario.

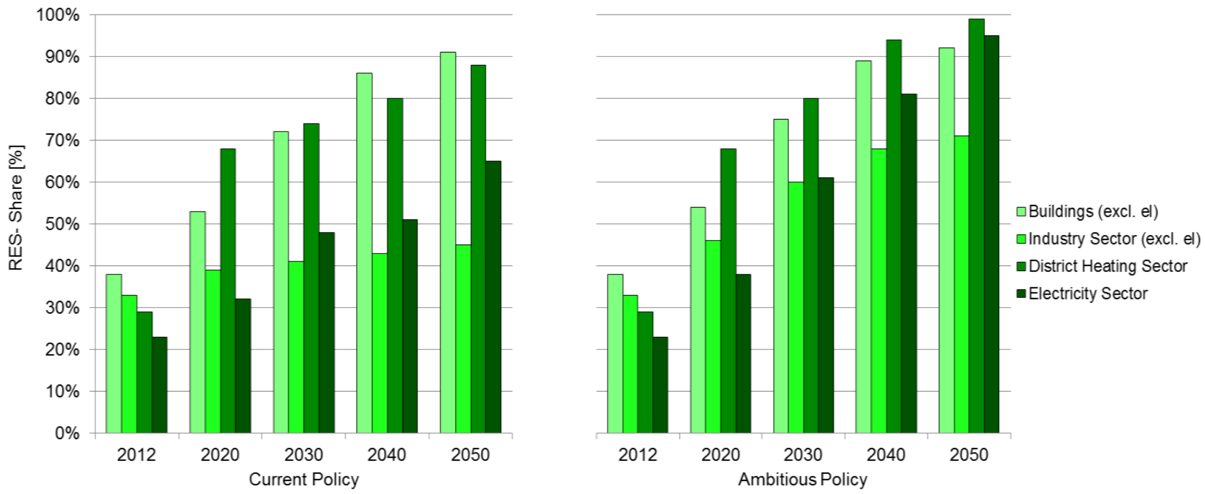

Figure 91: Share of renewables in heating and cooling by sector, Portugal

2.5.5 Conclusions and policy recommendations for Portugal

In the previous chapters the results of the quantitative assessment of the influence of two policy scenarios on demand and supply of H/C and related sectors in Portugal are documented. As shown in Figure 89 the CO_2 emissions for H/C are likely to be reduced with currently implemented policies at a low CO_2 price of 7,5 EUR/tCO_2 by 43% until 2050. More ambitious policies in the different sectors together with assuring a continuous increase of the CO_2 price to nearly 90 EUR/tCO_2 in 2050 might lead to a reduction of 77% until 2050. In the following key recommendations for policy making are described that result from the modelling of the national H/C systems within progRESsHEAT. A distinction is made between recommendations for policies targeting buildings, industry and DH and power generation.

The currently implemented and foreseen policies in Portugal targeting **buildings** are likely to reduce direct emissions from H/C in this sector to a large extent (-88%) until 2050, and at the same time remarkably increase the share of RES in this sector (from 38% to 91%). Thus, the current shape of the national building codes and renovation standards and the foreseen RES-H obligation are likely to show remarkable effects until 2050, even with a low price of CO_2. However, it has to be noted that the direct emissions from H/C in buildings do not include the emissions from electricity generated for use in air-conditioning units. These emissions are counted in the emissions from electricity generation in the country. Due to the fact that the current building codes and renovation standards focus on decreasing the heating demands and not the cooling demands, it is likely that the demand for space cooling will remarkably increase under current policies, thus leading to increased demand for electricity for this purpose. In any case, a continuous monitoring of the compliance with national building codes and renovation standards has to be installed and non-compliance has to be penalised, if the modelled emission reductions should become reality. Also, as the connection to DH is counted as an option to fulfil the RES-H obligation, it is important that DH generation is decarbonised in the mid to long term in order not to shift the source of emissions from buildings to DH. In this context it might be interesting to only allow accounting of DH for the compliance with the RES-H obligation, if for the DH system a commissioned decarbonisation roadmap exists.

Although the current policy framework leads to a remarkable decarbonisation of H/C in Portuguese buildings until 2050, more ambitious policies are needed to meet the emission reduction targets as set out in the Paris Agreement. This is especially important in order to reduce the cooling needs in the buildings, which will have a remarkable share of electricity demand (and more importantly of electricity peak load), if not mitigated. A very important measure in this context is the integration of additional shading and passive measures in the national building codes, renovation standards and nZEB-plans. To further speed up the diffusion of technologies using RES an intensified RES-H obligation is important: on the one hand the obligation should not only apply for buildings that are newly constructed, but also for buildings undergoing a major renovation and in case that the heating system is changed. On the other hand, the share of the heat to be supplied by RES should be increased, so that it becomes less interesting to fulfil the obligation with a combination of fossil fuels and solar thermal systems or paying a penalty instead of compliance. At the same time public budget for subsidising investments in technologies for RES-H should be established to additionally trigger the technology shift.

In order to stimulate the realisation of building retrofit including shading and passive measures to mitigate cooling needs public budget should be established. Retrofit could also be mandatory after a certain timeframe. For increasing retrofit rates it is also important to drive standardisation of retrofit activities and awareness raising by implementing energy performance certificates (EPC) of buildings, so that retrofit costs decrease compared to current levels. Finally, information campaigns to increase the awareness of the continuous increase of fuel and emission certificate prices are important, so that this is taken into account in the investment decisions related to building retrofit and heating and cooling systems. This, however, is linked to a continuous increase of the CO_2 prices, which can be assured by the application of a CO_2 tax or levy for all sectors at national level, if not achieved by the EU ETS.

Decarbonisation of the **industry** sector in Portugal is mainly a question of decarbonising cement production, as the non-metallic minerals sector was responsible for 75% of industrial CO_2 emissions in 2012. While half of the cement related emissions can be mitigated by switching to other fuels (biomass and RES waste, in the future maybe electric furnaces), the other half (process emissions) are more difficult to mitigate. They require either carbon capture and storage (CCS) or new low-carbon cement processes and products that are not yet on the market. Material efficiency in the construction industry might also be able to reduce cement demand, if effective policies can be implemented. Furthermore, the following recommendations are derived:

- The current policy is not on track towards decarbonisation, although emissions are decreasing slowly.
- A decarbonisation strategy for industry needs to find a solution for the high process related emissions from cement production, which accounts for nearly 60% of remaining CO_2 emissions in 2050 in the ambitious policy scenario. An option can be the use of CCS.
- Excess heat potentials should be exploited in the cement industry (and also paper, electric steel and chemicals). However, effective exploitation e.g. in DH first requires the construction of infrastructure, because Portugal currently only has one DH network in operation. The use of excess heat can be a door opener to build up new infrastructure, if issues related to risk (perception) can be overcome.
- Biomass is an important RES for the cement industry - if available according to sustainability criteria. The cement industry, however, can also use RES waste of different types in the furnaces currently in use. This should be supported.
- Regulative instruments are proposed to phase out the use of coal, fuel oil and other very CO_2 intensive fossil energy carriers.
- OPEX support of RES seems more effective than CAPEX support.
- Material efficiency and substitution of cement in the construction industry need to be supported with an entire policy mix in order to reduce the consumption (and production) of cement.
- The current policy mix already includes many policies directed towards overcoming barriers to energy efficiency (e.g. support for energy audits, energy efficiency networks and incentives for energy management schemes). While this is an important pillar of the policy mix, there are probably no more policies needed, rather the enforcement of the existing policies should be ensured.

Electricity demand in Portugal is substantially higher than the **district heating** demand. Therefore, the RES share in electricity and DH generation follows the RES share in electricity generation. This can be observed from Figure 87.

Wind and solar PV power plants seem to be cheap enough to enter to electricity generation mix even in the current policy scenario. This is mostly due to declining investment costs. However, it should be noted that Portugal has high solar PV potentials. In the ambitious policy scenario the use of coal declines faster but doesn’t completely disappear. Therefore, to completely phase out coal, higher CO_2 prices should be imposed.

In larger DH areas, coal remains an important part of the fuel mix even in 2050 in the current policy scenario. On the contrary, in the ambitious policy scenario coal is replaced by excess heat and waste. Thus, the assumed polices in the ambitious policy scenario lead to an effective conversion of larger DH systems to high shares of RES.

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In smaller DH areas a very high RES share is achieved even in the current policy scenario. Therefore, it should be considered to increase the support for RES in larger DH areas or redistributing the assumed support from smaller to largeer DH areas.

The modelling of the buildings furthermore shows the importance of DH prices as argument for the consumers to switch to DH. On the one hand can favourable financing conditions for DH infrastructure lower DH consumer prices. On the other hand it can be recommended to implement a stronger planning approach regarding H/C including the definition of DH priority areas in order to increase the connection rates and therefore lower the DH prices for all connected consumers.

2.6 The case of Romania

2.6.1 Buildings

This chapter documents selected indicators for the current and ambitious policy scenario related to buildings in the residential and tertiary sector.

For buildings the **current policy scenario** includes the following policies that are already in place in Romania:

- New buildings are constructed according to the current national building codes and the foreseen changes until 2021. This includes the national definitions of “Nearly Zero Energy Buildings”.
- The current building regulation includes a weak renewable heat obligation: after 2025 a share of 10% of the heat demand in newly constructed buildings has to be covered by heating technologies using renewable energy.
- A small public budget in the order of 100-150 MEUR per year is available for subsidising the retrofit of existing buildings and for subsidising the additional costs of constructing new buildings at heat demands lower than stated in the national building codes.
- For investment subsidies of heating technologies using renewable energy a small public budget in the order of 30-40 MEUR annually is available.

The **ambitious policy scenario** for the building sector includes additional policies in order to reach a remarkable CO_2 reduction of around 80% in the scenario timeframe. The following policies are implemented for the case of Romania:

1. The Building codes and nZEB-plans will be kept at current state.
2. The renewable heat obligation in the building regulation will be intensified: starting with around one third of heat demand that has to be covered by renewable energy after 2020, an increasing share has to be covered by renewables after 2030 and more than two thirds have to be renewable after 2035. This renewable heat obligation applies to new buildings only in the period from 2020 to 2030. Afterwards it also applies in case of a major renovation or a heating system replacement and district heating is counted 100% as an option to reach this share, even if district heating is not 100% supplied by renewable energies.

3. The public budget for subsidising the retrofit of existing buildings and for subsidising the additional costs of constructing new buildings at heat demands lower than stated in the national building codes will be almost doubled..
4. The public budget for subsidising heating technologies using renewable energy will be more than doubled, supporting 30% of the investment costs.
5. Favourable financing conditions for district heating infrastructure will lead to a decrease of district heating costs by 10% in all regions.
6. A stronger planning approach with definition of district heating zones will allow high connection rates leading to a 50% lower district heating price in these zones.
7. As stated in the general scenario assumptions in section 1.1 all sectors have to pay a rising CO_2 price according to the PRIMES projection. This causes higher energy end consumer prices for fossil fuels.
8. Information campaigns will lead to decision-makers being aware of the continuous increase in prices for fuels and CO_2 emission certificates. This causes that rising prices will be taken into account in their investment decisions.
9. It is assumed that by standardisation, awareness rising through EPCs etc. a decrease of building renovation costs by almost 15% can be reached until 2050.

In the following figures key indicators for the current and ambitious policy scenario for buildings in Romania are compared: direct CO_2 emissions, final energy demand, share of renewables (excluding electricity), total annual running and investment costs and the direct costs (of subsidies) for the described policy programmes.

Figure 92 shows the development of the direct CO_2 emissions from the building sector in Romania. As emissions from district heating and electricity are not included in this figure, the emissions only result from the use of individual natural gas and very few oil and coal boilers. A decrease in CO_2 emissions in the building sector from 4,8 Mt in 2012 to 2,3 Mt (-52%) in 2050 can be achieved in the current policy scenario and to 0,91 Mt (-81%) in 2050 in the ambitious policy scenario. This difference between the two policy scenarios originates to one part from a higher level of heat savings reached with the ambitious policies and to another part from the phase out of oil and the lower amount of natural gas that will remain in the 2050 heat supply in the ambitious policy scenario.

At least a part of the remaining gas demand could also be covered by renewable energy sources, which would further reduce CO_2-emissions and increase the share of renewable energy. However, this aspect was not further analysed in this project.

The considerable GHG-emission reductions already in the current policy scenario are mainly due to currently implemented (or expected) building codes and nZEB standards as well as existing renewable heat obligation and subsidy schemes. Also increasing energy prices contribute to the result. Thus, the result should not be understood in a way that this will happen anyway. First, continuous (and maybe even enhanced) efforts will need to be taken to ensure a proper compliance with existing building codes and regulations. Second, other existing instruments will need to be kept in place and the corresponding public budgets for subsidies will need to be provided. Third, in case of

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lower energy prices than expected, higher efforts will be required to achieve the result presented here as current policy scenario.

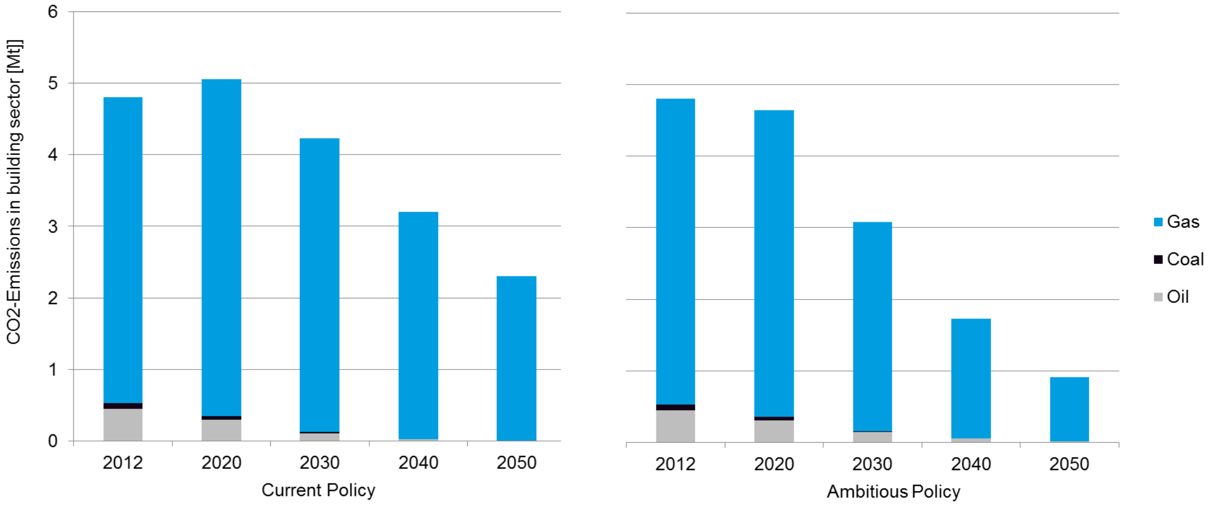

Figure 92: Direct CO_2 emissions for space heating and hot water preparation per energy carrier in the residential and tertiary sector, Romania

Figure 93 shows a decrease in final energy demand for heating and cooling from 75,7 TWh in 2012 to 54,7 TWh (-28%) until 2050 in the current policy scenario and to 45 TWh (-41%) in the ambitious policy scenario. On the secondary axis the figure shows the share of renewable energy in the building sector. For the heat delivered by district heating the respective renewable share of the district heating sector as shown in chapter 2.6.3 is used. Electricity used for heating and cooling is not included in the calculation of this share but the renewable share of the power sector is also shown in in chapter 2.6.3. While with current policies a share of renewable energy of 69% can be achieved in 2050, the share rises to 88% with ambitious policies. This increase derives mainly from less individual natural gas boilers and a higher share of renewable energies in the district heating sector.

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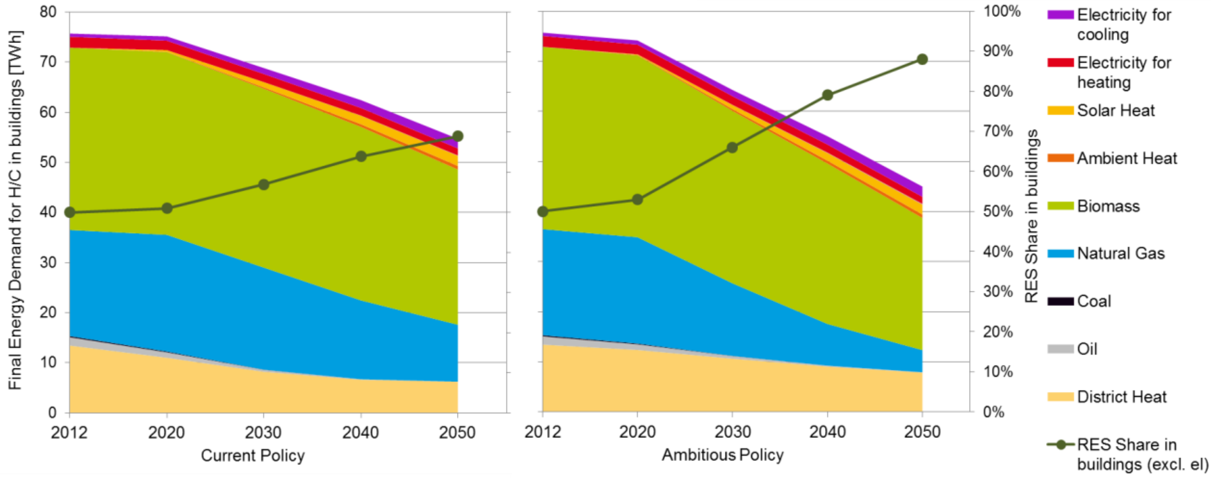

Figure 93: Final energy demand and share of renewables for space heating, hot water preparation and space cooling by energy carrier in the residential and tertiary sector, Romania

Figure 94 shows the development of the annual total investment and running costs for both policy scenarios. Running costs can be reduced by 22% in 2050 compared to the current policy scenario due to a reduction in the amount of natural gas boilers. The increased subsidies for retrofitting and heating systems using renewable energy generate additional investments in the ambitious policy scenario.

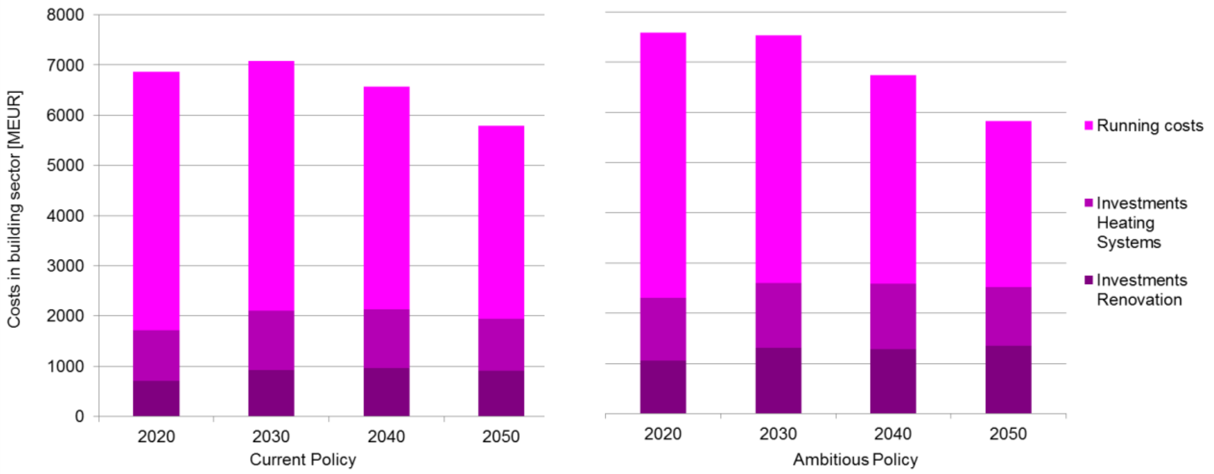

Figure 94: Investments and running costs for building renovation and heating and hot water systems in the residential and tertiary sector, Romania

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Figure 95 shows the increasing policy programme costs for the ambitious scenario compared to the current policy scenario. These costs include subsidies for renovation measures and subsidies for heating technologies using renewable energy, also including solar thermal systems. The latter will be used to a large extent for replacing individual natural gas boilers. This leads to an additional CO_2 reduction of more than 60% in 2050 compared to the current policy scenario.

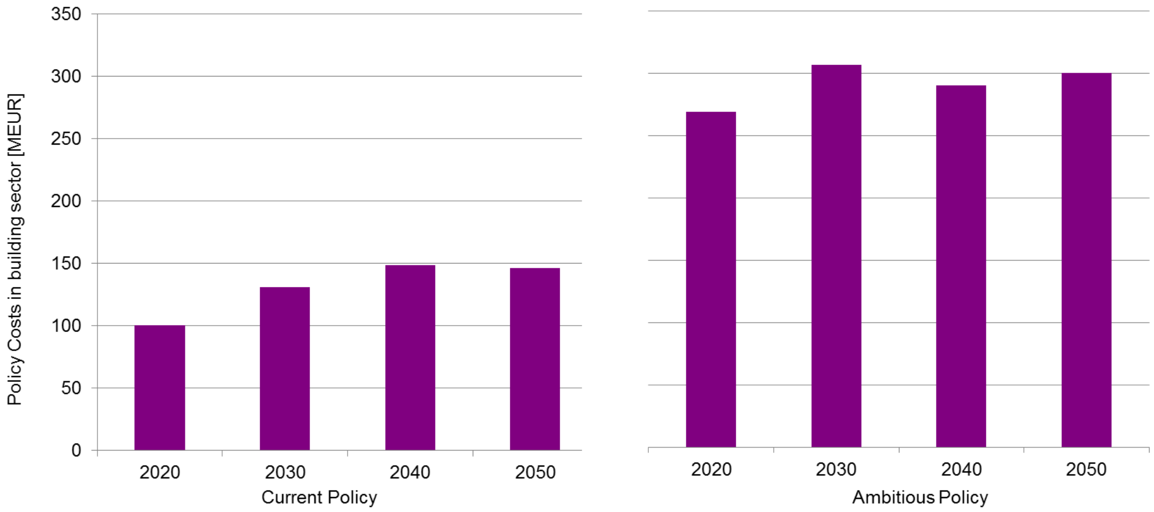

Figure 95: Policy programme costs for the residential and tertiary sector, Romania

2.6.2 Industry

This chapter documents selected indicators for the current and ambitious policy scenario in the Romanian industry sector.

- The **current policy scenario** considers policies implemented by 2015 including among others. This includes among others the CO_2 price, EU Ecodesign Standards for energy using products as well as Energy taxes as reported by Eurostat in 2015.

The **ambitious policy scenario** represents a much more ambitious policy mix towards the transformation of the industrial heating and cooling sector. It comprises of the following main elements:

1. Policy package addressing classical non-financial barriers to energy efficiency including the roll-out of energy management systems, energy audits, soft loans, etc.
2. Extension of Ecodesign Minimum standards to additional equipment including steam boilers and industrial furnaces
3. Increasing investment grants for RES-H technologies including power-to-heat using heat pumps or electric boilers for steam generation

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4. RES OPEX support: ~5 Euros/MWh for RES-H including district heating, heat pumps and electric boilers
5. CO_2 price: extending the CO_2 price beyond the ETS (same level) and changing price expectations: Companies now consider the CO_2 price 10 years ahead for their investment appraisal. This is achieved via a transparent and defined tax increase and/or a floor price for the EU ETS
6. Comprehensive support of material efficiency and circular economy: Reduced production of basic materials products due to efficiency improvements along the value chain and shift towards secondary production (e.g. electric steel replacing oxygen steel, more recycled paper, etc.). See table below and Table 9 and Table 10 in the annex for an overview on recycling and secondary production assumptions.

Table 7: Assumptions on use of recycled materials for steel, cement, aluminium and paper in Romania [%]

Indicator		Current policy scenario		Ambitious policy scenario	
	2012	2030	2050	2030	2050
Share of electric steel in total crude steel production	48%	50%	60%	54%	73%
Share of clinker in total cement production	89%	100%	100%	91%	80%
Share of secondary aluminium in total aluminium production	5%	5%	6%	11%	20%
Share of recovered fibres in total pulp production	n.a.	n.a.	n.a.	n.a.	n.a.

7. Exploitation of industrial excess heat potentials of heat >100°C for use in district heating or, where district heating networks are not nearby, for electricity generation. This can be implemented via financial support but also via regulation (e.g. related to pollution control)
8. Innovation support to speed-up the market introduction of low-carbon production processes for the basic materials industries. This includes various strategies from niche markets via requirements for public procurement, to research, development and innovation (R&D&I) support as grants and soft loans (see e.g. discussion on EU Innovation Fund) a minimum CO_2 price path and more.

Results of the current and the ambitious policy scenarios are presented and compared below, beginning with CO_2 emissions, before discussing final energy demand and excess heat potentials from industrial activity. Results are shown for the entire industrial sector including non-H/C applications like mechanical energy. However, non-H/C applications are nearly exclusively found in electricity use, while fuel consumption can be attributed to H/C.

In 2012, the Romanian industry emitted about 24 million tonnes of CO_2, of which about 7 million tonnes are process related emissions, mainly from the cement industry. While in the current policy scenario emissions remain relatively constant until 2050, they decrease by about 45% in the ambitious policy scenario (see Figure 96). In 2050, the remaining emissions are from coal, natural gas and to a large extend related to processes. The latter accounts for about 51% of total remaining CO_2 emissions in the ambitious policy scenario.

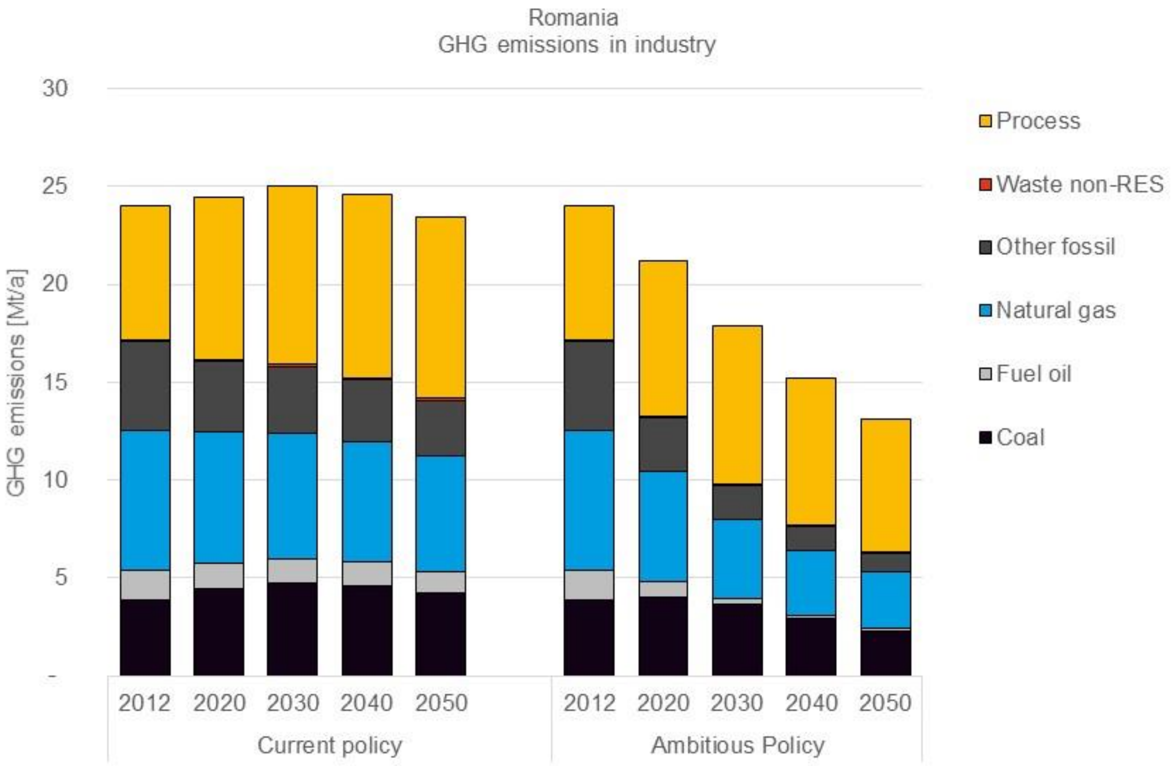

Figure 96: Direct GHG emissions in industry by energy carrier (including process emissions), Romania

The breakdown of industrial CO_2 emissions by sub-sector reveals the importance of the non-metallic minerals industry (mainly cement), the iron and steel industry and the chemical industry (Figure 97). In the ambitious policy scenario, all sub-sectors reduce emissions compared to 2012 but also compared to the development in the current policy scenario. Still, the non-metallic minerals industry is gaining in relative importance and accounts for about 48% of total remaining emissions in 2050. The main reason is the amount of process related emissions from the cement (clinker) production. These emissions are difficult to mitigate with current technologies. Carbon capture and storage might be an option, but was not considered in both scenarios.

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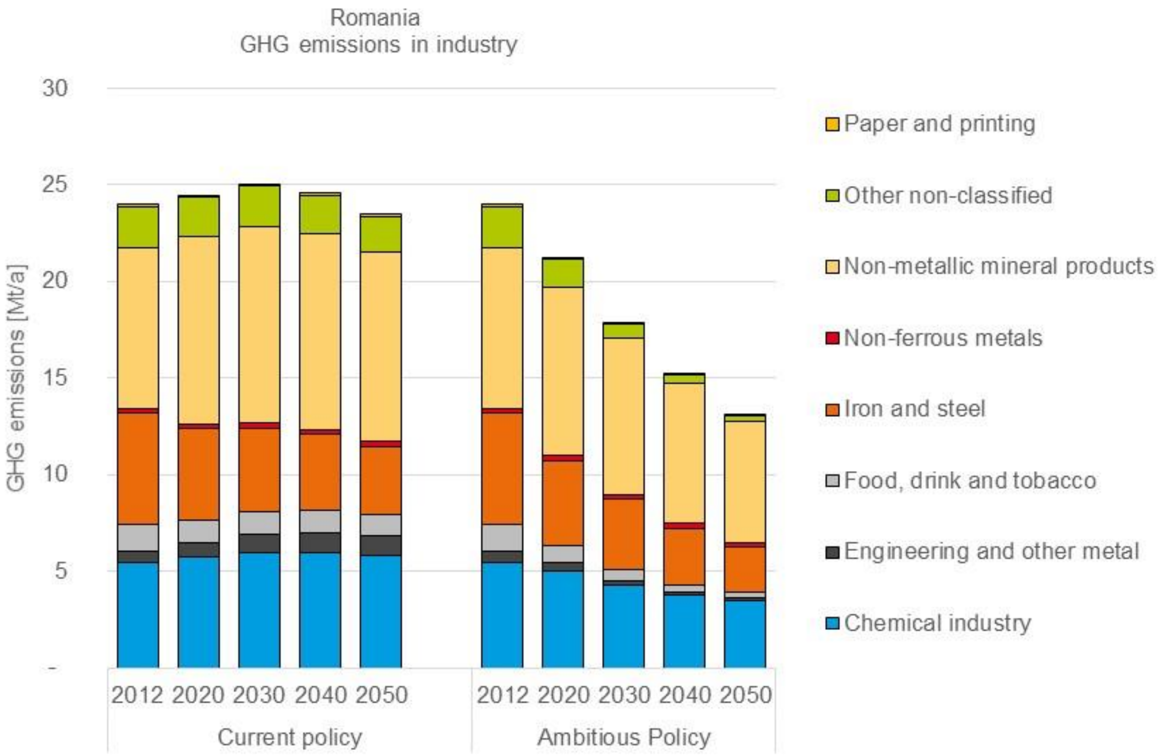

Figure 97: Direct GHG emissions in industry by sub-sector (including process emissions), Romania

Final energy demand slowly decreases in the ambitious policy scenario until 2050 (by 10% compared to 2012) as shown in Figure 98. Fuel oil is nearly completely phased out by 2050, but also the importance of natural gas and coal is diminishing over time, while biomass is increasing from about 3 TWh in 2012 to 25 TWh in 2050. Consequently, also the share of renewable energy is increasing from a very low level of 5% in 2012 to about 53% in 2050. Note that electricity is not included in the calculation of this share. However, the main part of electricity is used for mechanical energy in industry.

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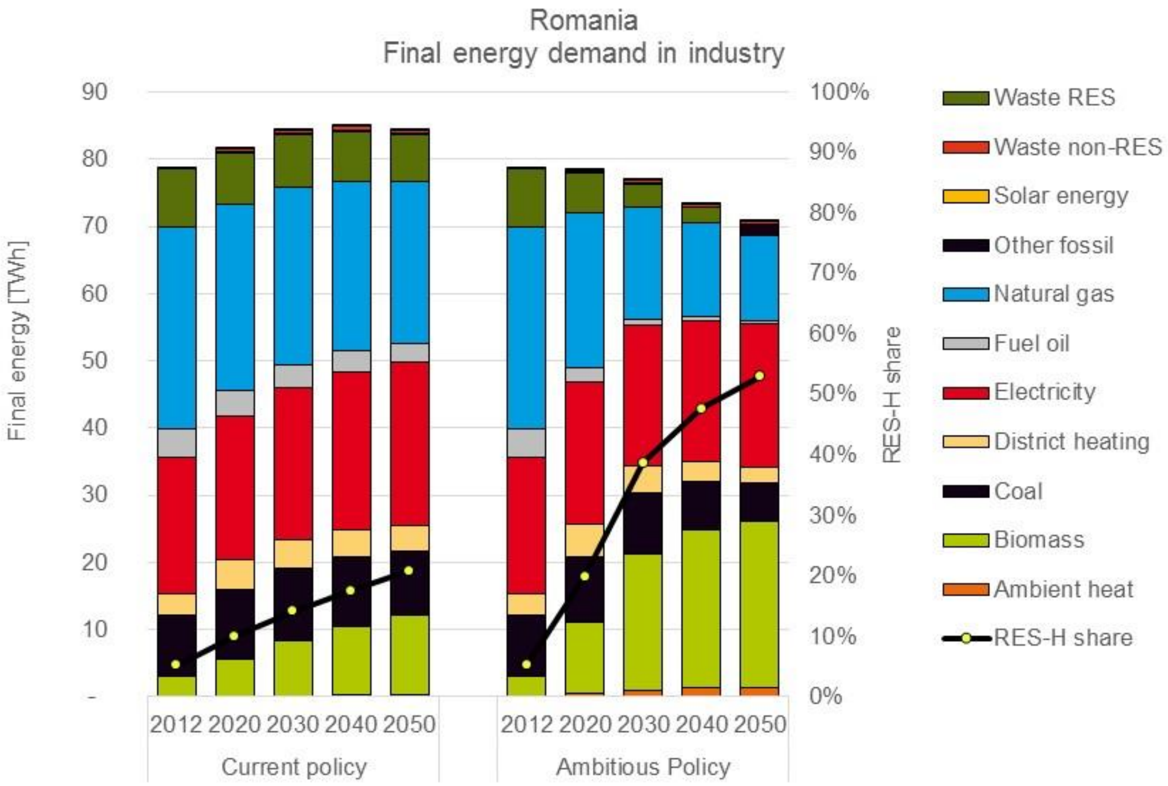

Figure 98: Final energy demand and share of renewables in industry by energy carrier, Romania

Industrial excess heat potentials (flue gas >100°C) in Romania are dominated by the clinker (cement) production, however, other processes like electric steel, primary aluminium, glass, lime or ammonia also show substantial potentials. These potential heat sources can feed into district heating grids.

Note that our assessment of excess heat potentials only considered 30 energy intensive processes/ products and only looked at excess heat from flue gases available at temperatures above 100°C. There is potentially more excess heat available from other sources not covered here and also at lower temperature levels than 100°C.

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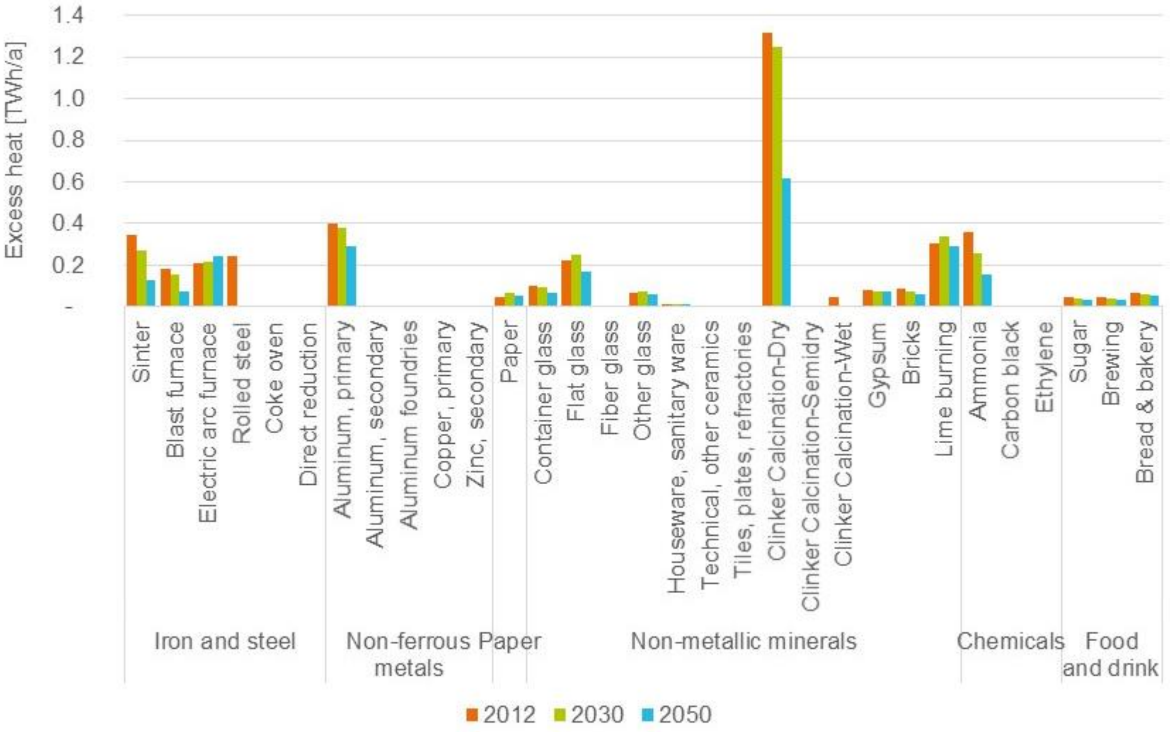

Figure 99: Industrial excess heat potential (>100°C) by process in the ambitious policy scenario, Romania

The assessment of individual policy instruments shows a large impact for energy efficiency policies, financial OPEX support for renewable energy technologies and material efficiency policies (see Figure 100).

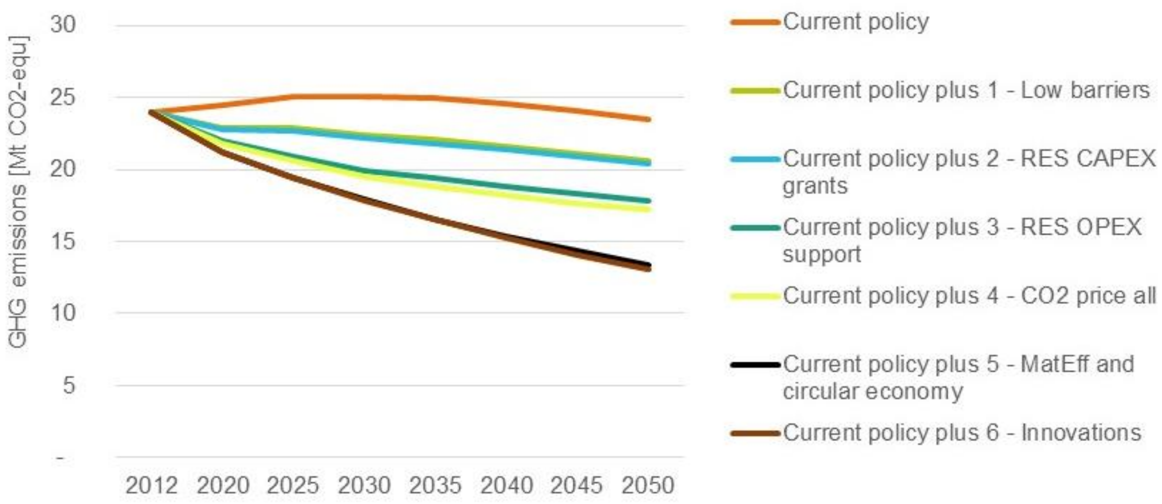

Figure 100: Direct GHG emissions in industry by policy variant, Romania

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To summarize, industrial sector GHG emissions are dominated by the non-metallic minerals (cement and to less extend also lime), the iron and steel and the chemicals industries. Emissions are reduced by half in the ambitious policy scenario until 2050 compared to 2012.

2.6.3 District heating and the power sector

This chapter documents selected indicators for the current and ambitious policy scenario in the Romanian district heating (DH) and power sectors. As described in the methodology section, the results are based on an optimisation model (TIMES), which does not necessarily include all relevant and realistic barriers and diffusion constraints. Thus, the results illustrate the cost-optimal investments and operation of the electricity and district heating system, while some non-economic factors (diffusion constraints, social acceptance, political factors, etc.) might not be represented in the results.

In addition to the scenario assumptions outlined in chapter 1.1, the following assumptions are specific for the case of Romania:

- Annual capacity growth of large-scale PVs is limited
- The annual production from nuclear plants in both scenarios is set to 9% of the electricity demand in 2020 and 17% of the electricity demand in 2050 in accordance with the Romanian energy strategy

The energy demand in large and small DH plants is presented for the two policy scenarios in Figure 101 and Figure 102, respectively. The most notable effect in both policy scenarios is the out-phasing of natural gas and coal for small DH areas and natural gas and heavy fuel oil for large DH areas. The general reduction in fuels used for generation of DH can be observed - from 31 TWh in 2012 to 15 TWh and 13 TWh in 2050 in the current and the ambitious policy scenario, respectively. This is mostly the results of falling heat demands, as projected by the INVERT/EE-Lab model.

Regarding the large DH areas, coal powered CHPs will take over as the main contributor to heat generation within the current policy scenario. In the ambitious policy scenario, however, wood pellet powered CHPs take the role as main contributor with geothermal and solar thermal collectors gradually entering the system from 2030 onwards.

Within the small DH areas, coal gradually decreases in the generation with the overtaking from large-scale heat pumps, waste incineration and natural gas plants within the current policy scenario. Within the ambitious policy scenario, the use of natural gas is gradually decreasing, while straw plants are phased in from 2015 and large-scale heat pumps are appearing from 2030 onwards. The combination of approx. 2,5 TWh of heat each generated by heat pumps, straw and waste incineration plants, provides the main supply of small DH. Coal, natural gas, geothermal and excess heat are contributing with a minor part to the generation mix (below 0,5 TWh).

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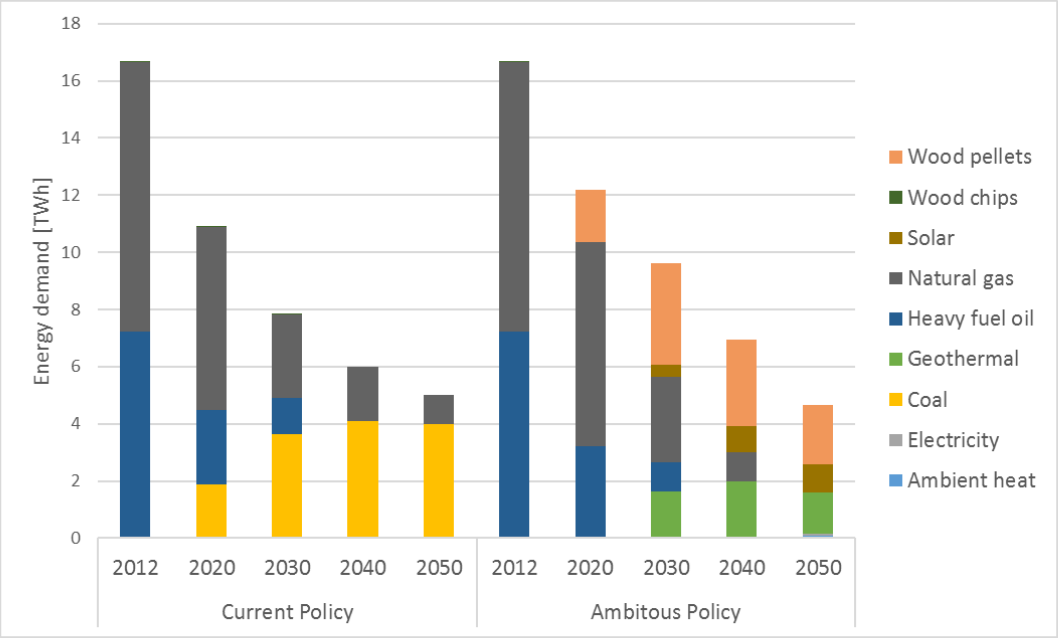

Figure 101: Energy demand in large district heating areas by energy carrier, Romania

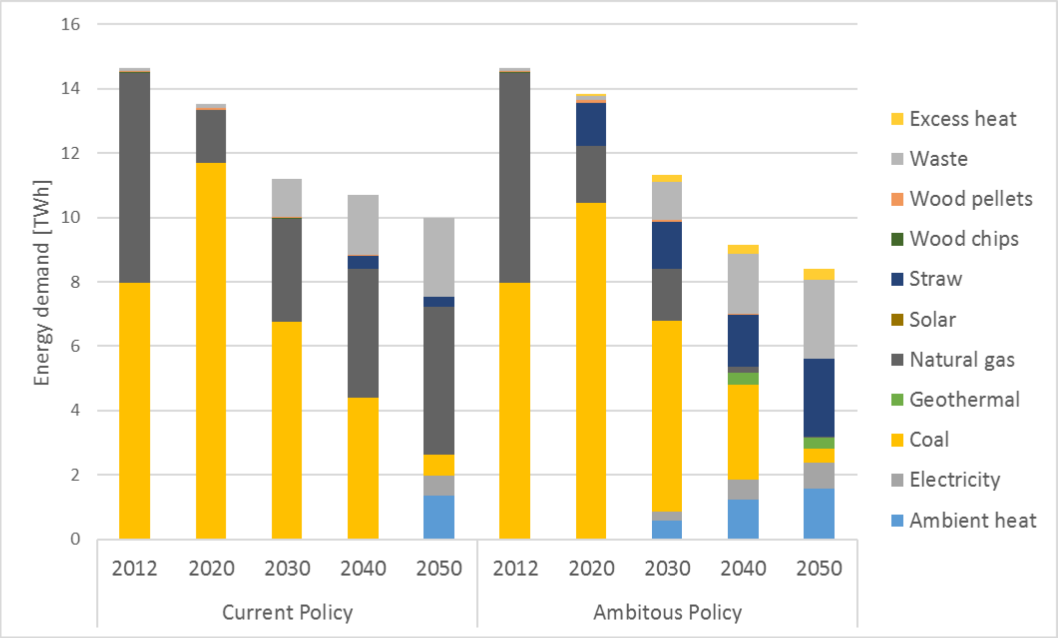

Figure 102: Energy demand in small district heating areas by energy carrier, Romania

Energy demand for electricity generation equalled 126 TWh in 2012 (Figure 103), remaining almost constant up to 2050 in both the current policy and the ambitious policy scenario. The fuel mix does not change drastically within the current policy scenario, except for increased diffusion of solar and geothermal power at the expense of natural gas and coal. On the other hand, the electricity generation undergoes deeper modifications under the ambitious policy scenario - the electricity

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generation almost entirely converts to a 100% fossil free fuel mix. In the ambitious policy scenario the implementation of plants powered by wood pellets overtake most of the remaining 47 TWh electricity generation from coal plants, while a small increase in both solar and wind power can be seen compared to the current policy scenario. The generation from hydro and nuclear power plants remains constant throughout the analysed period due to constraints explained in the beginning of the present chapter and in chapter 1.1. In other words, the TIMES model does not optimise on the investments in nuclear and hydro power plants in Romania.

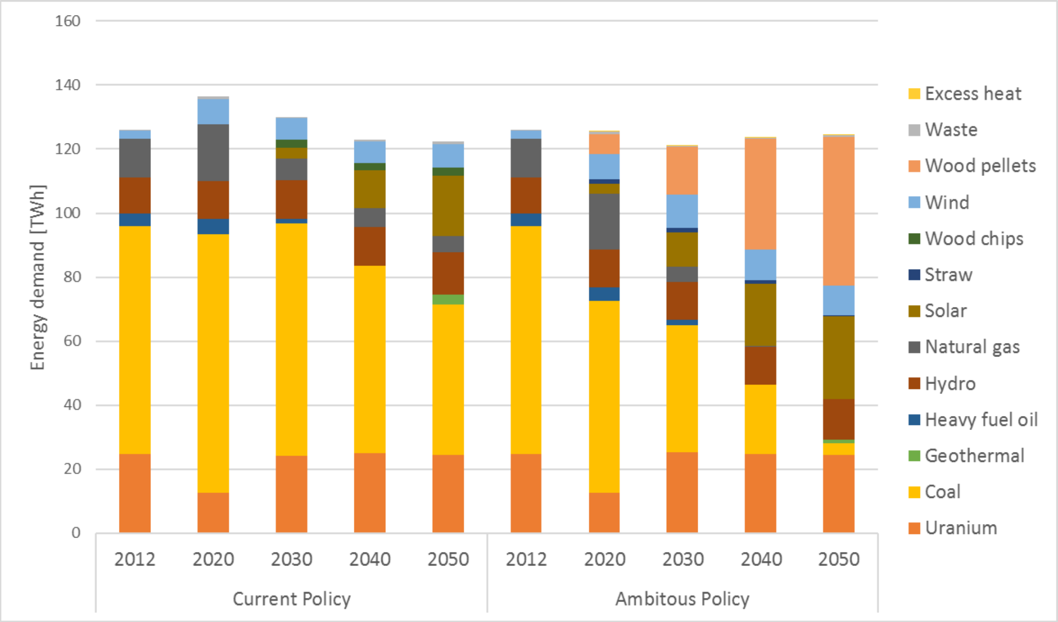

Figure 103: Energy demand for electricity generation by energy carrier, Romania

The annual CO_2 emissions from the electricity and DH generation are shown in Figure 104 for the analysed scenarios. Whereas the implementation of RES within the current policy scenario does provide a decrease in the emissions of around 45%, in the ambitious policy scenario fossil CO_2 emissions are almost entirely phased out in 2050. The remaining CO_2 emissions in the ambitious policy scenario are generated by coal powered CHP.

In the ambitious policy scenario in Romania the CO_2 emissions are lowered severely in the period towards 2050 and in the year 2050 by more than 18 Mt compared to the current policy scenario. This could prove a significant factor in the European ambition towards an 80% reduction in total CO_2 emissions, within the Union, by the year 2050.

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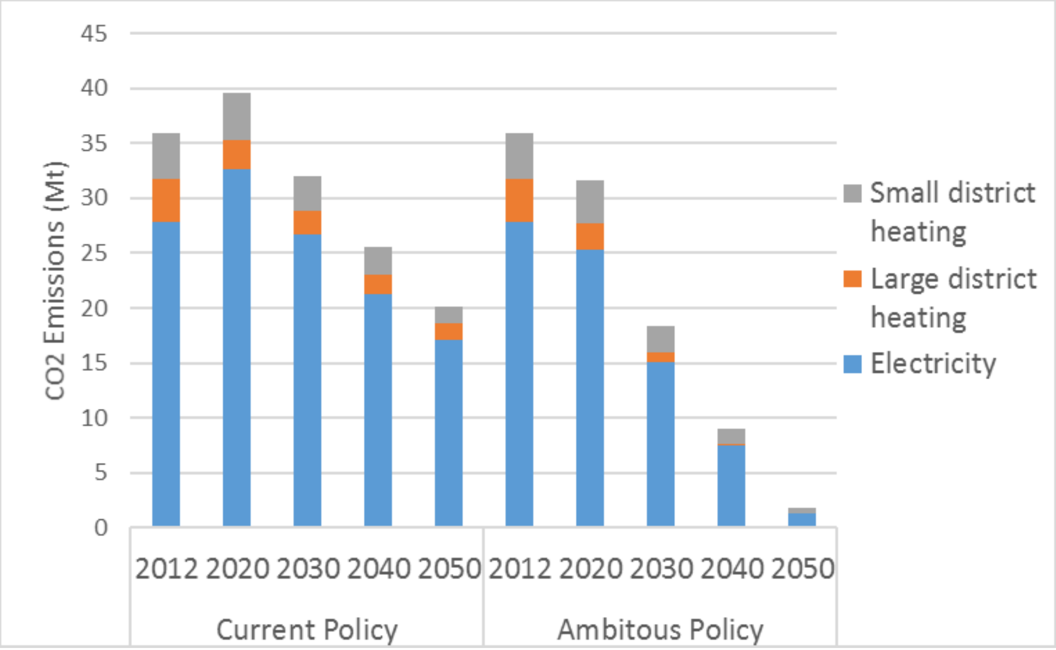

Figure 104: CO_2 emissions from generation of district heat and electricity, Romania

The RES share on the total energy used in DH and electricity generation increases in both policy scenarios (Figure 105) moving towards 2050. The growing trend translates from the increase of RES electricity and DH generation at the expense of fossil fuels. In 2050, the share of RES reaches 37% and 79% in the current and the ambitious policy scenario, respectively. The share of RES evolves at different paces. In the current policy scenario the fastest implementation of RES appears in the last 10 years. In contrast, in the ambitious policy scenario the development accelerates drastically in the period between 2020 and 2030, where 45% of the DH and electricity generation shifts to RES. In the ambitious policy scenario only 1% of the electricity and DH generation is supplied by fossil fuels emitting CO_2, with the remaining 20% of generation coming from nuclear power plants. The investments in nuclear power plants are the result of the constraints and are not optimised by the TIMES model.

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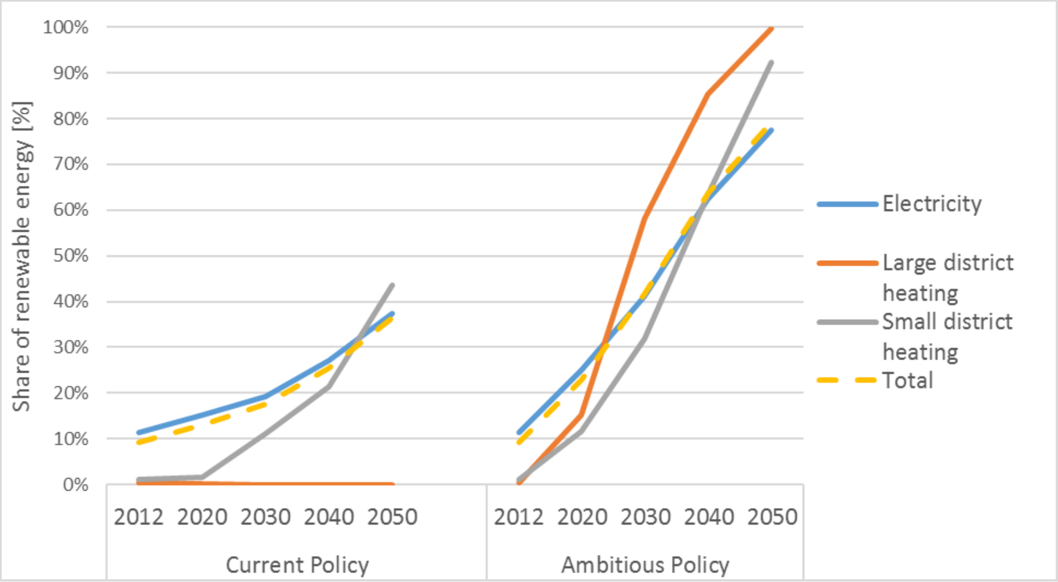

Figure 105: Share of renewable energy in district heat and electricity, Romania

Three effects lead to the small difference in the system costs for the analysed scenarios. First, a significant part of investments in electricity generation (hydro and nuclear) is a result of the implemented constraints and is not optimised within the model. This leads to the same investment costs. Second, the switch from cheap coal and natural gas in the current policy scenario to more expensive biomass plants in the ambitious policy scenario for the generation of electricity and DH is evened out due to 0% interest rate on investments in technologies using RES. Third, the projected demand is smaller in the ambitious scenario. Therefore, supply from slightly more expensive technologies is possible at the same total cost.

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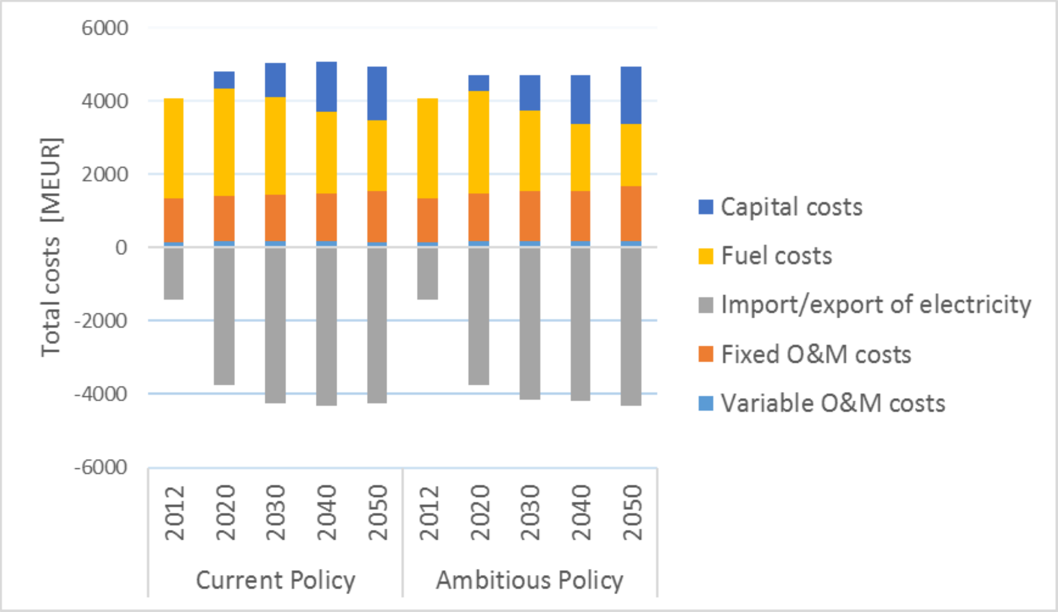

Figure 106: Total costs of district heat and electricity generation, Romania

A general increase in CO_2 taxes in the ambitious compared to the current policy scenario leads to minimised consumption of fossil fuels. Furthermore, governmental support to high-cost and high-risk plants as wind, solar and geothermal power and heating plants as assumed in the ambitious policy scenario could result in an increased investment in such technologies.

2.6.4 Overall heating and cooling (H/C) indicators

In this chapter the indicators for countrywide heating and cooling are documented. This comprises the results of the modelling of the buildings, industry, district heating and power sector as documented in the previous chapters, but only taking into account the amounts of emissions, energy and the share of renewable energy related to heating and cooling.

Figure 107 shows the CO_2 emissions for heating and cooling purposes from the different sectors. The overall CO_2 emissions comprise the direct emissions from the buildings and the industry sector, the emissions from the district heating sector and the emissions of the power sector originating from electricity used for heating and cooling. High reductions can be achieved in all sectors in the ambitious policy scenario. The share of the industry sector on the overall emissions increases until 2050. The current policies lead to a CO_2 reduction of 35%, while the combined effort of the ambitious policies in all sectors leads to a reduction of 76% in the modelling.

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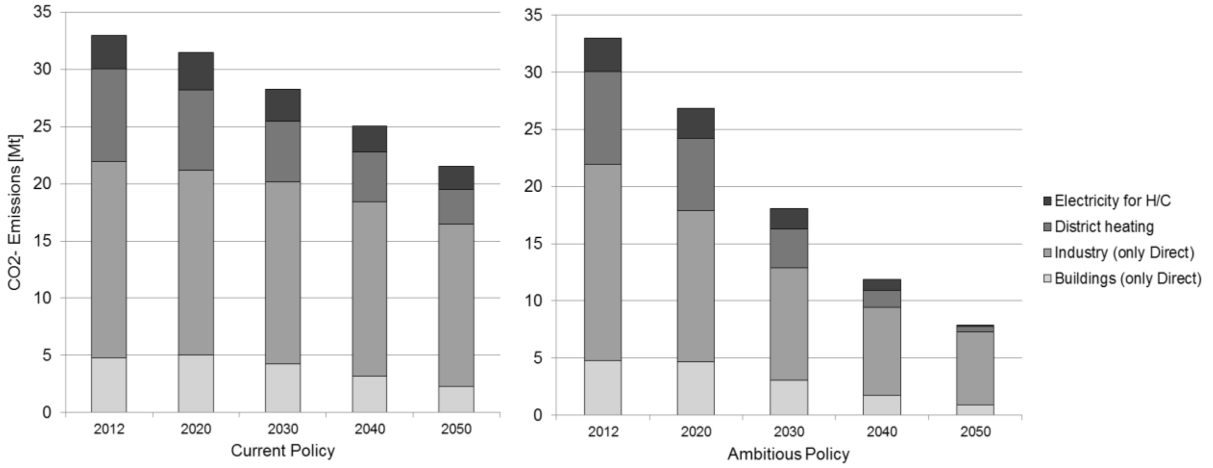

Figure 107: CO$_2$ emissions from heating and cooling by sector, Romania

Figure 108 shows the primary energy demand for space heating, hot water, cooling and process heat by energy carrier of all sectors. The reflected energy demand in this indicator comprises the fuel demand for heating and cooling from the buildings and industry sector (excluding electricity and district heating) plus the primary energy input into the district heating sector plus the primary energy input into the power sector for electricity used for heating and cooling purposes. In the industry sector in Romania around 78% of the final energy demand is used for heating and cooling purposes. Ambient heat is the ambient part of the heat from heat pumps. Biomass includes wood chips, wood pellets and straw. Other fossils include diesel. Other renewables include biogas, biodiesel, geothermal and wave energy. Solar include solar thermal and solar PV. Waste includes renewable and non-renewable waste.

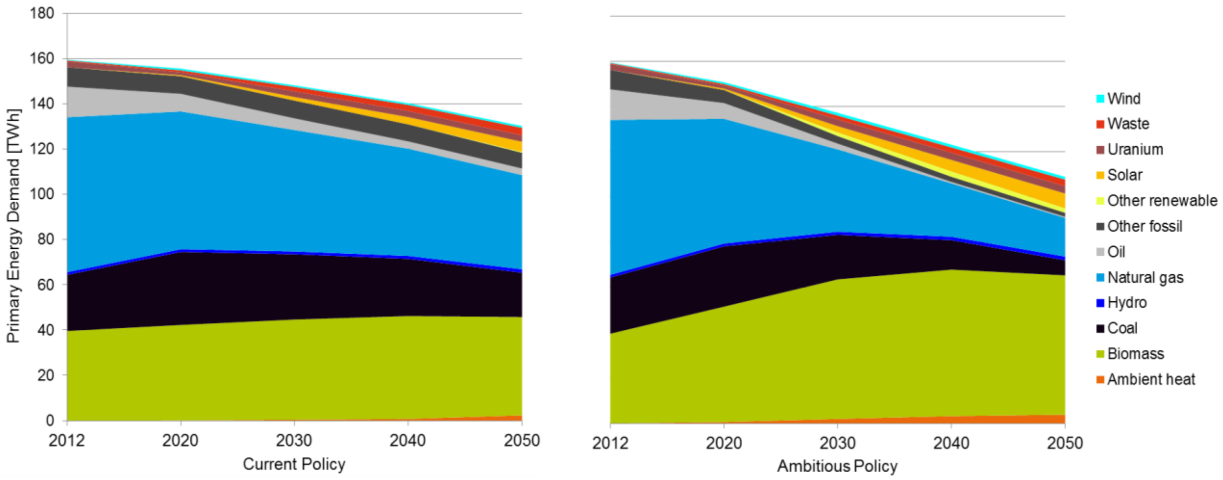

Figure 108: Primary energy demand for heating and cooling by energy carrier, including space heating, hot water, cooling and process heat, Romania

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Figure 109 shows the share of renewable energy used for heating and cooling in the different sectors. For the buildings and industry sector this share is calculated excluding electricity both in the overall demand for heating and cooling and in amount of renewable energy used to generate electricity. The share of renewable energy in district heating, however, is taken into account in this calculation. In the current policy scenario a share of renewable energy of 20-40% is reached in the different sectors in 2050, except for the building sector, which reaches a share of nearly 70%. In the ambitious policy scenario all sectors reach shares above 50% with the buildings and district heating sector around 90% and the industry sector below 60%.

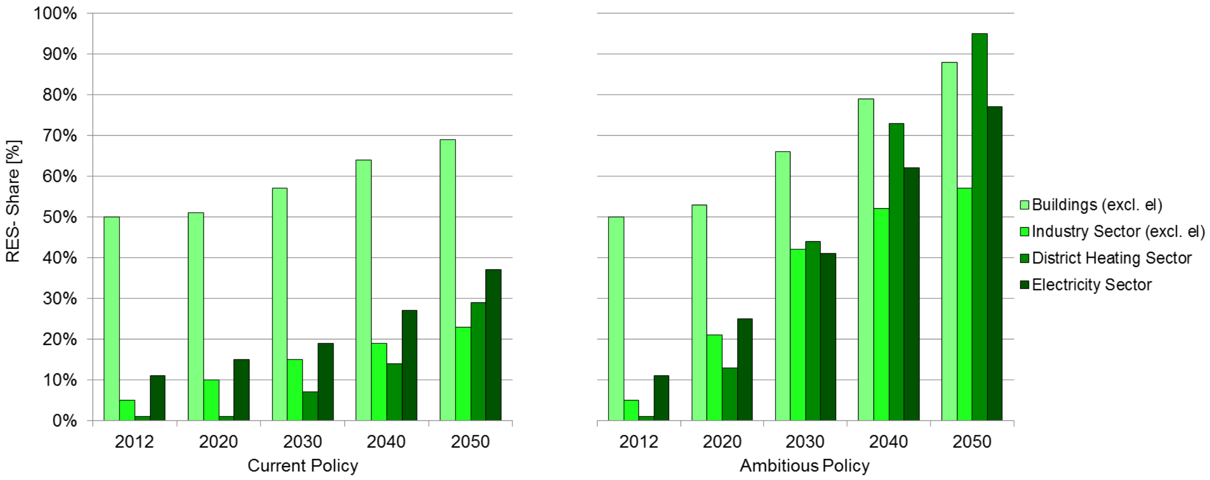

Figure 109: Share of renewables in heating and cooling by sector, Romania

2.6.5 Conclusions and policy recommendations for Romania

In the previous chapters the results of the quantitative assessment of the influence of two policy scenarios on demand and supply of H/C and related sectors in Romania are documented. As shown in Figure 107 the CO_2 emissions for H/C are likely to be reduced with currently implemented policies at a low CO_2 price of 7,5 EUR/tCO_2 by 35% until 2050. More ambitious policies in the different sectors together with assuring a continuous increase of the CO_2 price to nearly 90 EUR/tCO_2 in 2050 might lead to a reduction of 76% until 2050. In the following key recommendations for policy making are described that result from the modelling of the national H/C systems within progRESsHEAT. A distinction is made between recommendations for policies targeting buildings, industry and DH and power generation.

The currently implemented and foreseen policies in Romania targeting **buildings** are likely to reduce direct emissions from H/C in this sector to a remarkable extent (-52%) until 2050, and at the same time increase the share of RES in this sector (from 50% to 69%). Thus, the current shape of the national building codes and renovation standards, the foreseen RES-H obligation and the available public budgets for subsidising renovation and investments in technologies for RES-H are likely to

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show remarkable effects until 2050, even with a low price of CO_2. However, these emission reductions will only be achieved with the current policy framework, if a continuous monitoring of the compliance with national building codes and renovation standards is installed and non-compliance is penalised. Also, as the connection to DH is counted as an option to fulfil the RES-H obligation, it is important that DH generation is decarbonised in the mid to long term in order not to shift the source of emissions from buildings to DH. In this context it might be interesting to only allow accounting of DH for the compliance with the RES-H obligation, if for the DH system a commissioned decarbonisation roadmap exists.

Although the current policy framework leads to a remarkable decarbonisation of H/C in Romanian buildings until 2050, more ambitious policies are needed to meet the emission reduction targets as set out in the Paris Agreement. Thus, faster and deeper decarbonisation of H/C in Romanian buildings is needed. An important measure to reach this is an intensified RES-H obligation: on the one hand the obligation should not only apply for buildings that are newly constructed, but also for buildings undergoing a major renovation and in case that the heating system is changed. On the other hand, the share of the heat to be supplied by RES should be increased, so that it becomes less interesting to fulfil the obligation with a combination of fossil fuels and solar thermal systems or paying a penalty instead of compliance. At the same time the public budget for subsidising investments in technologies for RES-H should be increased to additionally trigger the technology shift.

As in many EU countries, the potential for reducing the heat demand in buildings is very high. In order to stimulate the realisation of building retrofit the public budget might be increased, but also could be set mandatory after a certain timeframe. Increased retrofit rates would also help to reduce biomass use for heating in buildings. This is important as on the one hand the amount of sustainable biomass resources might not be sufficient to supply large shares of heat demand in buildings in 2050, and on the other hand will biomass be more essential for the decarbonisation of the industry sector than for buildings. For increasing retrofit rates it is also important to drive standardisation of retrofit activities and awareness raising by implementing energy performance certificates (EPC) of buildings, so that retrofit costs decrease compared to current levels. Finally, information campaigns to increase the awareness of the continuous increase of fuel and emission certificate prices are important, so that this is taken into account in the investment decisions related to building retrofit and heating systems. This, however, is linked to a continuous increase of the CO_2 prices, which can be assured by the application of a CO_2 tax or levy for all sectors at national level, if not achieved by the EU ETS.

The following conclusions and policy recommendations can be drawn for the **industry** sector in Romania:

- The current policy is not on track towards decarbonisation. Today's policy framework will not induce the radical changes needed in the cement, iron and steel and chemicals industry.
- A decarbonisation strategy for industry needs to find a solution for the high process related emissions from cement production, but also the remaining oxygen steel production. Options can be the use of CCS or low-carbon technologies like direct reduced iron based on hydrogen from renewable energy sources.

- Excess heat potentials should be exploited across all basic materials sectors. Particularly, as the district heating infrastructure is already very widespread in Romania. Strategies to modernise the old and often inefficient district heating networks might be an opportunity to also connect industrial heat sources.
- Biomass is an important renewable energy source for the industry, if available according to sustainability criteria. Power to heat and methane based on renewable sources are not yet competitive on a large scale also in the ambitious policy scenario. More specific policies would be needed.
- OPEX support of renewable energy seems more effective than CAPEX support.
- Material efficiency and substitution of cement and steel in the construction industry need to be supported with an integrated policy mix.
- The current policy mix already includes many policies directed towards overcoming barriers to energy efficiency (e.g. support for energy audits, energy efficiency networks and incentives for energy management schemes). While this is an important pillar of the policy mix, there are probably no more policies needed, rather the enforcement of the existing policies should be ensured.

With a reduction of about 53% by 2050, also the ambitious policy scenario is not compatible with the Paris agreement. To achieve even deeper emission cuts in the long run, more policies are needed that might include a prohibition of using coal where not technically needed, carbon capture and storage/use, more ambitious process innovations in cement, lime, chemicals and steel including the extensive use of synthetic fuels like RES-based methane or RES-H_2 and a more important role of power to heat.

Electricity demand in Romania is substantially higher than the **district heating** demand. Therefore, the share of RES in electricity and DH generation follows the share of RES in electricity generation. This can be observed from Figure 105.

Electricity generation from hydro and nuclear power plants is a result of the constraints and is not effectively optimised by the TIMES model. In the current policy scenario the electricity generation is dominated by coal, while in the ambitious policy scenario solar PV and biomass become significant. The switch from coal to RES becomes especially visible from 2030 onwards due to increasing CO_2 prices. Higher CO_2 prices than the ones assumed in the ambitious policy scenario are needed to phase out coal.

The policies implemented in the ambitious policy scenario are very effective in larger DH areas, i.e. dramatic change from coal and natural gas to solar thermal, geothermal and biomass can be observed. Also in smaller DH areas the ambitious policy scenario shows remarkable technology shifts from fossil to RES based. However, similarly as for the electricity generation, higher CO_2 prices are needed to completely phase out coal in small DH areas.

The modelling of the buildings furthermore shows the importance of DH prices as argument for the consumers to switch to DH. On the one hand can favourable financing conditions for DH infrastructure lower DH consumer prices. On the other hand it can be recommended to implement a stronger planning approach regarding H/C including the definition of DH priority areas in order to increase the connection rates and therefore lower the DH prices for all connected consumers.

3. Cross-Country results and conclusions

As outlined in chapter 1 two scenarios have been defined, reflecting different intensities of policy influence towards the transition of the energy systems related to heating and cooling: a current policy and an ambitious policy scenario. In this chapter we compare the results of the two scenario calculations for the different countries and based on these draw conclusions for policy making regarding the decarbonisation of H/C in Europe. Hereby we distinguish between the different sectors as before in the country-specific chapters: buildings, industry, district heat and electricity generation.

3.1 Buildings

In this analysis of the building sector the quantitative assessment included the energy demand for space heating, space cooling and preparation of domestic hot water in buildings from the residential as well as tertiary sector. Thus, all energy demand figures of the building sector in this report refer to the energy demand for H/C. CO_2 emissions from H/C in the buildings in this report only reflect the emissions that are generated directly in the buildings, CO_2 emissions resulting from the generation of electricity or district heat, which might be used in the buildings for H/C, is reflected in the emissions from the electricity and DH generation sector (see also chapter 1.3 for a definition of all indicators). Figure 110 shows the direct CO_2 emission for H/C in buildings by energy carrier of all 6 countries included in the calculations for both policy scenarios. In 2012 the main sources of direct CO_2 emissions in the buildings have been natural gas and oil. Coal has played a minor role. In the current policy scenario direct CO_2 emissions decrease by 73% until 2050.

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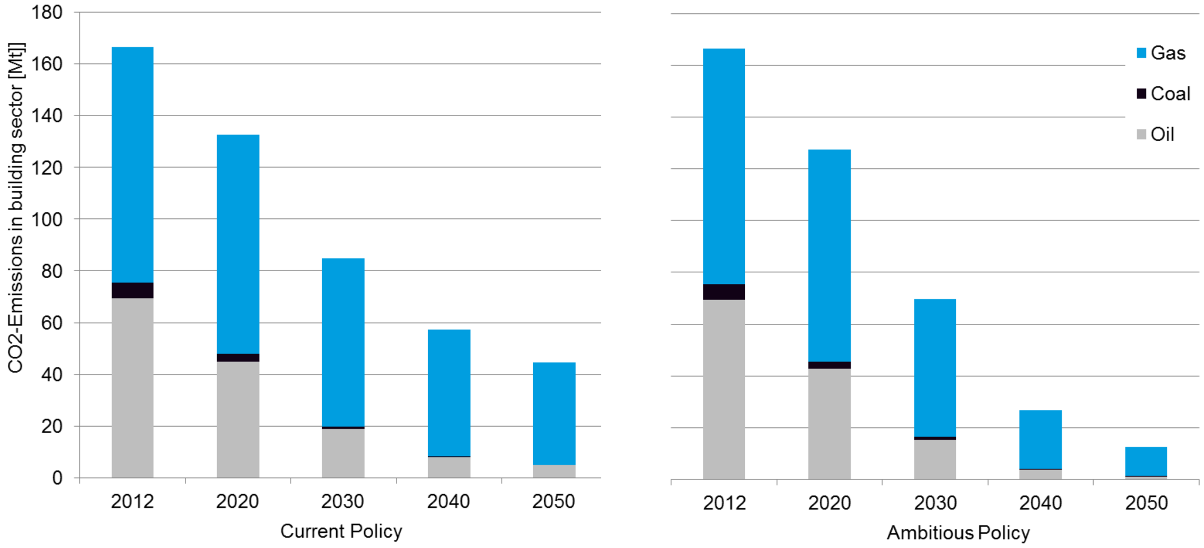

Figure 110: Direct CO_2 Emissions for heating and cooling in buildings by energy carrier as a sum for all target countries

This decrease mainly results from a reduction of energy demand in the buildings due to lower energy demand in newly constructed buildings and at the same time an increasing use of renewable energy. This leads to a remarkable reduction of oil use and a phase out of coal boilers in nearly all investigated countries. Thus, the current policy frameworks in the investigated countries lead to a remarkable reduction of direct CO_2 emissions in buildings. However, this reduction is not enough to reach the reduction targets as set out in the Paris Agreement at COP 21. Underlying more ambitious policy intervention like an intensification of the RES-H obligation, increased budgets for RES-H and retrofit measures, favourable financing conditions for district heating infrastructure etc. in the ambitious policy scenario in this assessment leads to a calculated reduction of 92% until 2050 compared to 2012 (see also Figure 110).

Figure 111 shows the importance of the different fossil energy carriers used for H/C in the buildings in the different countries. In Austria, Germany, Denmark and Portugal 40-60% of direct emissions result from natural gas and oil, and very small or no share is taken by coal. The Czech Republic and Romania, however, show a different picture. The Czech Republic is the only analysed country that has a remarkable share of 25% of coal in the direct emissions of H/C in buildings. At the same time, oil doesn't play a role there. In Romania on the other hand, H/C in buildings currently relies largely on natural gas. Figure 111 also shows the nearly complete phase out of coal in the different countries. This also applies to the Czech Republic.

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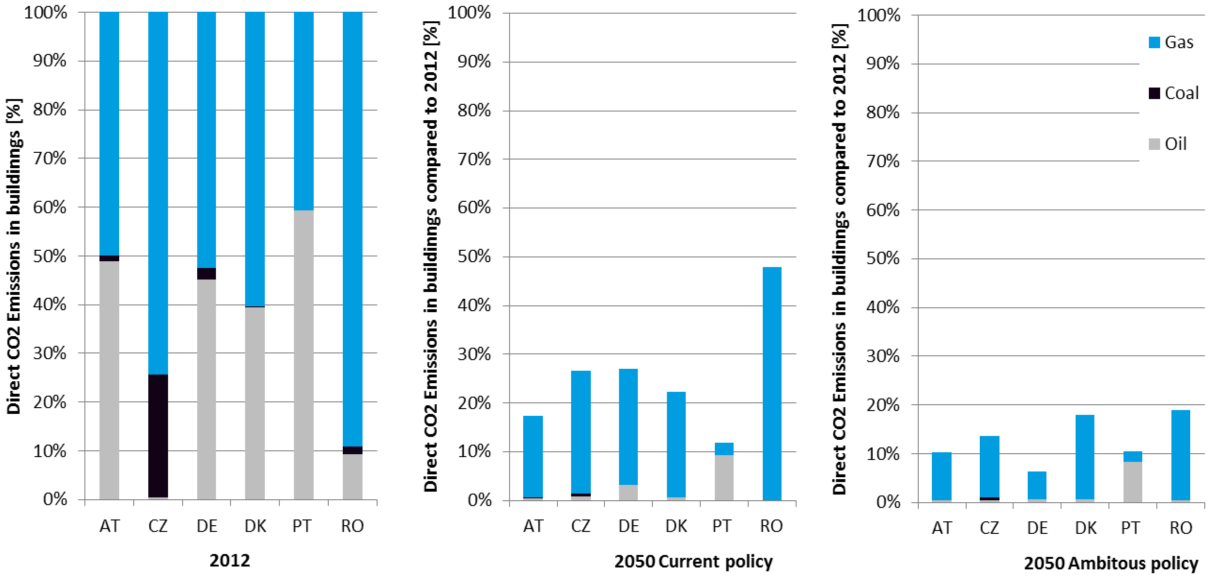

Figure 111: Direct CO_2 Emissions for heating and cooling in buildings relative for all target countries

Emission reductions in the buildings result from reductions in the overall energy demand for H/C and a simultaneous shift in the use from fossil to renewable energy sources. In the current policy scenario a decrease in the final energy demand by 39% from 2012 until 2050 is calculated (see Figure 112). In the ambitious policy scenario the final energy demand is further decreased by 47% in the same period. While fossil energy carriers will decrease in importance in both scenarios, the amounts of renewable energy carriers increase, even more substantially in the ambitious policy scenario. District heat will not increase in its final energy demand, but will increase in its share, according to the model calculations. While biomass is the single most important renewable energy carrier in the current policy scenario, its importance is remarkably reduced in the ambitious policy scenario towards more intensified use of heat pumps.

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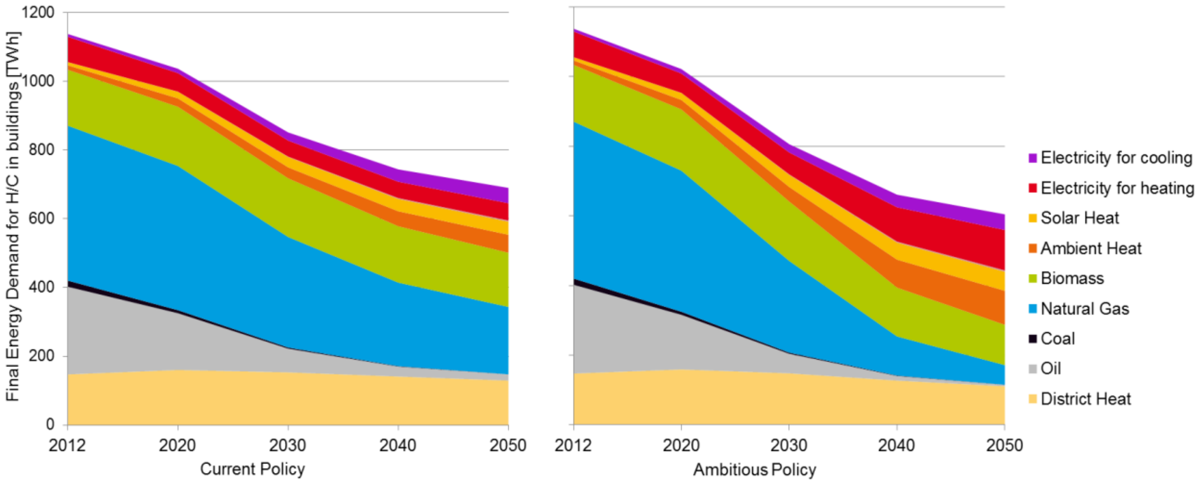

Figure 112: Final energy demand per energy carrier for heating and cooling in buildings as a sum for all target countries

Policy conclusions

The currently implemented and foreseen policies targeting buildings in the countries under investigation in the project are likely to reduce direct emissions from H/C in this sector to a large extent (-73%) until 2050, if compliance with regulatory instruments like building codes is guaranteed and energy prices develop as assumed. At the same time the share of RES-H would remarkably increase under this scenario setting. Thus, the current shape of the national building codes and renovation standards, the foreseen RES-H obligations and the available public budgets for subsidising renovation and investments in technologies for RES-H are likely to show remarkable effects until 2050, even with a low price of CO_2. However, these emission reductions will only be achieved with the current policy framework, if a continuous monitoring of the compliance with national building codes and renovation standards is installed and non-compliance is penalised. Also, as the connection to DH is counted as an option to fulfil the RES-H obligation, it is important that DH generation is decarbonised in the mid to long term in order not to shift the source of emissions from buildings to DH. In this context it might be interesting to only allow accounting of DH for the compliance with the RES-H obligation, if for the DH system a commissioned decarbonisation roadmap exists.

Although the current policy framework leads to a remarkable decarbonisation of H/C in buildings in the analysed countries until 2050, more ambitious policies are needed to meet the emission reduction targets as set out in the Paris Agreement. Thus, faster and deeper decarbonisation of H/C in buildings is needed. An important measure to reach this is an intensified RES-H obligation: on the one hand the obligation should not only apply for buildings that are newly constructed, but also for buildings undergoing a major renovation and in case that the heating system is changed. On the other hand, the share of the heat to be supplied by RES should be increased, so that it becomes less interesting to fulfil the obligation with a combination of fossil fuels and solar thermal systems or paying a penalty instead of compliance. At the same time the public budget for subsidising

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investments in technologies for RES-H should be increased to additionally trigger the technology shift.

The potential for reducing the heat demand in buildings is remarkable in many EU countries. In order to stimulate the realisation of building retrofit the public budget might be increased, but also could be set mandatory after a certain timeframe. Increased retrofit rates would also help to reduce biomass use for heating in buildings. This is important as on the one hand the amount of sustainable biomass resources might not be sufficient to supply large shares of heat demand in buildings in 2050, and on the other hand will biomass be more essential for the decarbonisation of the industry sector than for buildings. For increasing retrofit rates it is also important to drive standardisation of retrofit activities and awareness raising by implementing energy performance certificates (EPC) of buildings, so that retrofit costs decrease compared to current levels. Finally, information campaigns to increase the awareness of the continuous increase of fuel and emission certificate prices are important, so that this is taken into account in the investment decisions related to building retrofit and heating systems. This, however, is linked to a continuous increase of the CO_2 prices, which can be assured by the application of a CO_2 tax or levy for all sectors at national level, if not achieved by the EU ETS.

3.2 Industry

For the industrial sector, the analyses included the complete final energy demand, thus including non-H/C applications like mechanical energy. This extended scope is justified by the focus of policies addressing a transition in the entire industrial sector and not only on process heating and cooling. However, the share of H/C in industrial final energy demand is very high - in 2012 it ranged between 73 and 77% in the countries analysed (see Figure 113).

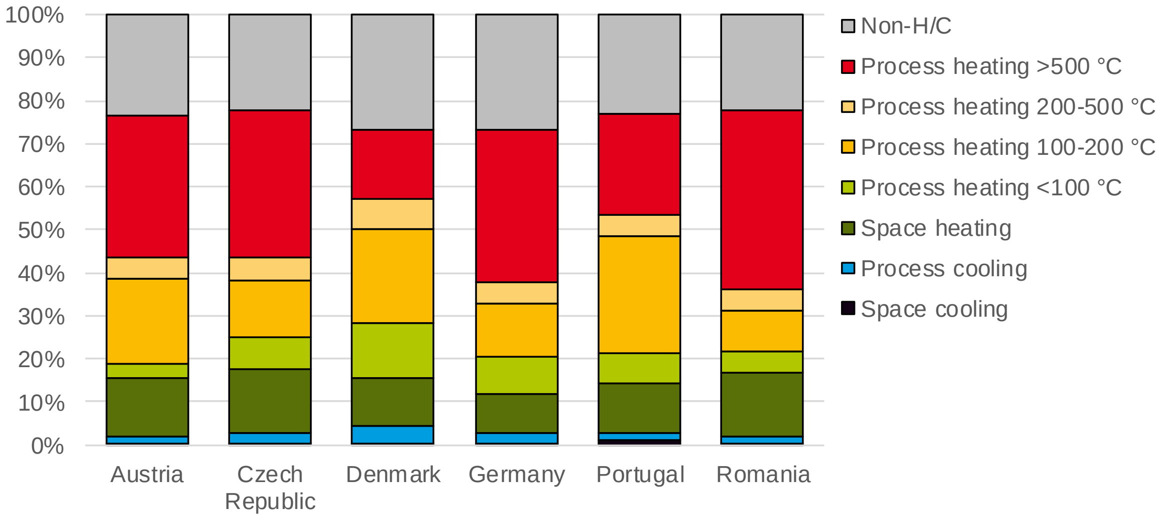

Figure 113: Share of heating and cooling in industrial final energy demand (Fraunhofer ISI et al. 2017)

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Table 8: Industrial final energy demand by country in comparison [TWh]

	2012	2020	2030	2040	2050	Change 2050/2012
Current policy						
Austria	108	106	107	106	105	-2%
Czech Republic	93	95	98	103	108	16%
Denmark	25	25	26	27	30	17%
Germany	711	687	655	626	608	-15%
Portugal	54	51	51	50	48	-11%
Romania	79	82	85	85	85	7%
Ambitious policy						
Austria	108	100	90	82	78	-28%
Czech Republic	93	90	85	82	82	-11%
Denmark	25	24	24	24	25	1%
Germany	711	661	591	531	500	-30%
Portugal	54	49	44	41	39	-28%
Romania	79	79	77	73	71	-10%

The final energy demand for H/C purposes is depicted in Table 8 showing the development of the individual energy carriers by country and in Figure 114 showing the energy carrier mix for H/C for each country. It can be observed that in all countries biomass gains increasing shares in both scenarios until 2050 compared with 2012. However, a particularly strong growth is observed in the ambitious policy scenario, where it is the major energy carrier for H/C in 2050 in all analysed countries. Other RES remain marginal (solar and ambient heat for heat pumps) although they increase substantially compared to 2012. Power-to-heat (Electricity) is also gaining importance until 2050 in the ambitious policy scenario (note that electricity in Figure 114 also includes process and space cooling). Still, even in the ambitious policy scenario it remains substantially lower than biomass, indicating the still relatively high price of electricity compared to biomass. Fossil fuels play a relatively important role even in the ambitious policy scenario in 2050. Coal is still used in the steel industry and natural gas is used throughout all industries for process heat generation. The characteristics of natural gas (low air emissions, good process control, high energy density, simple transportation with mostly existing infrastructure, etc.) make it still attractive compared to RES alternatives even with high CO_2 prices and other policies in place. Replacing the remaining share of coal and natural gas by renewables would require even more substantial policies and structural changes than assumed in the ambitious policy scenario. This is needed, if the Paris Agreement is to be taken seriously.

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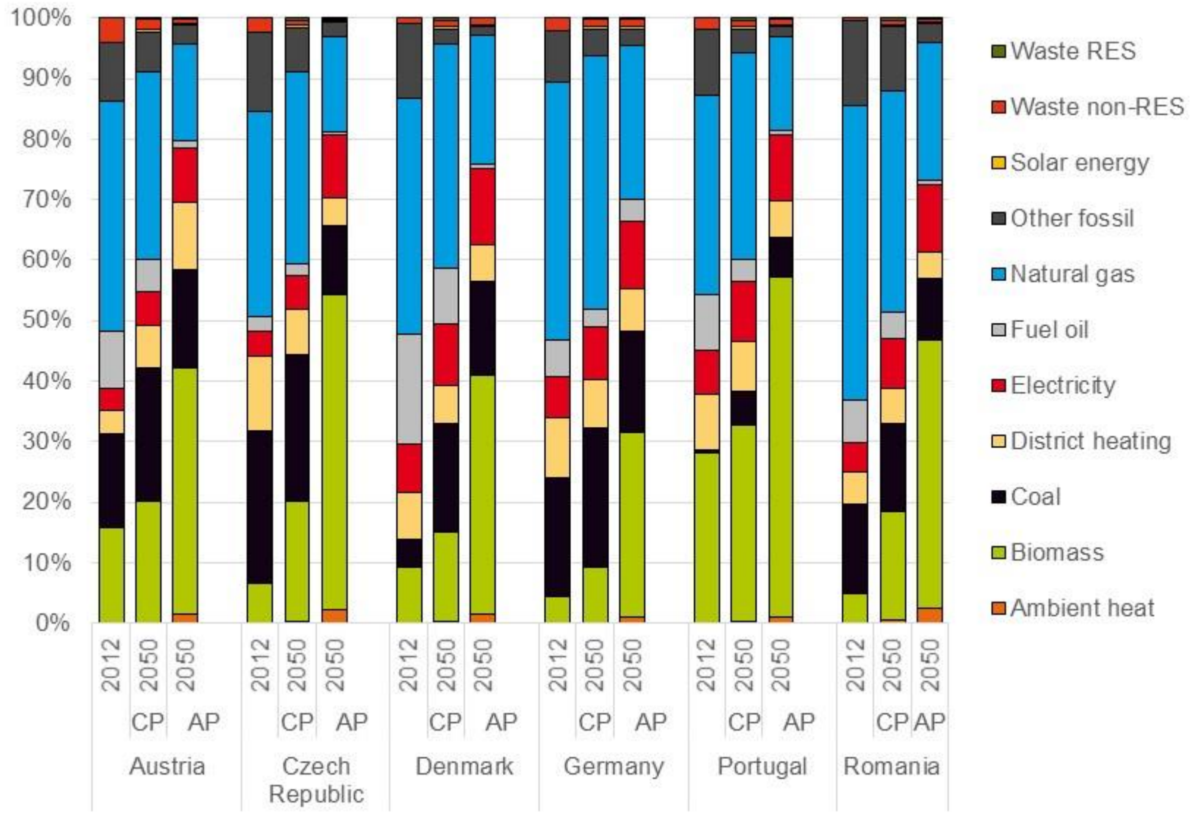

Figure 114: Energy carrier mix of industrial final energy demand for H/C by energy carrier (CP: current policy scenario; AP: ambitious policy scenario)

Policy conclusions

While the structure of the industrial sector clearly varies across the six countries analysed, the production processes itself do hardly differ as do the economic and technical circumstances for decarbonisation and RES in industry. Thus, the following cross-country recommendations can be derived from the country analyses. Most likely they are also valid for other EU countries not analysed.

- Current policy is not on track towards decarbonisation in all countries analysed, though, a slow decrease of industrial CO_2 emissions is expected. Although, the ambitious policy scenario achieves substantial additional emission cuts, also this scenario is not in line with the Paris agreement in all countries analysed.
- Deep emission cuts require substantial changes in the iron and steel, cement and chemicals industries, but also support for RES and energy efficiency in other sectors and companies.
- Excess heat potentials are available and should be exploited. However, the resulting potentials in the analysed processes and with the assumptions taken (only heat >100°C) are limited. More potential is certainly available from smaller installations, less energy-intensive industries and particularly at lower temperature levels.

- Biomass is the most important RES in industry, particularly in the medium term. In the long-term RES-based electricity (power to heat) can play a more important role, particularly if very low emission levels are reached in electricity generation, as (sustainable) biomass potentials are restricted. However, with the policy definition taken and the assumed development of energy prices, electricity is not yet competitive with biomass in the ambitious policy scenario. Replacing biomass by electricity would require more specific policies.
- OPEX support of RES seems more effective than CAPEX support for steam and hot water generation. The low specific price of large scale steam boilers (<100 Euros/kW) result in a very low share of CAPEX in the total cost of ownership.
- Improved material efficiency and circular economy provide a huge mitigation potential - though an effective policy mix is still to be proven and probably contains a bunch of individual measures. Material efficiency activities need to focus on the construction industry, where the major parts of CO_2 intensive materials are used.
- Implementing policies to overcome barriers to energy efficiency (energy management schemes, audits and soft loans) is a prerequisite also for other (price based) policies to work effectively. While this is an important pillar of the policy mix, there are probably no more policies needed, rather the enforcement of the existing policies should be ensured.

Although, the ambitious policy scenario achieves substantial additional emission cuts compared to the current policy scenario, it is still not achieving reduction targets for industry that can be in line with the Paris goals of a nearly carbon neutral economy. Still, they comprise a substantial step towards a transition of the industrial sector addressing various levers ranging from energy efficiency, via fuel switch to excess heat use, downstream material efficiency and innovation support. To achieve even deeper emission cuts in the long term, more policies are needed that might comprise a prohibition of using coal where not technically needed, carbon capture and storage/use, more ambitious process innovations in cement, lime, chemicals and steel including the extensive use of synthetic fuels like RES-based methane or RES-H_2. Such policies are more likely to be implemented and developed in the frame of industrial energy transitions and probably less in the frame of H/C transitions, because they require industry specific considerations like international competition and industrial policy.

3.3 District heating and the power sector

In all analysed countries except from Denmark, electricity demand is substantially higher than DH demand. Therefore, the share of RES in electricity and DH generation in these countries follows the share of RES in electricity generation. In Denmark, the sizes of electricity and DH demands are comparable. Therefore, both electricity and DH generation can significantly affect the overall share of RES.

Very high shares of RES in electricity generation are achieved in Austria and Denmark even in current policy scenario. This is mainly due to declining investment costs of technologies using RES such as wind and solar PV.

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In the other countries, high shares of RES in the electricity generation are achieved in the ambitious policy scenario. A learning point is that the implemented polices in the ambitious policy scenario are sufficient to achieve high shares of RES in the electricity generation.

However, for all the countries except form Austria, Denmark and the Czech Republic, there is still some coal in the electricity generation mix even in the ambitious policy scenario. In Austria, the result is achieved with the combination of hydro, solar PV and wind, in Denmark mainly by wind, while in the Czech Republic a significant part of electricity generation is based on nuclear power plants. Therefore, higher CO_2 prices or higher subsidies for technologies using RES are needed to phase out coal completely from the electricity generation mix in all analysed countries except from Austria and Denmark.

In Denmark, stronger taxation of CO_2 (it did not prove to be needed to achieve 100% renewable electricity) would work in the same direction as the subsidies for technologies using RES, i.e. they would not work as a push for nuclear power plants. This is due to long anti-nuclear tradition in Denmark followed by strong political decisions. On the other hand, in the Czech Republic for example, high CO_2 prices can work as a push for nuclear power plants. This is an important learning point from this policy analysis – high CO_2 prices can contribute to phase out coal, but it does not necessarily lead towards wind and solar PV; it can lead towards electricity generation from nuclear power plants.

DH generation in Denmark is completely shifted to technologies using RES even in the current policy scenario, i.e. the taxes on fossil fuels and declining costs of technologies for RES seem to be enough to completely shift to renewable energy. Consecutively, the implemented polices in the ambitious policy scenario do not seem to be necessary. The subsidies for investments in renewable energy technologies and the rising CO_2 costs can be transferred to other sectors of the energy system, such as industry, transportation, etc. and thus help decarbonisation of these sectors.

In all the remaining countries, polices implemented in the ambitious policy scenario are effective in achieving high shares of RES in DH generation**.** However, a share of 100% RES is only achieved in some areas in some countries. To achieve a share of 100% RES in DH generation in all countries, higher CO_2 prices and higher support for technologies using RES in DH generation are needed**.**

In case of Austria, the Czech Republic and Portugal, either large or small DH areas are completely switched to RES in the ambitious policy scenario, but not in both types. In these cases, an option would be to move the support for renewables (higher CO_2 prices and financial support for renewables in DH generation) from one group of areas to another.

In case of Austria, the Czech Republic, Portugal and Romania, there is a strong link between electricity and DH generation through large-scale heat pumps. In these cases, higher shares of RES in DH generation can be achieved by introducing higher support for technologies using RES in the electricity generation. However, it is important to also recognize the substantial barriers for implementing large scale heat pumps and get access to corresponding heat sources allowing sufficiently attractive seasonal COPs. These barriers might only partly be taken into account in the

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modelling exercise. This will need to be considered thoroughly both in future technology implementation and policy making.

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5. Annex

In this annex we provide details on important assumptions for the modelling of future development of the heating and cooling systems in the 6 countries under investigation in this modelling exercise. This includes fuel and CO_2 prices, development of main demand drivers as well as excess heat potentials from industrial activity. As also written in chapter 1, more details on data sources for the current state and calibration of the three models used, on the functioning of the models themselves as well as on splitting the calculated district heat demands in industry and buildings to small and large district heating areas can be found in the report (Pedersen et al 2016)[9].

5.1 Assumptions on fuel and CO_2 prices

As written in chapter 1 the fuel and CO_2 prices used in this analysis are taken from the EU Reference scenario 2016. Figure 115 and Figure 116 show the development of the international fuel prices as used in the analysis.

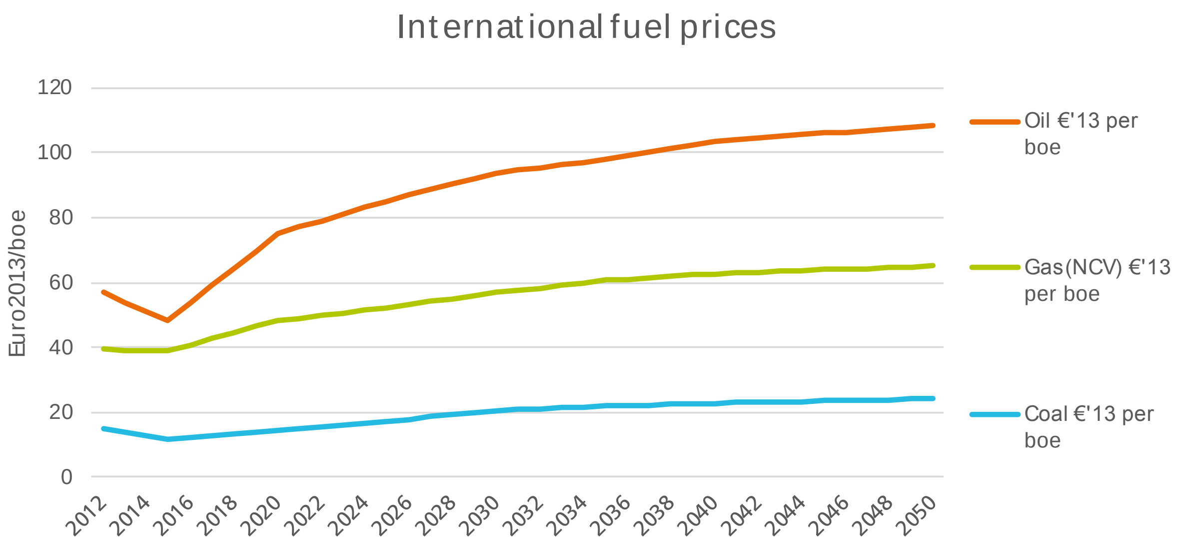

Figure 115: International fuel price assumptions (Source: EU Reference Scenario 2016)

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[9] "Documentation of energy demand for heating and cooling in buildings and industry sectors, district heating diffusion and renewable energy potentials", D2.3 of the project progRESsHEAT, available at http://www.progressheat.eu/National-analysis.html

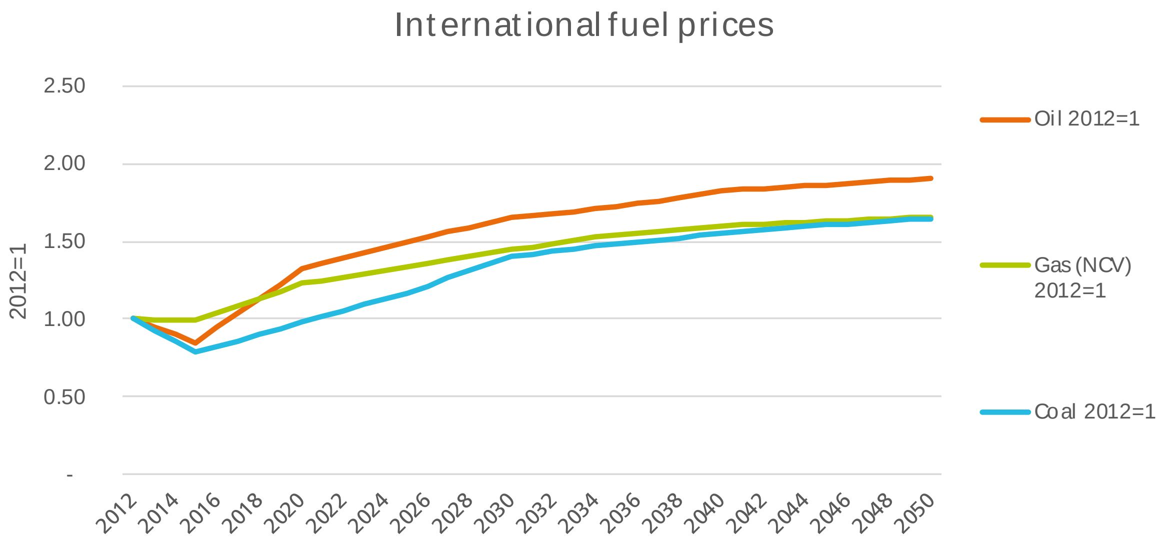

Figure 116: International fuel price assumptions as index (Source: EU Reference Scenario 2016)

The following Figure 117 shows the costs of electricity generation resulting in the EU Reference scenario 2016. These were used in the demand side models Invert/EE-Lab and FORECAST-Industry, while in the TIMES model the electricity generation costs are output of the model.

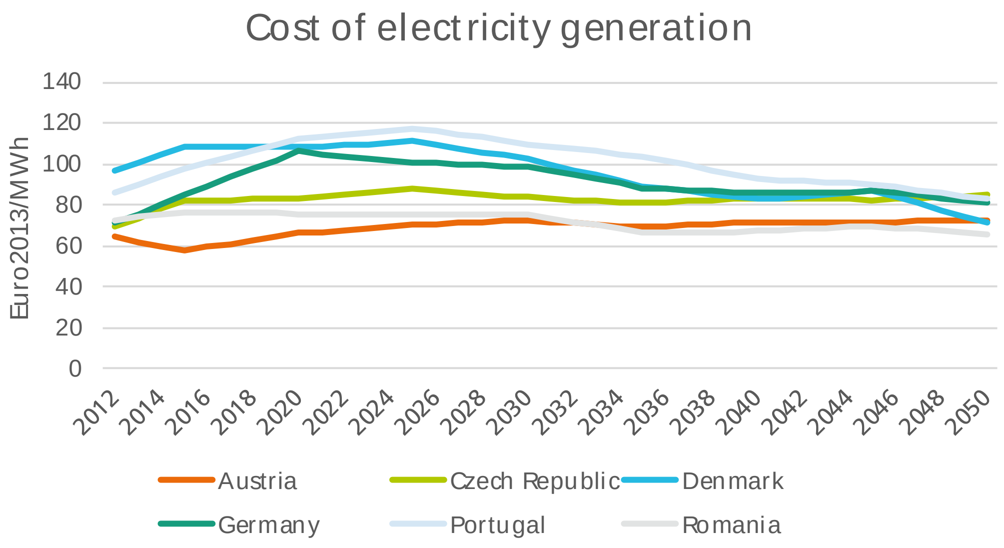

Figure 117: Cost of electricity generation by country (Source: EU Reference Scenario 2016)

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Figure 118 shows the development of the CO_2 certificate price in course of the EU ETS from the EU reference scenario 2016. As written in chapter 1 we use this development of CO_2 prices for the ambitious policy scenario, while for the current policy scenario we assume a non-functioning EU ETS leading to a constantly low certificate price of 7,5 €/t.

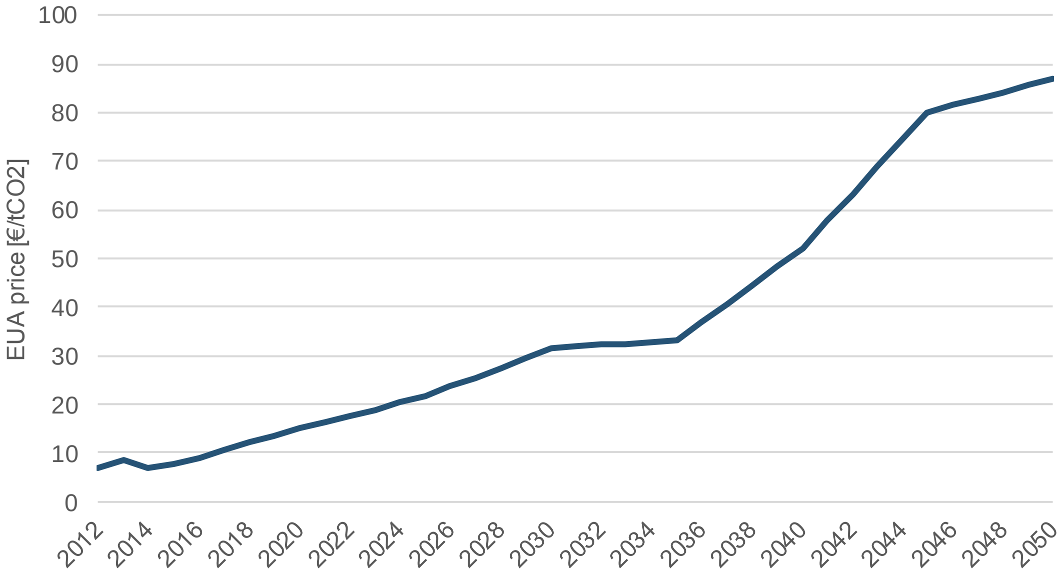

Figure 118: CO_2 certificate price for the EU ETS (Source: EU Reference Scenario 2016)

5.2 Assumptions on main demand drivers

The following Table 9 shows the development of the product quantities of main industrial products in the analysed countries in the current policy and the ambitious policy scenarios. The subsequent Table 10 shows selected key indicators related to the use of recycled materials in production.

Table 9: Production assumption for main industrial products by country in the current policy scenario [1000 t/year]

			Current policy			Ambitious Policy		
Country	Product	2012	2030	2050	Change 2050/2012	2030	2050	Change 2050/2012
Austria	Ammonia	400	422	448	12%	339	242	-39%
	Ethylene	500	528	560	12%	505	504	1%
	Oxygen steel	6,746	7,313	6,690	-1%	5,795	3,582	-47%
	Electric steel	674	695	636	-6%	1,854	2,930	335%
	Aluminum, primary	-	-	-		-	-	

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	Aluminum, secondary	373	376	380	2%	371	369	-1%
	Cement	4,455	5,518	5,783	30%	5,282	5,204	17%
	Clinker	3,206	3,784	3,887	21%	3,312	2,882	-10%
	Paper	5,004	6,435	6,642	33%	6,159	5,978	19%
Czech Republic	Ammonia	200	211	217	9%	169	117	-41%
	Ethylene	412	435	462	12%	416	416	1%
	Oxygen steel	4,701	5,381	5,862	25%	3,592	1,529	-67%
	Electric steel	371	395	431	16%	1,951	4,134	1014%
	Aluminum, primary	-	-	-		-	-	
	Aluminum, secondary	50	54	58	16%	53	56	13%
	Cement	3,537	5,242	5,745	62%	5,017	5,170	46%
	Clinker	2,371	3,270	3,512	48%	2,861	2,859	21%
	Paper	759	1,104	1,173	55%	1,057	1,056	39%
Denmark	Ammonia	-	-	-		-	-	
	Ethylene	-	-	-		-	-	
	Oxygen steel	-	-	-		-	-	
	Electric steel	-	-	-		-	-	
	Aluminum, primary	-	-	-		-	-	
	Aluminum, secondary	25	25	25	0%	25	24	-3%
	Cement	1,820	2,676	2,868	58%	2,562	2,582	42%
	Clinker	1,406	1,111	634	-55%	1,459	1,470	5%
	Paper	204	239	248	22%	229	223	9%
Germany	Ammonia	2,823	2,979	3,163	12%	2,392	1,708	-39%
	Ethylene	4,897	5,943	6,682	36%	5,688	6,013	23%
	Oxygen steel	28,872	31,418	29,730	3%	26,053	17,384	-40%
	Electric steel	13,789	14,800	14,625	6%	17,713	21,248	54%
	Aluminum, primary	410	499	460	12%	461	380	-7%
	Aluminum, secondary	635	666	700	10%	689	746	17%
	Cement	32,432	35,281	33,770	4%	33,769	30,393	-6%
	Clinker	23,348	24,391	23,021	-1%	21,345	16,812	-28%
	Paper	22,630	20,337	18,963	-16%	19,465	17,067	-25%
Portugal	Ammonia	244	244	244	0%	196	132	-46%
	Ethylene	188	448	448	139%	429	403	115%
	Oxygen steel	-	-	-		-	-	
	Electric steel	1,960	2,241	2,292	17%	2,151	2,063	5%
	Aluminum, primary	-	-	-		-	-	
	Aluminum, secondary	18	18	18	0%	18	17	-3%
	Cement	5,077	6,146	5,958	17%	5,883	5,362	6%
	Clinker	4,882	5,534	5,264	8%	4,843	3,790	-22%
	Paper	1,915	2,072	1,947	2%	1,983	1,752	-8%
Romania	Ammonia	1,149	1,213	1,288	12%	974	695	-39%
	Ethylene	-	-	-		-	-	
	Oxygen steel	1,701	1,709	1,332	-22%	1,511	810	-52%

	Electric steel	1,591	1,738	2,002	26%	1,797	2,191	38%
	Aluminum, primary	249	278	280	12%	257	231	-7%
	Aluminum, secondary	13	16	19	45%	33	59	352%
	Cement	7,763	10,107	9,929	28%	9,674	8,936	15%
	Clinker	6,915	10,066	9,979	44%	8,809	7,185	4%
	Paper	298	485	518	74%	464	467	57%

Table 10: Assumptions on use of recycled materials for steel, cement, aluminium and paper [%]

		Current policy scenario		Ambitious policy scenario	
Indicator/country	**2012**	**2030**	**2050**	**2030**	**2050**
Share of electric steel in total crude steel production					
Austria	9%	9%	9%	24%	45%
Czech Republic	7%	7%	7%	35%	73%
Denmark					
Germany	32%	32%	33%	40%	55%
Portugal	100%	100%	100%	100%	100%
Romania	48%	50%	60%	54%	73%
Share of clinker in total cement production					
Austria	72%	69%	67%	63%	55%
Czech Republic	67%	62%	61%	57%	55%
Denmark	77%	42%	22%	57%	57%
Germany	72%	69%	68%	63%	55%
Portugal	96%	90%	88%	82%	71%
Romania	89%	100%	100%	91%	80%
Share of secondary aluminium in total aluminium production					
Austria	100%	100%	100%	100%	100%
Czech Republic	100%	100%	100%	100%	100%
Denmark	100%	100%	100%	100%	100%
Germany	61%	57%	60%	60%	66%
Portugal	100%	100%	100%	100%	100%
Romania	5%	5%	6%	11%	20%
Share of recovered fibres in total pulp production					
Austria	60%	66%	70%	76%	89%
Czech Republic	26%	29%	33%	36%	46%
Denmark	100%	100%	100%	100%	100%
Germany	86%	90%	90%	99%	100%
Portugal	13%	14%	15%	20%	26%
Romania	n.a.	n.a.	n.a.	n.a.	n.a.

5.3 Assumptions for industrial excess heat potentials

The calculation of industrial excess heat potentials is based on a bottom-up estimation of available excess heat from the main processes of the basic materials industry. More specifically, the following steps were undertaken:

1. Estimation of specific energy consumption by process based on literature
2. Literature review of specific excess heat potentials on a process/product level. The review focuses on excess heat above 100°C in selected energy intensive processes (see table below).
3. Multiplication of specific excess heat potential with physical production (forecasts) in tonnes on a process/product level to estimate total excess heat available by country
4. Estimating the share of available excess heat that can be used in DHC grids
5. Estimating the amount of electricity generation for excess heat sources too distant from heat demand centres making a direct use of the heat too expensive.

The approach used provides an order of magnitude for the industrial excess heat potentials available in a country. In future research, it might be further elaborated by taking into account more products/processes, also lower temperature levels, GIS-based matching of excess heat sources with heat demand densities and existing DHC infrastructure and consideration of today's level of excess heat exploitation.

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Table 11: Specific energy consumption and excess heat potential per process

Sector	Process	Specific energy consumption [kWh/t]		Excess heat [%]		Excess heat [kWh/t]		Source
		Fuels	Electricity	Fuels	Electricity	Fuels	Electricity	
Iron and steel	**Sinter**	622	37	0.33	-	203	-	McKenna (2008); Brauer (1996)
	Blast furnace	3,232	167	0.03	-	107	-	McKenna (2008)
	Electric arc furnace	272	635	0.30	0.08	81	49	Element energy et al 2016; Rehfeldt (2014)
	Rolled steel	663	168	0.12	-	80	-	Rehfeldt (2014)
	Coke oven	889	34	0.06	-	50	-	McKenna (2008)
	Direct reduction	4,167	117	0.25	-	1,042	-	Rehfeldt (2014)
Non-ferrous metals	**Aluminium, primary**	1,444	14,900	-	0.10	-	1,490	McKenna (2008); Achternbosch and Bräutigam (2000)
	Aluminium, secondary	2,500	464	0.20	-	500	-	Rehfeldt (2014)
	Aluminium foundries	2,000	1,556	0.20	-	400	-	Rehfeldt (2014)
	Copper, primary	2,222	775	0.42	-	926	-	Aurubis Hamburg Umwelterklärung und FW Ausbau
	Zinc, secondary	278	167	0.18	-	50	-	Rehfeldt (2014)
Paper	**Paper**	1,528	531	0.10	-	153	-	McKenna (2008)
Non-metallic minerals	**Container glass**	1,606	392	0.20	-	321	-	Rehfeldt (2014)
	Flat glass	3,033	922	0.20	-	607	-	McKenna (2008)
	Fibre glass	1,367	503	0.20	-	273	-	McKenna (2008)
	Other glass	3,189	1,403	0.20	-	638	-	McKenna (2008)
	Houseware, sanitary ware	6,732	1,338	0.10	-	673	-	McKenna (2008)
	Technical, other ceramics	3,364	897	0.10	-	336	-	McKenna (2008)
	Tiles, plates, refractories	1,517	246	0.10	-	152	-	McKenna (2008)
	Clinker Calcination-Dry	972	39	0.20	-	194	-	McKenna (2008); Element energy et al (2016)
	Clinker Calcination-Semidry	1,111	44	0.20	-	222	-	McKenna (2008); Element energy et al (2016)
	Clinker Calcination-Wet	1,528	44	0.20	-	306	-	McKenna (2008); Element energy et al (2016)
	Gypsum	278	56	0.10	-	28	-	McKenna (2008)
	Bricks	389	56	0.10	-	39	-	McKenna (2008); Element energy et al (2016)
	Lime burning	1,028	39	0.15	-	154	-	McKenna (2008); Element energy et al (2016)
Chemicals	**Ammonia**	3,132	133	0.10	-	313	-	McKenna (2008)
	Carbon black	17,986	494	0.10	-	1,799	-	McKenna (2008)
	Ethylene	9,973	-	0.10	-	997	-	McKenna (2008)
Food and drink	**Sugar**	1,281	192	0.10	-	128	-	McKenna (2008)
	Brewing	261	107	0.10	-	26	-	McKenna (2008)
	Bread & bakery	667	402	0.10	-	67	-	McKenna (2008)

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